A Large Ion Collider Experiment

Precision measurements in the multi-strange baryon sector using LHC Run 2 data with the ALICE experiment

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Motivations

- Almost 4 years after the end of LHC Run 2, the LHC has restarted, as well as the experiments installed on the ring (ATLAS, CMS, LHCb, **ALICE**).

- During this long shut down, the hardware and the software of **ALICE** have been upgraded in order to get :
  - → More statistics
  - → Better tracking and vertexing

→ With the LHC Run 3, ALICE steps into the precision era !

Motivations

You are here

Run 1	Run 2	Run 3	Run 4	Run 5	Run 6
2009 - 2013	2015 - 2018	2022 - 2025	2029 - 2032		

ALICE 1 (Run 1 – Run 2)
ALICE 2 (Run 3)
ALICE 2.1 (Run 4)
ALICE 3 (Run 5 – Run 6)

- In the (multi-)strange hadron sector, with the end of LHC Run 2, ALICE has already entered the precision era.

- In order to fully exploit and push the Run 2 data to their limits :
  - Testing the CPT symmetry via the mass measurements of the Ξ(dss) and Ω(sss)
  - A multidifferential study on the correlation between Ω(sss) and ϕ(s$\bar{\text{s}}$) yields

The ALICE 1 set-up

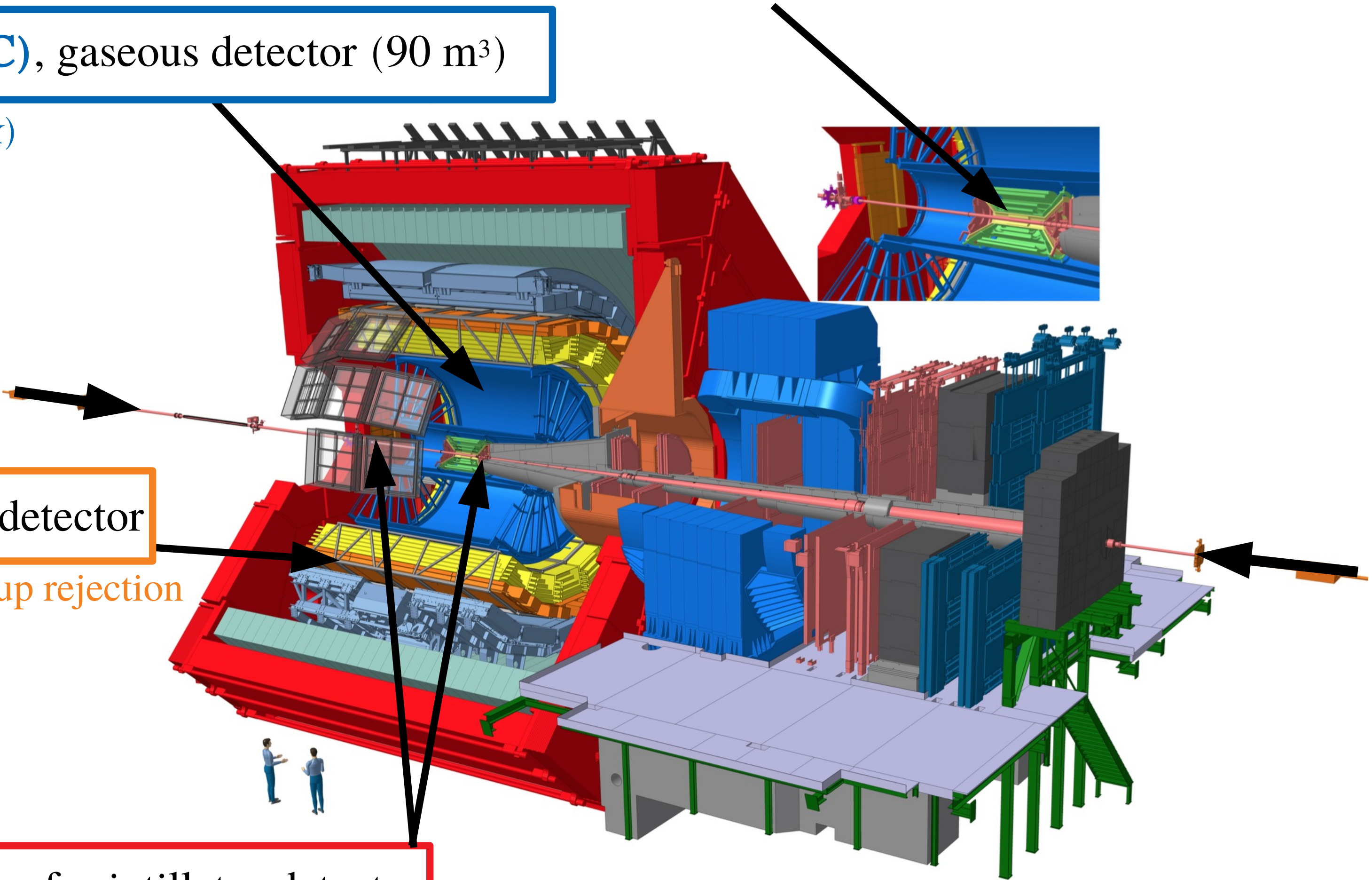
ALICE 1 is composed of 19 detection systems (during LHC Runs 1 & 2)

Inner Tracking System (ITS), six layers of silicon detector (SPD, SDD, SSD)

→ Reconstruct tracks and vertices + trigger + multiplicity estimation (SPD)

Time Projection Chamber (TPC), gaseous detector (90 m^3)

→ Reconstruct tracks + PID (dE/dx)



Time Of Flight (TOF), gaseous detector

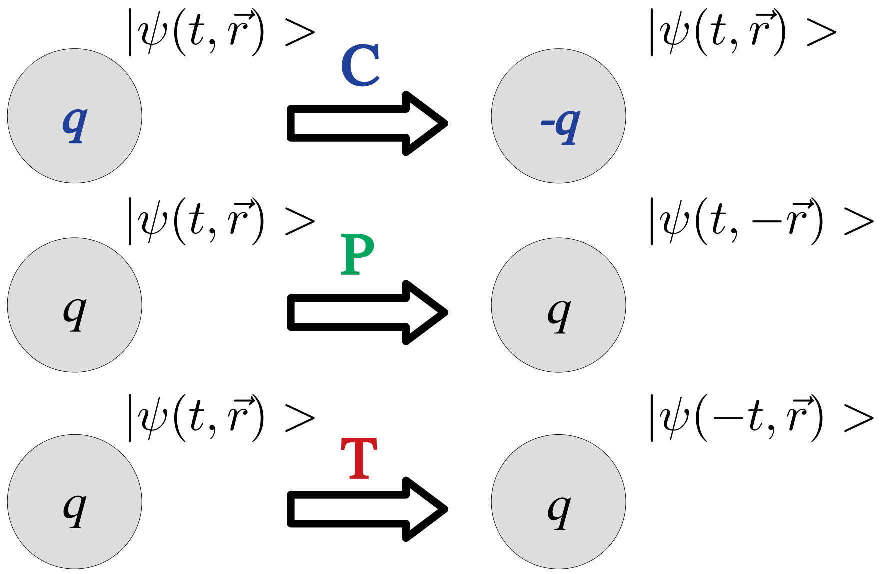
→ PID + out-of-bunch(OOB)pile up rejection

V0 : V0A and **V0C,** two arrays of scintillator detector

→ Trigger, multiplicity estimation at forward rapidity

Motivations

- The Standard Model was initially built upon the invariance of the discrete symmetries of
  - **Charge conjugation (C),**
  - **Parity transformation (P),**
  - **Time reversal (T),**
  - And the combined **CPT-symmetry**



- Strong and electromagnetic interactions are invariant under these transformations

  BUT the weak interaction violates CP-symmetry → T is violated

Motivations

- Only the combined CPT-symmetry is conserved

  → 2 consequences :

  1) **Particles and antiparticles share the same fundamental properties**

     Ex : Lifetime, mass,... (except for the sign of the quantum numbers)

  2) **Particles and antiparticles are created in pairs**

     → contradiction with astronomical observations (matter-antimatter asymmetry)

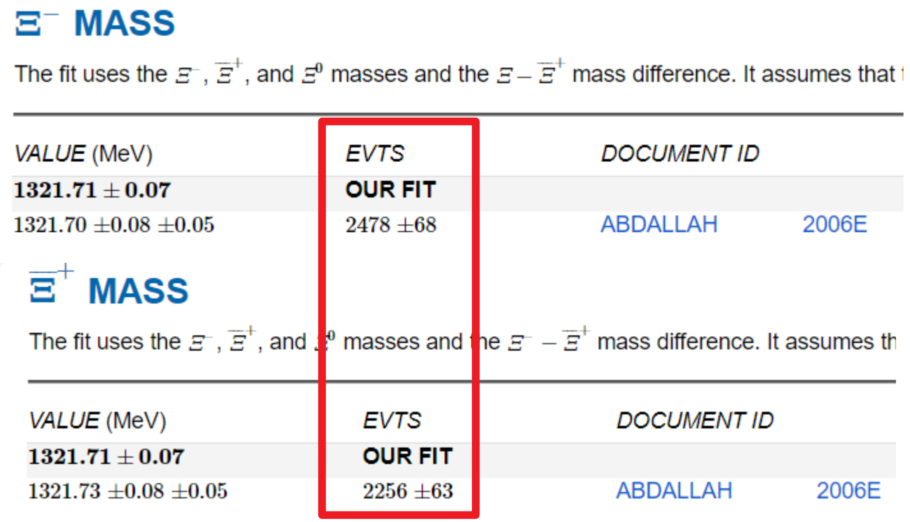
- CP violation is too small to account for the matter-antimatter asymmetry

  → need additionnal sources of symmetry violation including CPT-symmetry violation

- It is decisive to **test CPT invariance, especially when a precision gain is possible**

Motivations

- Previous mass measurements suffer of low statistics



Ξ^- MASS

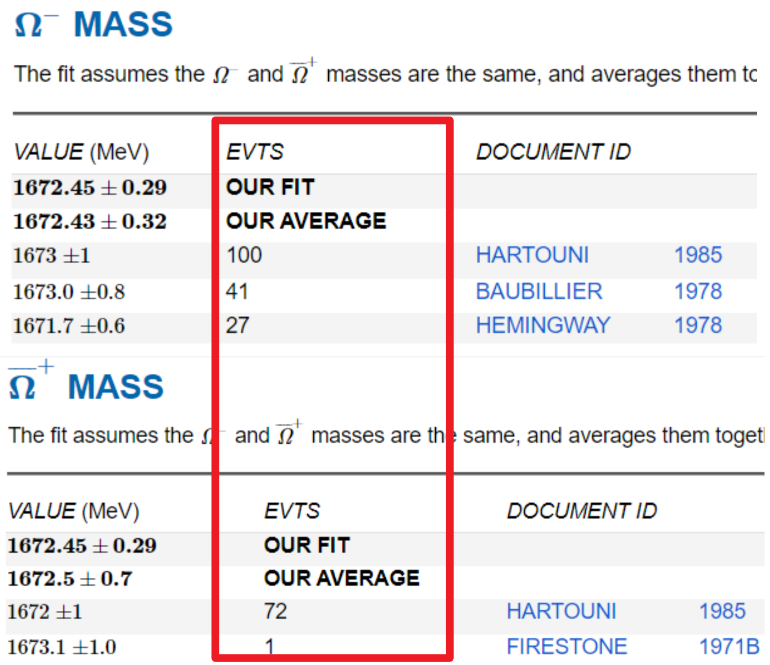
The fit uses the Ξ^-, $\overline{\Xi}^+$, and Ξ^0 masses and the $\Xi - \overline{\Xi}^+$ mass difference. It assumes that

VALUE (MeV)	*EVTS*	*DOCUMENT ID*	
1321.71 ± 0.07	**OUR FIT**		
1321.70 ±0.08 ±0.05	2478 ±68	ABDALLAH	2006E

$\overline{\Xi}^+$ MASS

The fit uses the Ξ^-, $\overline{\Xi}^+$, and Ξ^0 masses and the $\Xi^- - \overline{\Xi}^+$ mass difference. It assumes th

VALUE (MeV)	*EVTS*	*DOCUMENT ID*	
1321.71 ± 0.07	**OUR FIT**		
1321.73 ±0.08 ±0.05	2256 ±63	ABDALLAH	2006E



Ω^- MASS

The fit assumes the Ω^- and $\overline{\Omega}^+$ masses are the same, and averages them to

VALUE (MeV)	*EVTS*	*DOCUMENT ID*	
1672.45 ± 0.29	**OUR FIT**		
1672.43 ± 0.32	**OUR AVERAGE**		
1673 ±1	100	HARTOUNI	1985
1673.0 ±0.8	41	BAUBILLIER	1978
1671.7 ±0.6	27	HEMINGWAY	1978

$\overline{\Omega}^+$ MASS

The fit assumes the Ω^- and $\overline{\Omega}^+$ masses are the same, and averages them toget

VALUE (MeV)	*EVTS*	*DOCUMENT ID*	
1672.45 ± 0.29	**OUR FIT**		
1672.5 ± 0.7	**OUR AVERAGE**		
1672 ±1	72	HARTOUNI	1985
1673.1 ±1.0	1	FIRESTONE	1971B

→ coming from the difficulty to produce as much matter as antimatter

With the LHC, we have an excellent source of matter and antimatter !

- Goal : Using the ALICE detector
  - Provide new mass measurements of the Ξ and Ω
  - And compute their mass difference to test CPT invariance

The dataset

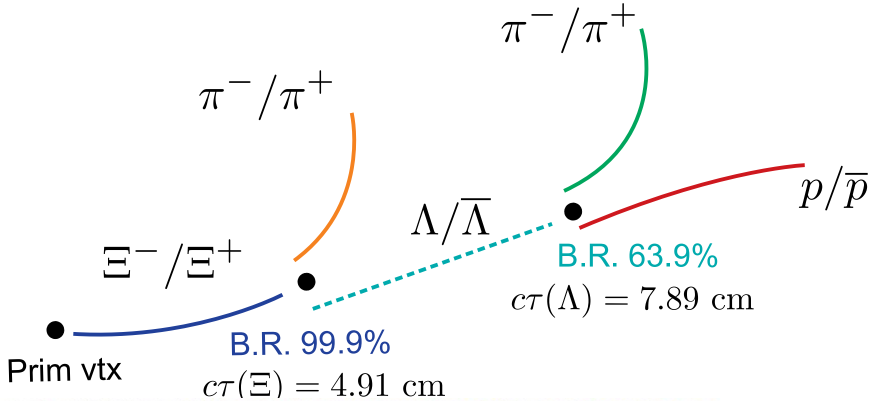
Objective : measure the mass of the Ξ and Ω, using LHC run II data

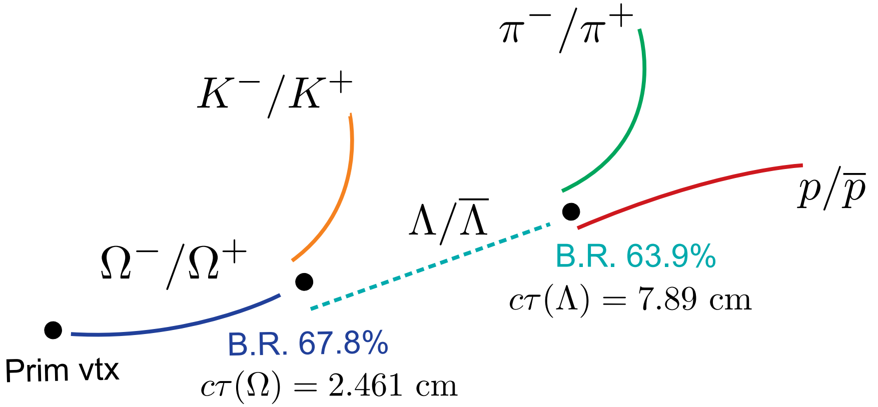
- Data :
  - ~ 2.2×10^9 pp collisions at $\sqrt{s} = 13$ TeV (LHC16 + LHC17 + LHC18)
  - Represents ~140×10^6 cascade candidates
- Event Selection :
  - ESDs,
  - Revertexing,
  - kINT7 and/or kHighV0M (MB + high multiplicity),
  - Remove in-bunch (IB) and out-of-bunch (OOB) pile up
- Analysis task : https://github.com/alisw/AliPhysics/blob/master/PWGLF/STRANGENESS/Cascades/Run2/AliAnalysisTaskStrangenessVsMultiplicityRun2

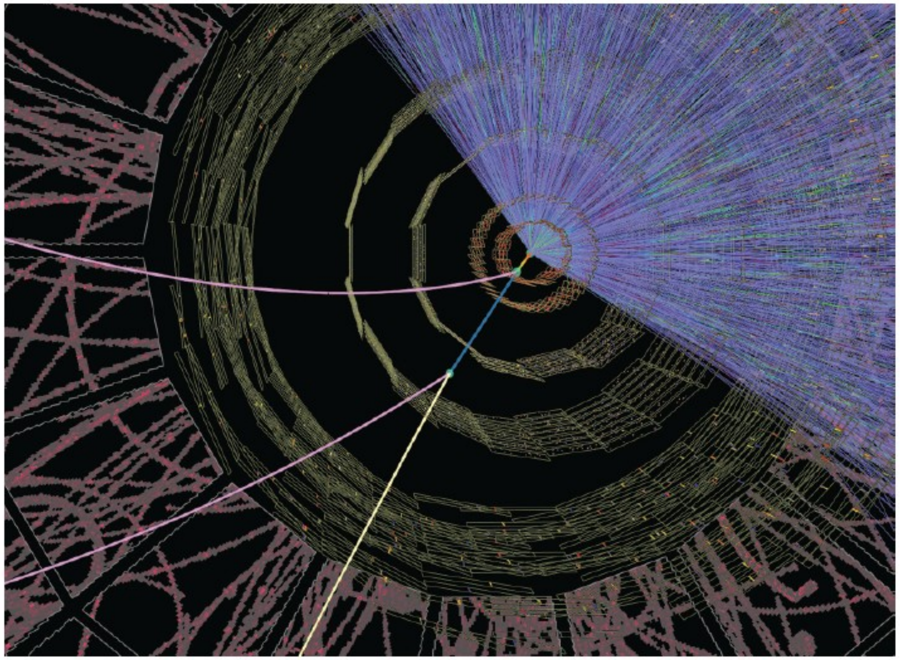
Analysis details

- Ξ and Ω will be studied in the following decay channel :

$$\begin{cases} \Xi^- \to \Lambda\,\pi^- \to p\,\pi^-\,\pi^- \\ \overline{\Xi}^+ \to \overline{\Lambda}\,\pi^+ \to \overline{p}\,\pi^+\,\pi^+ \end{cases} \qquad \begin{cases} \Omega^- \to \Lambda\,K^- \to p\,\pi^-\,K^- \\ \overline{\Omega}^+ \to \overline{\Lambda}\,K^+ \to \overline{p}\,\pi^+\,K^+ \end{cases}$$







- Ξ and Ω are distinguished from the combinatorial background using topological selections

Ξ selections

- Ξ are reconstructed using topological selections

Ξ-(Ξ+)	Cut value
|y|	< 0.5
pT	[1 ; 5] GeV/c

- Cascade selections

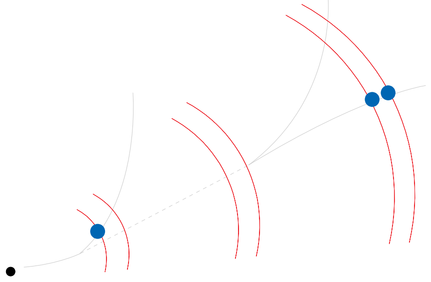
DCA Bach To PV	> 0.04 cm
DCA Casc daughters	< 1.3 cm
Casc Radius	> 0.6 cm
Casc Cos PA	> 0.97
Proper Lifetime	> 3 x 4.91 cm
Wrong PA	> 0.04

- Track selections :
  - $|\eta| < 0.8$
  - TPC refit
  - TPC Nbr Crossed Rows > 70
  - TPC PID Nsigma < 3

- V0 selections

DCA V0 to PV	> 0.04 cm
DCA Pos to PV	> 0.03 (0.04) cm
DCA Neg to PV	> 0.04 (0.03) cm
DCA V0 daughters	< 1.5 cm
V0 Radius	> 1.2 cm
V0 Cos PA	> 0.97
|V0 Mass - Λ Mass|	< 0.008 GeV/c²

- ITS hit requirements
  - Bachelor : SPD 0 OR 1
  - Proton : SSD 4 OR 5



Ω selections

- Ω are reconstructed using topological selections

Ω-(Ω+)	Cut value
|y|	< 0.5
pT	[1 ; 5] GeV/c

- Cascade selections

DCA Bach To PV	> 0.04 cm
DCA Casc daughters	< 1.3 cm
Casc Radius	> 0.5 cm
Casc Cos PA	> 0.97
Proper Lifetime	> 3 x 2.46 cm
Wrong PA	> 0.04
|Casc Mass - Ξ Mass|	> 0.008 GeV/c2

- Track selections :
  - $|\eta| < 0.8$
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  - TPC Nbr Crossed Rows > 70
  - TPC PID Nsigma < 3

- V0 selections

DCA V0 to PV	> 0.04 cm
DCA Pos to PV	> 0.03 (0.04) cm
DCA Neg to PV	> 0.04 (0.03) cm
DCA V0 daughters	< 1.5 cm
V0 Radius	> 1.1 cm
V0 Cos PA	> 0.97
|V0 Mass - Λ Mass|	< 0.008 GeV/c²

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  - Bachelor : SPD 0 OR 1
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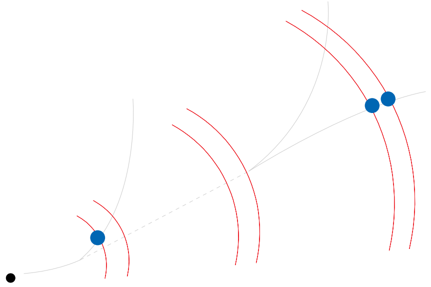
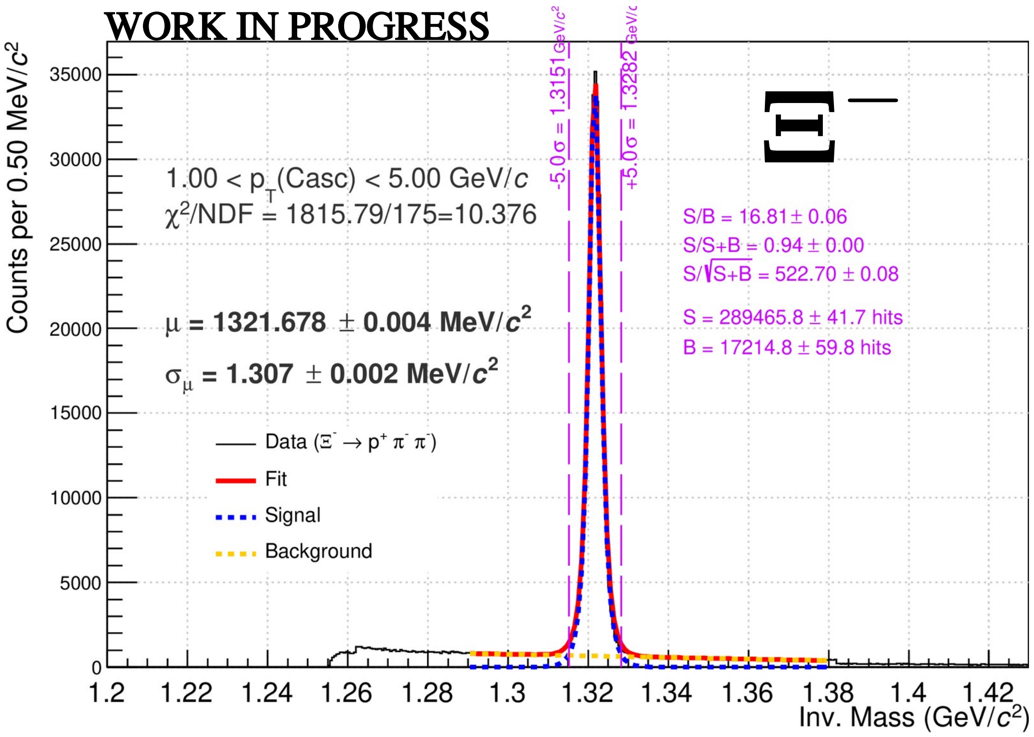
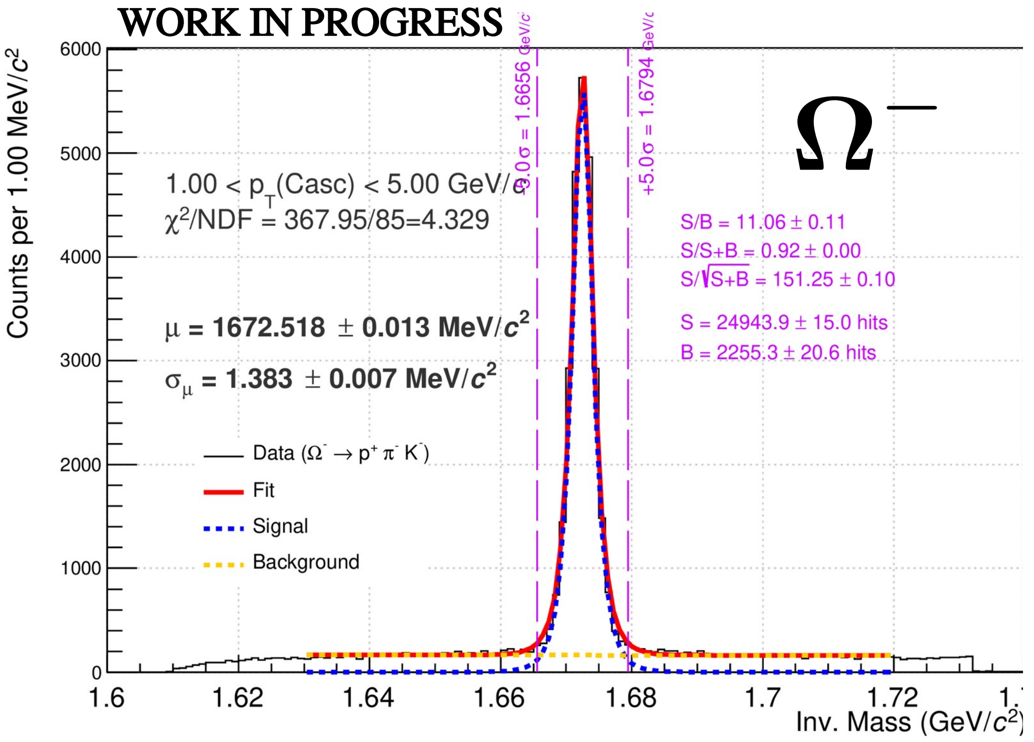


Mass extraction

- Background substraction for inv. mass analysis :
  - Fit with a *modified* Gaussian + linear function

$$\text{Modified Gaussian} = A \cdot \exp\left(-0.5u^{1+\frac{1}{1+0.5u}}\right) \quad ; \quad u = \left|\frac{x-\mu}{\sigma}\right|$$



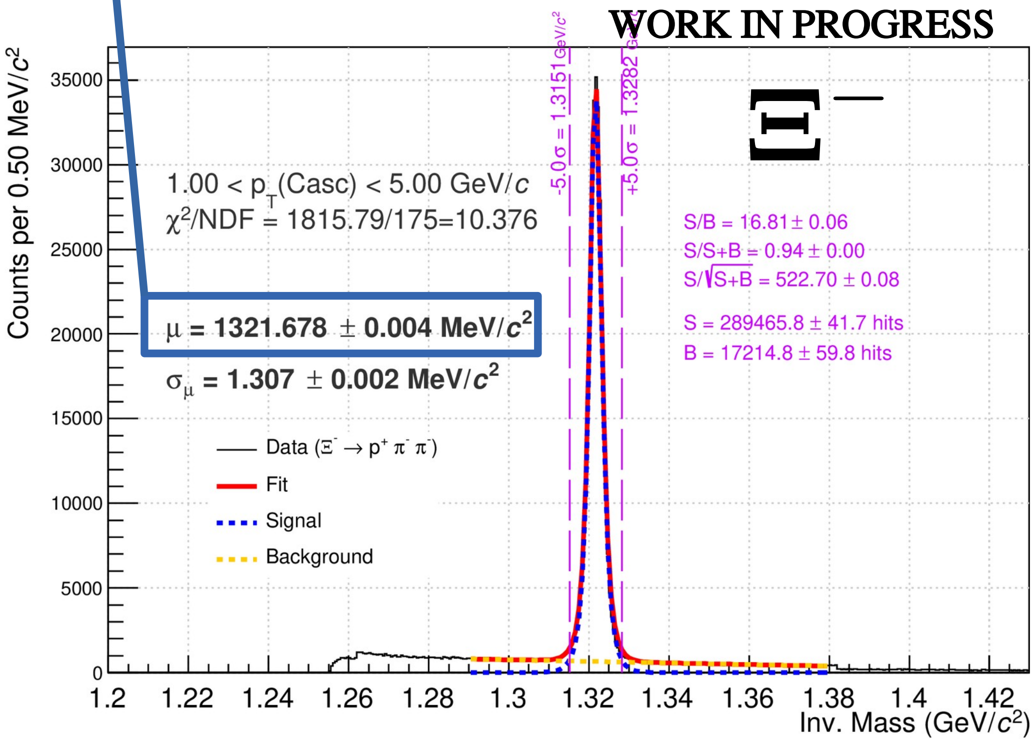


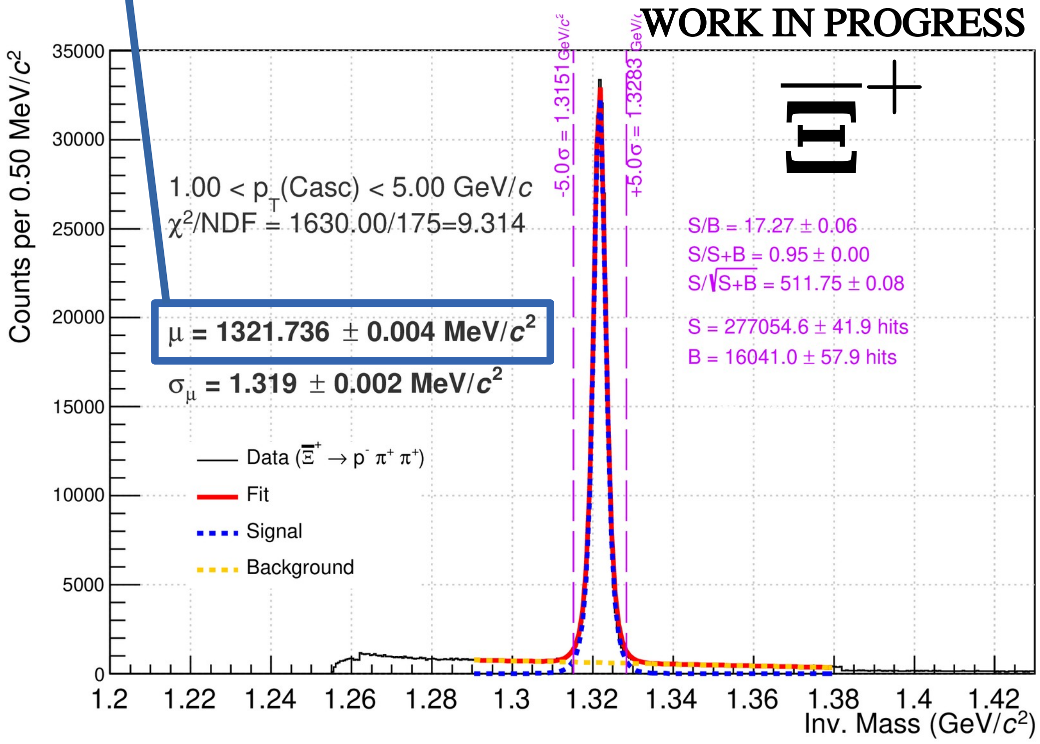
First Ξ mass measurements

$$\mathbf{M_{PDG}(\Xi) = 1321.710 \pm 0.070\ MeV/c^2}$$

$$\mu = \mathbf{1321.678 \pm (stat.)0.004\ MeV/c^2}$$

$$\mu = \mathbf{1321.736 \pm (stat.)0.004\ MeV/c^2}$$

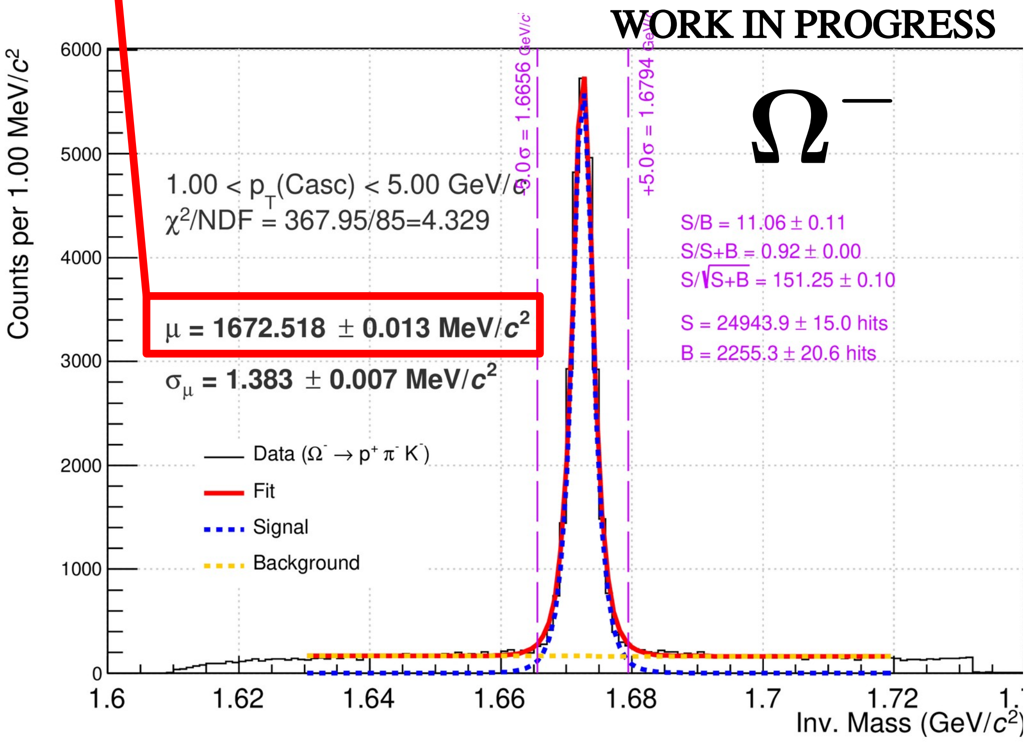




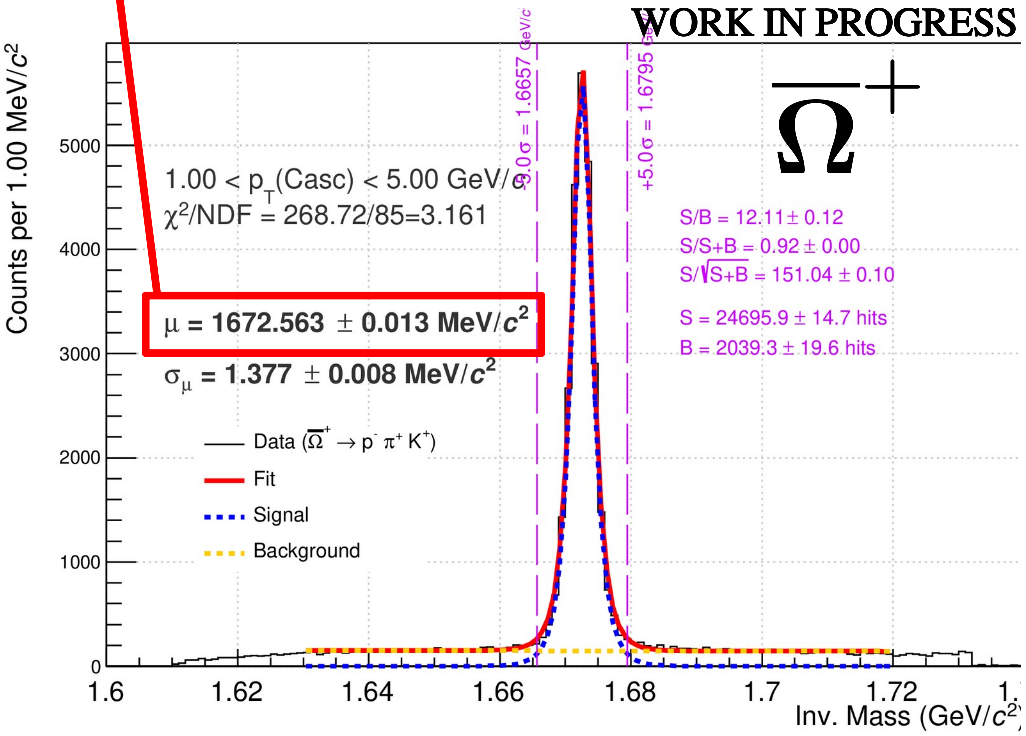
First Ω mass measurements

$$\mathbf{M_{PDG}(\Omega) = 1672.450 \pm 0.290\ MeV/c^2}$$

$$\mu = \mathbf{1672.518 \pm (stat.)0.013\ MeV/c^2}$$



$$\mu = \mathbf{1672.563 \pm (stat.)0.013\ MeV/c^2}$$



Systematic effects

- Expected main source of systematic uncertainties :
  - Topological selections
  - TPC selections
- Quantification of systematic uncertainties :
  - Vary these selections (14 selections)
  - Observe how the extracted mass and the error are distributed over 20 000 different set of selections

Variables	Default values	Range (Signal variation)
DCA Bach To PV	> 0.04 cm	[0.05–0.2] (19%)
DCA Casc daughters	< 1.3 cm	[0.4-1.2] (22%)
Casc Radius	> 0.5 cm	[0.5–1.6] (21%)
Casc Cos PA	> 0.97	[0.97-0.999] (55%)
Proper Lifetime	> 3 x 2.46 cm	[2.5-5] (27%)
DCA V0 to PV	> 0.04 cm	[0.06-0.2] (18%)
DCA Pos to PV	> 0.03 (0.04) cm	[0.04-0.5] (28%)
DCA Neg to PV	> 0.04 (0.03) cm	[0.04-0.5](29%)
DCA V0 daughters	< 1.5 cm	[0.4-1.2] (32%)
V0 Radius	> 1.1 cm	[1.2-5] (17%)
V0 Cos PA	> 0.97	[0.97-0.998] (50%)
|V0 Mass – Λ Mass|	< 0.008 GeV/c^2	[0.002-0.007] (33%)

$$\Omega^{-}$$

TPC Min Nbr Cr Rows	> 70	[70-90] (17%)
TPC PID	$< 3\sigma$	[1-3] (15%)

Systematic study strategy

- For each selection, a random cut value is extracted from the actual distribution of this variable in the variation range (using TUnuran)

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- This procedure is repeated 20 000 times
- For each set of selections i, we extract :
  - The measured mass μ_i
    → store in an histogram ➡
    $$\begin{cases} \mathrm{Mass} = \mathrm{Mean} = \bar{\mu} \\ \sigma_{\mathrm{syst}} = \mathrm{RMS} \end{cases}$$
  - The error on the mass σ_i
    → store in an histogram ➡ $\sigma_{\mathrm{stat}} = \bar{\sigma}$

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- This procedure is repeated 20 000 times
- For each set of selections i, we extract :

  - The measured mass difference $\Delta\mu_i/\mu_i^{\text{part}} = (\mu_i^{\overline{\text{part}}} - \mu_i^{\text{part}})/\mu_i^{\text{part}}$

    → store in an histogram ➡ $\left\{ \begin{array}{l} \dfrac{\Delta\text{Mass}}{\text{Mass}} = \text{Mean} = \overline{\dfrac{\Delta\mu_i}{\mu_i^{\text{part.}}}} \\ \sigma_{\text{syst}} = \text{RMS} \end{array} \right.$

  - The error on the mass difference $\sigma_{(\mu_i^{\overline{\text{part}}} - \mu_i^{\text{part}})/\mu_i^{\text{part}}}$

    → store in an histogram ➡ $\sigma_{\text{stat}} = \overline{\sigma}_{(\mu_i^{\overline{\text{part}}} - \mu_i^{\text{part}})/\mu_i^{\text{part}}}$

Systematic effects

- Systematic uncertainties :
  - **Topological and TPC selections :**

Mass Values		
Particle	Stat. Uncert. (MeV/c^2)	Syst. Uncert. (MeV/c^2)
Ξ	0.005	**0.010**
Ω	0.015	**0.014**

Mass difference		
Particle	Stat. Uncert. ($\times\ 10^{-5}$)	Syst. Uncert. ($\times\ 10^{-5}$)
Ξ	0.77	**0.79**
Ω	0.79	**1.19**

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  - **B field precision**

Precision : 0.0001 T

$$p_{\mathrm{T}} = 0.3 \cdot B \cdot R \quad \longrightarrow \quad p_{\mathrm{T,\ new}} = \frac{B}{B_0} p_{\mathrm{T,\ 0}}$$

Here B/B_0 = 1.0001 or 0.9999

Systematic effects

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Mass difference		
Particle	Stat. Uncert. ($\times$ 10^{-5})	Syst. Uncert. ($\times$ 10^{-5})
Ξ	0.77	**0.79**
Ω	0.79	**1.19**

  - **B field precision**

Ξ	/	**0.006**
Ω	/	**0.006**

Ξ	/	**Negl. (?)**
Ω	/	**Negl. (?)**

Systematic effects

- Systematic uncertainties :
  - **Topological and TPC selections :**

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  - **B field precision**

Ξ	/	**0.006**
Ω	/	**0.006**

Ξ	/	**Negl. (?)**
Ω	/	**Negl. (?)**

  - **Choice of the fit functions**

Try different fit functions : Gaussian, double Gaussian, modified Gaussian, Bukin function

- Extracted mass = weighted average
- Systematic uncertainties = weighted RMS

Systematic effects

- Systematic uncertainties :

  - **Topological and TPC selections :**

Mass Values		
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Ξ	0.77	**0.79**
Ω	0.79	**1.19**

  - **B field precision**

Ξ	/	**0.006**
Ω	/	**0.006**

Ξ	/	**Negl. (?)**
Ω	/	**Negl. (?)**

  - **Choice of the fit functions**

Ξ	/	0.004
Ω	/	0.003

Ξ	/	0.25
Ω	/	0.01

Systematic effects

- Systematic uncertainties :

◆ **Topological and TPC selections :**

Mass Values		
Particle	Stat. Uncert. (MeV/c^2)	Syst. Uncert. (MeV/c^2)
Ξ	0.005	**0.010**
Ω	0.015	**0.014**

Mass difference		
Particle	Stat. Uncert. ($\times\ 10^{-5}$)	Syst. Uncert. ($\times\ 10^{-5}$)
Ξ	0.77	**0.79**
Ω	0.79	**1.19**

◆ **B field precision**

Ξ	/	**0.006**
Ω	/	**0.006**

Ξ	/	**Negl. (?)**
Ω	/	**Negl. (?)**

◆ **Choice of the fit functions**

Ξ	/	0.004
Ω	/	0.003

Ξ	/	0.25
Ω	/	0.01

◆ **Choice of the fitting range**

→ Vary the fitting range and look at the mass and mass difference deviations wrt to the default fitting range

Systematic effects

- Systematic uncertainties : **WORK IN PROGRESS**
  - **Topological and TPC selections :**

Mass Values		
Particle	Stat. Uncert. (MeV/c^2)	Syst. Uncert. (MeV/c^2)
Ξ	0.005	**0.010**
Ω	0.015	**0.014**

Mass difference		
Particle	Stat. Uncert. ($\times\ 10^{-5}$)	Syst. Uncert. ($\times\ 10^{-5}$)
Ξ	0.77	**0.79**
Ω	0.79	**1.19**

  - **B field precision**

Ξ	/	**0.006**
Ω	/	**0.006**

Ξ	/	**Negl. (?)**
Ω	/	**Negl. (?)**

  - **Choice of the fit functions**

Ξ	/	0.004
Ω	/	0.003

Ξ	/	0.25
Ω	/	0.01

  - **Choice of the fitting range**

Ξ	/	0.002
Ω	/	0.003

Ξ	/	0.17
Ω	/	0.17

Systematic study results

- Mass values : **WORK IN PROGRESS**

Particle	Mass (MeV/c^2)	Tot Uncert. (MeV/c^2)	Stat. Uncert. (MeV/c^2)	Syst. Uncert. (MeV/c^2)	PDG Mass (MeV/c^2)	PDG Tot Uncert. (MeV/c^2)
Ξ	1321.762	**0.014**	0.005	0.013	1321.71	**0.07**
Ω	1672.570	**0.022**	0.015	0.016	1672.45	**0.29**

  - Improve current PDG mass values by a factor 5 for Ξ and ~13 for Ω

- Test CPT-invariance : mass difference values **WORK IN PROGRESS**

Particle	Mass diff. ($\times 10^{-5}$)	Tot Uncert. ($\times 10^{-5}$)	Stat. Uncert. ($\times 10^{-5}$)	Syst. Uncert. ($\times 10^{-5}$)	PDG Mass diff($\times 10^{-5}$)	PDG Tot Uncert ($\times 10^{-5}$)
Ξ	4.33	**1.15**	0.77	0.85	2.5	**8.7**
Ω	0.61	**2.13**	1.75	1.21	1.44	**7.98**

  - Improve current PDG mass diff. values by a factor ~7.6 for Ξ and ~3.8 for Ω
  - Mass difference ~ 0 : CPT still valid

Check : compare with PDG mass

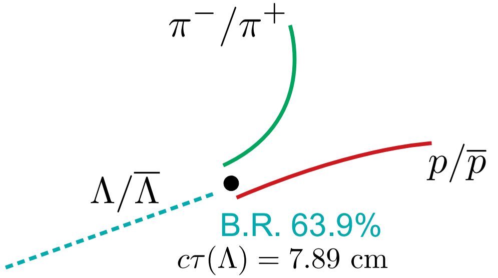
- Mass values : **WORK IN PROGRESS**

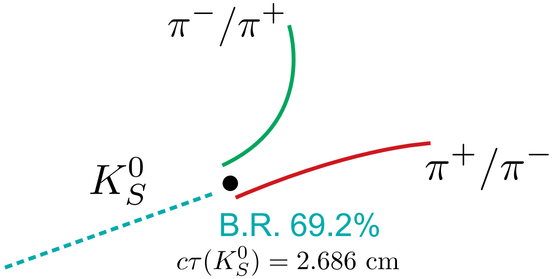
Particle	Mass (MeV/c^2)	Tot Uncert. (MeV/c^2)	Stat. Uncert. (MeV/c^2)	Syst. Uncert. (MeV/c^2)	PDG Mass (MeV/c^2)	PDG Tot Uncert. (MeV/c^2)
Ξ	1321.762	**0.014**	0.005	0.013	1321.71	**0.07**
Ω	1672.570	**0.022**	0.015	0.016	1672.45	**0.29**

- Gap between our mass values and the PDG ones **(almost 1σ for the Ξ)**
- To check that the analysis is working properly :
  - Take a particle whose PDG mass is evaluated very precisely (σ ~ few keV/c²),
  - Check that the mass extracted by the analysis corresponds to the PDG mass

- Here, this check will be done using Λ and K0s

$$m_{\mathrm{PDG}}(\Lambda) = 1115.683 \pm 0.006\ \mathrm{MeV}/c^2 \qquad m_{\mathrm{PDG}}(K^0_S) = 497.611 \pm 0.013\ \mathrm{MeV}/c^2$$





V0 candidate selections

- Candidates are **Λ, anti-Λ and K0s**

- V0 selections

Variables	Cut
Rapidity	< 0.5
Pt	[1; 5] GeV/c

- Track Selections

TPC refit	kTRUE
TPC PID N Sigma	< 3 σ
Nbr crossed rows	> 70
η	< 0.8

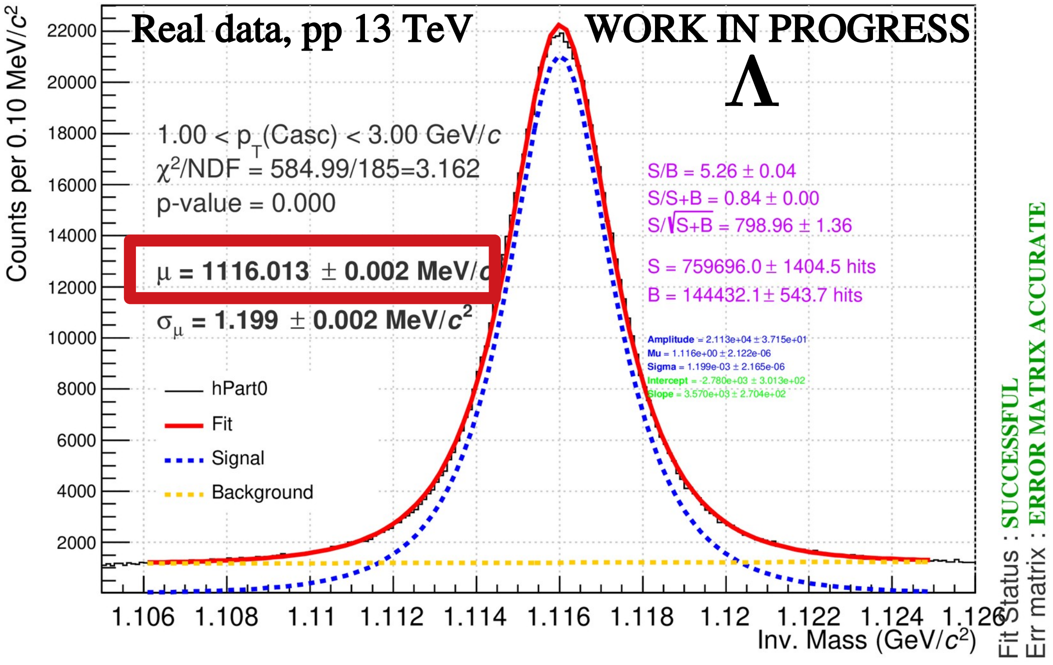
- Topological selections

Variables	Cut Λ (K0s)
DCA V0 daughters	< 1.5 (1.0)
V0 Radius	> 0.5 cm
V0 Cos PA	> 0.97
V0 Lifetime	< 3x7.89 (3x2.686) cm
DCA V0 to PV	< 1 (0.06) cm
DCA Pos to PV	> 0.06 cm
DCA Neg to PV	> 0.06 cm

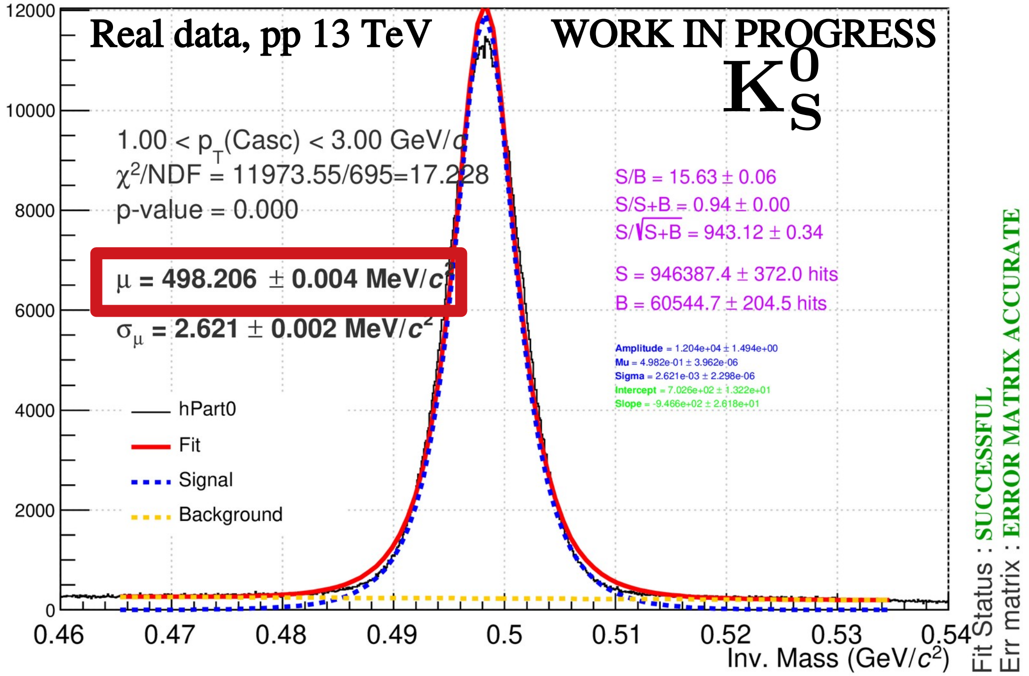
Mass shift

- Same procedure as for the Ξ and Ω
- The extracted mass is above the PDG mass by
  - ~ 300 keV/c^2 for Λ
  - ~ 600 keV/c^2 for K0s

$$\mathbf{m_{PDG}(\Lambda) = 1115.683 \pm 0.006}\ \mathrm{MeV}/\mathbf{c^2}$$

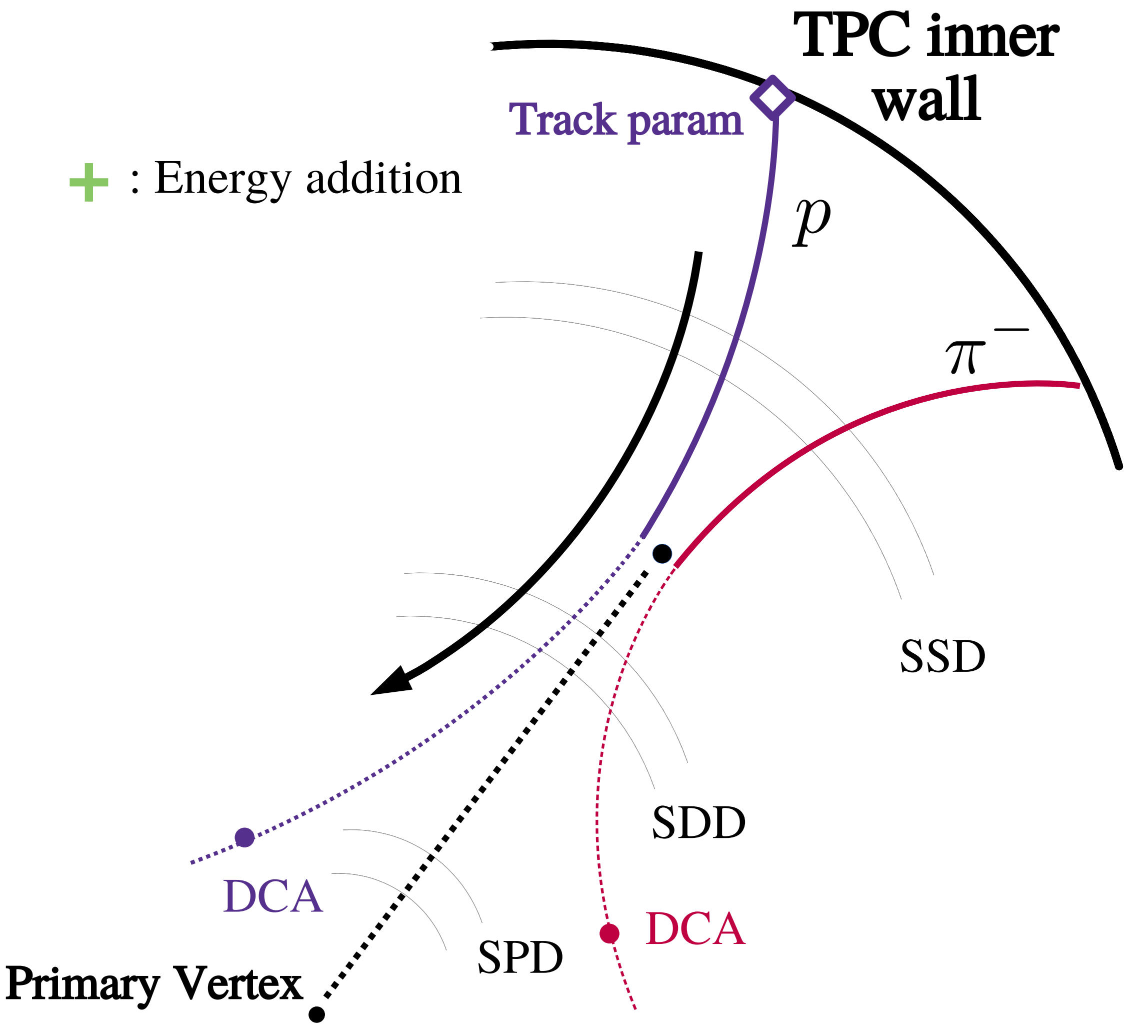


$$\mathbf{m_{PDG}(K^0_S) = 497.611 \pm 0.013}\ \mathrm{MeV}/\mathbf{c^2}$$



Main cause of the mass shift

- Once all tracks are reconstructed, they are **propagated to their point of closest approach to the primary vertex** (= hypothesis that all the tracks are primaries)
- In the propagation, corrections on the energy loss (based on PID used for tracking) are applied :



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  - → add energy
- Outward propagation (PV→TPC):
  - → subtract energy

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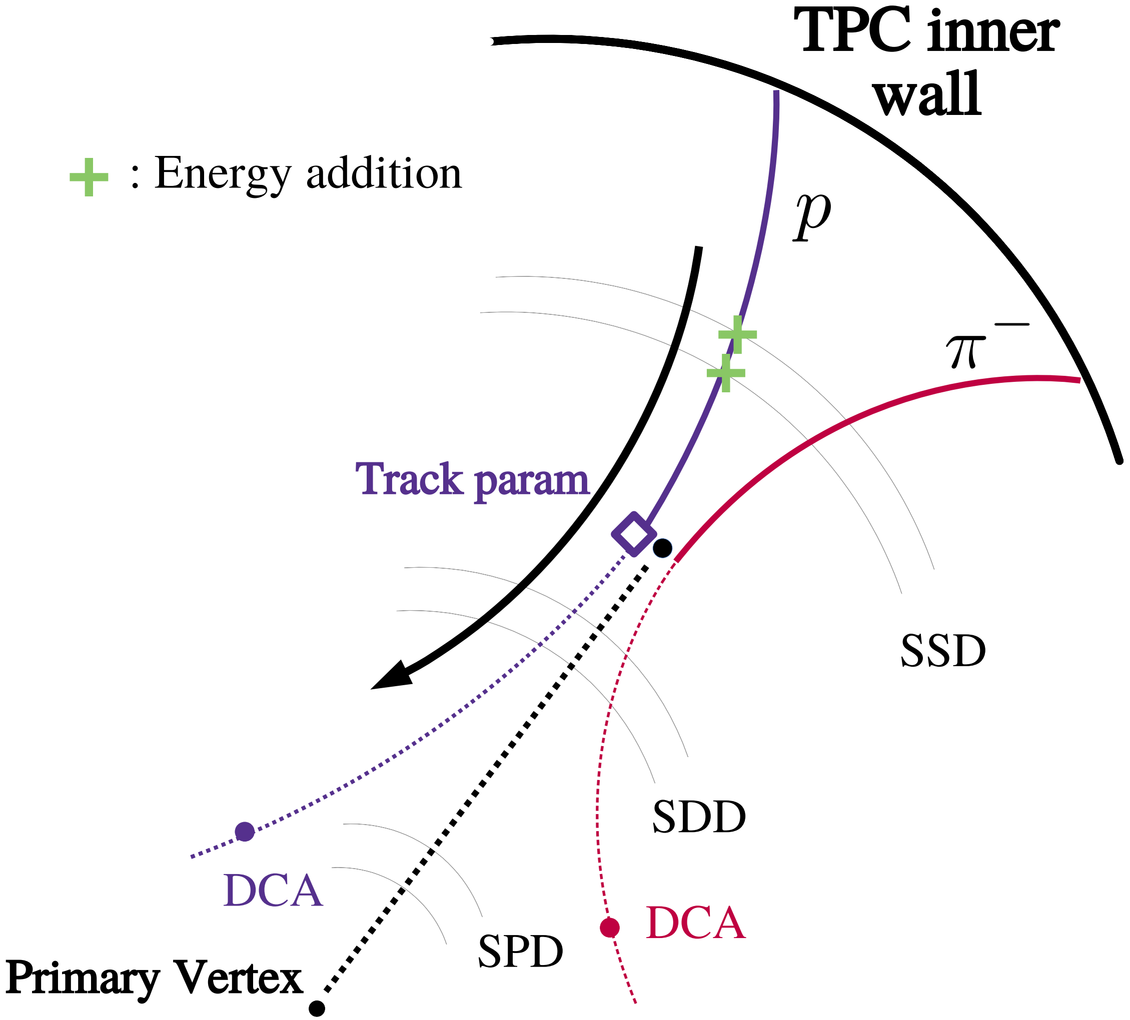

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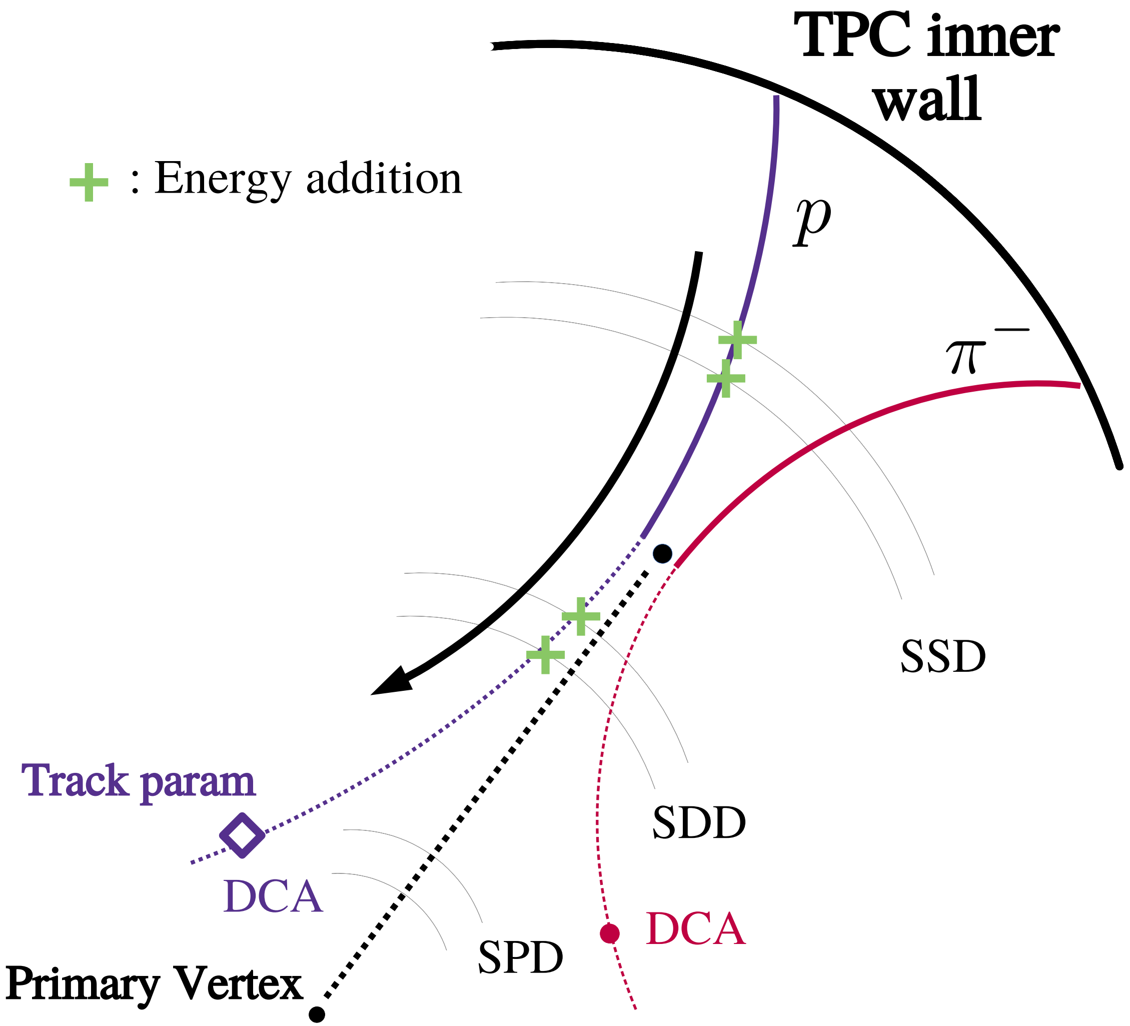

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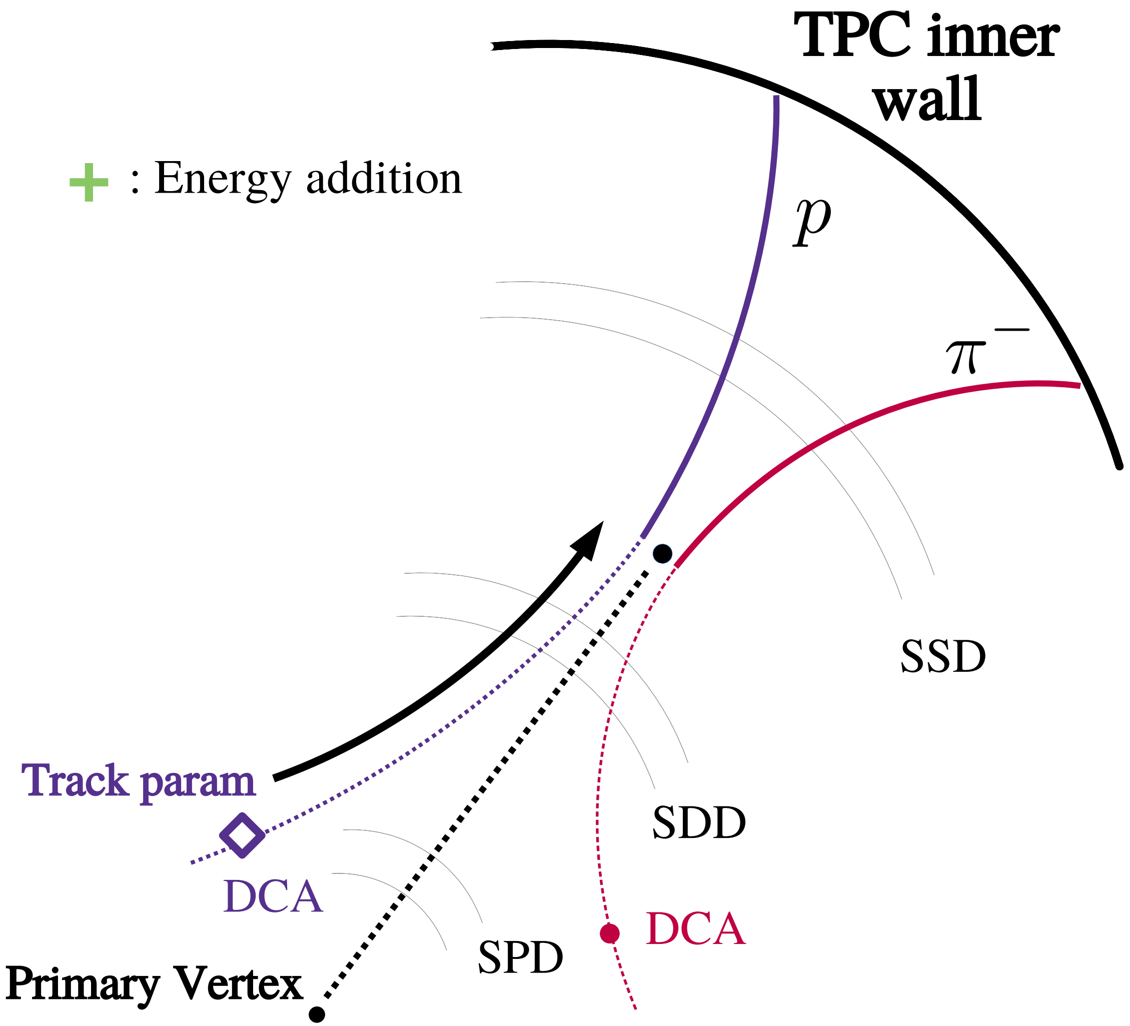

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- V0/cascade offline finding :
  - Propagate the tracks to decay point
  - Energy corrections are not redone
  - → **daughters have extra-momentum**
  - → **invariant mass is shifted**

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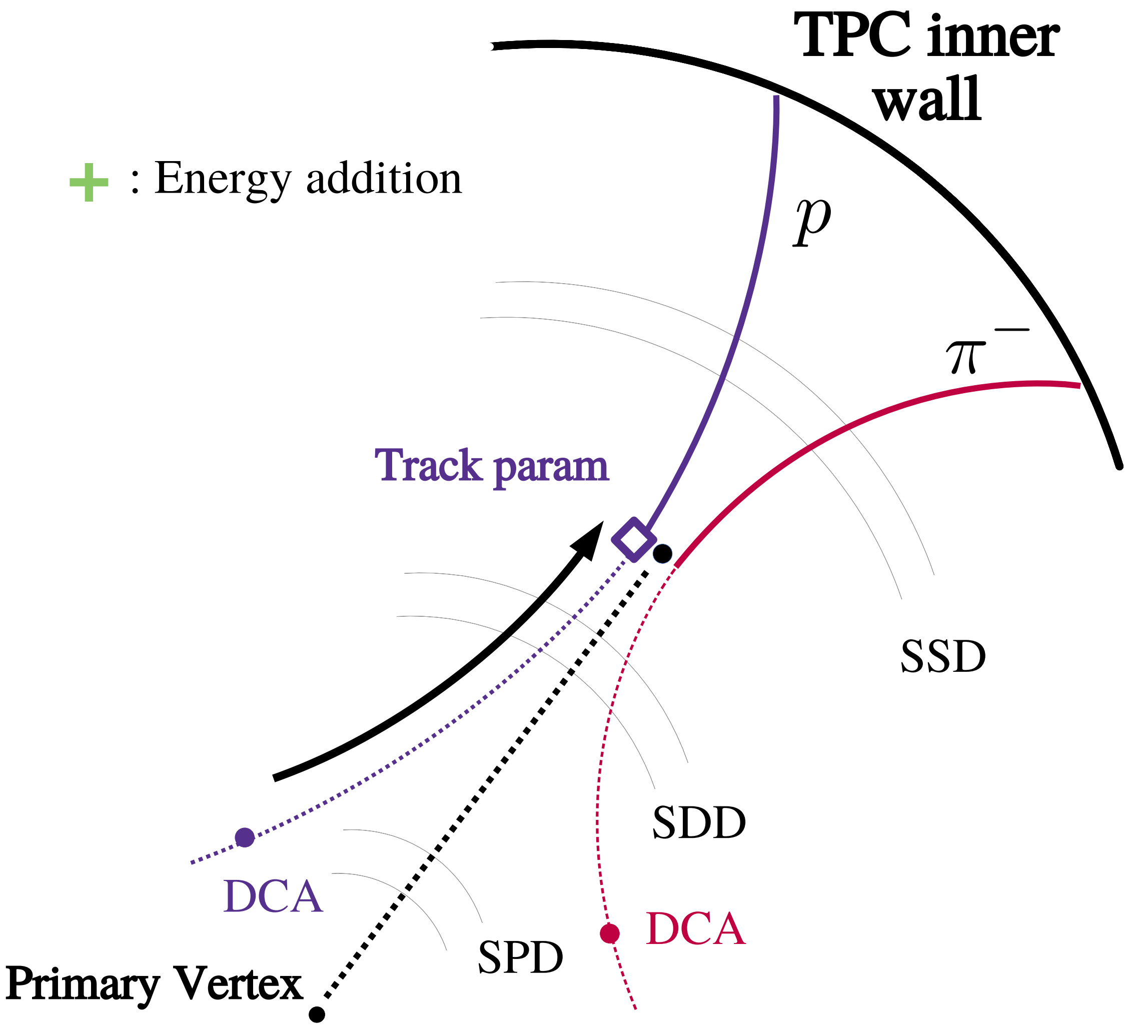

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  - Propagate the tracks to decay point
  - Energy corrections are not redone
    → **daughters have extra-momentum**
    → **invariant mass is shifted**

The dataset

Objective : Correct for extra energy loss correction, using a MC sample.

- 2 MC samples :
  - General purpose, anchored on LHC18m (LHC21a5a)
  - Enriched in Ξ and Ω, anchored on LHC18i (LHC20i2b)
- Event Selection :
  - ESDs,
  - Revertexing,
  - kINT7 and/or kHighV0M (MB + high multiplicity),
  - Remove in bunch (IB) and out-of-bunch (OOB) pile up
- Analysis task : https://github.com/alisw/AliPhysics/blob/master/PWGLF/STRANGENESS/Cascades/Run2/AliAnalysisTaskStrangenessVsMultiplicityRun2

Candidate selections

- Candidates are **primary Λ, anti-Λ and K0s**

- V0 selections

Variables	Cut
Rapidity	< 0.5
p_T	[1; 5] GeV/*c*
MC association	YES

- Track Selections

TPC refit	kTRUE
TPC PID N Sigma	< 3 σ
Nbr crossed rows	> 70
η	< 0.8

- Topological selections

Variables	Cut Λ (K0s)
DCA V0 daughters	< 1.5 (1.0)
V0 Radius	> 0.5 cm
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V0 Lifetime	< 3*7.89 (3*2.686) cm
DCA V0 to PV	< 1 (0.06) cm
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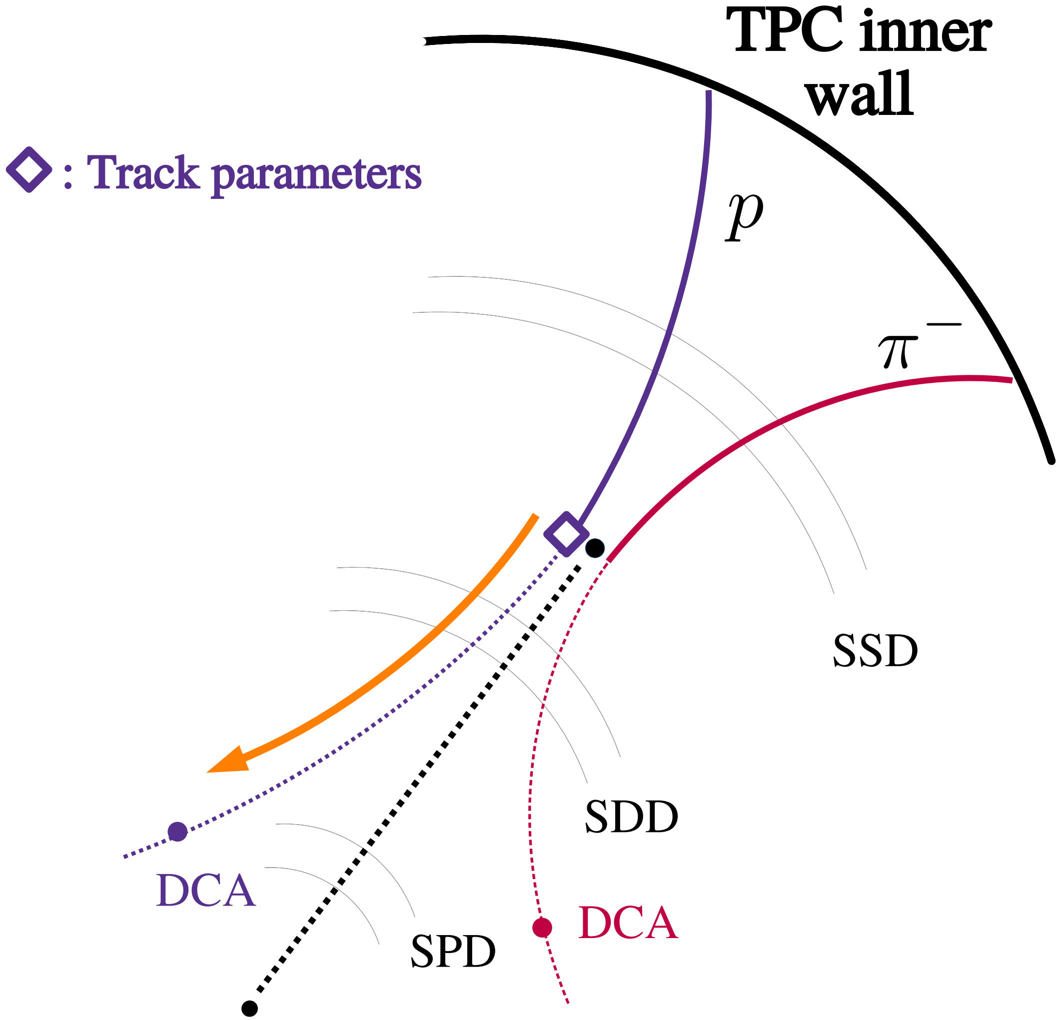
Apply retrocorrections

- Redo track propagation with the appropriate energy loss correction
  - **Propagate the track to the inner wall of the TPC** (w/ energy correction)
  - **Go back to the decay point**, applying energy correction w/ the correct PID assumption



- 1st step : propagate to the DCA to PV **without** energy correction

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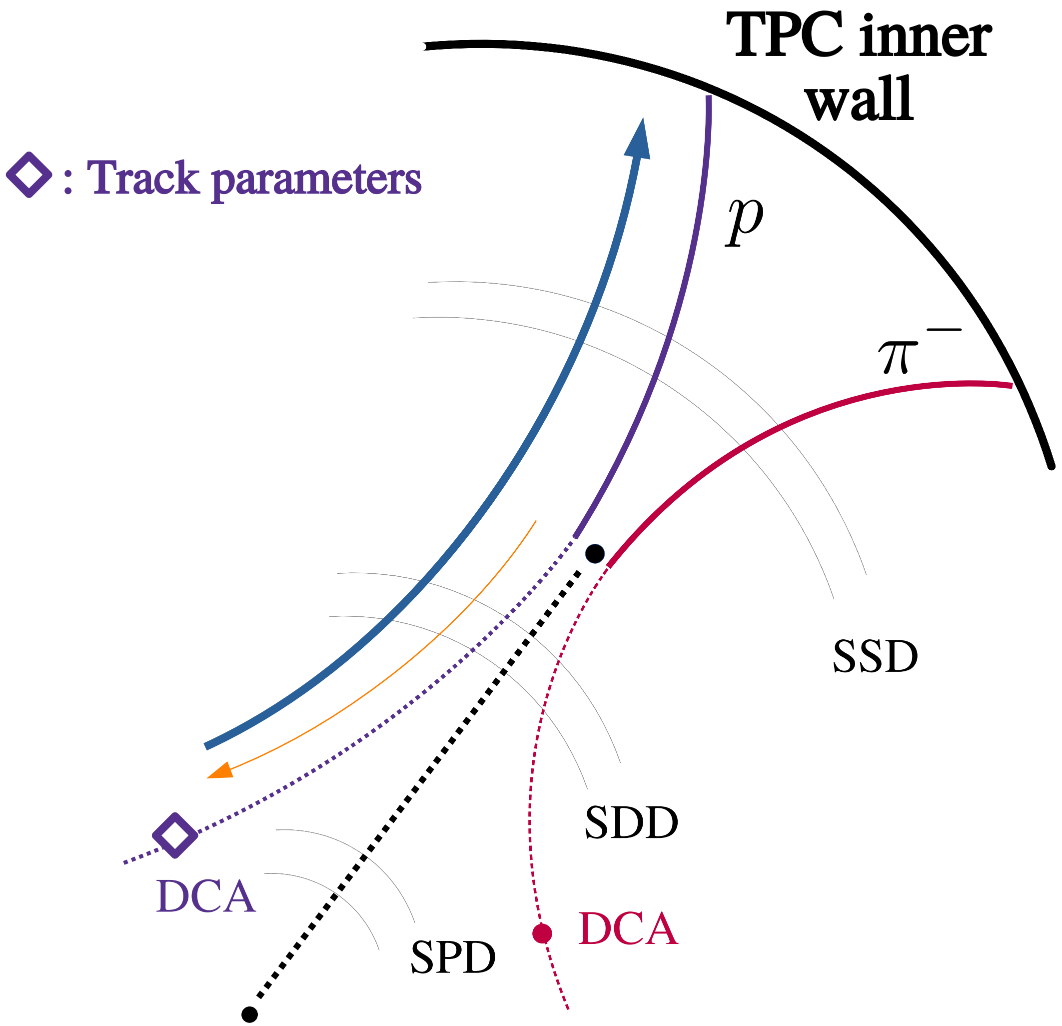

- 1st step : propagate to the DCA to PV **without** energy correction
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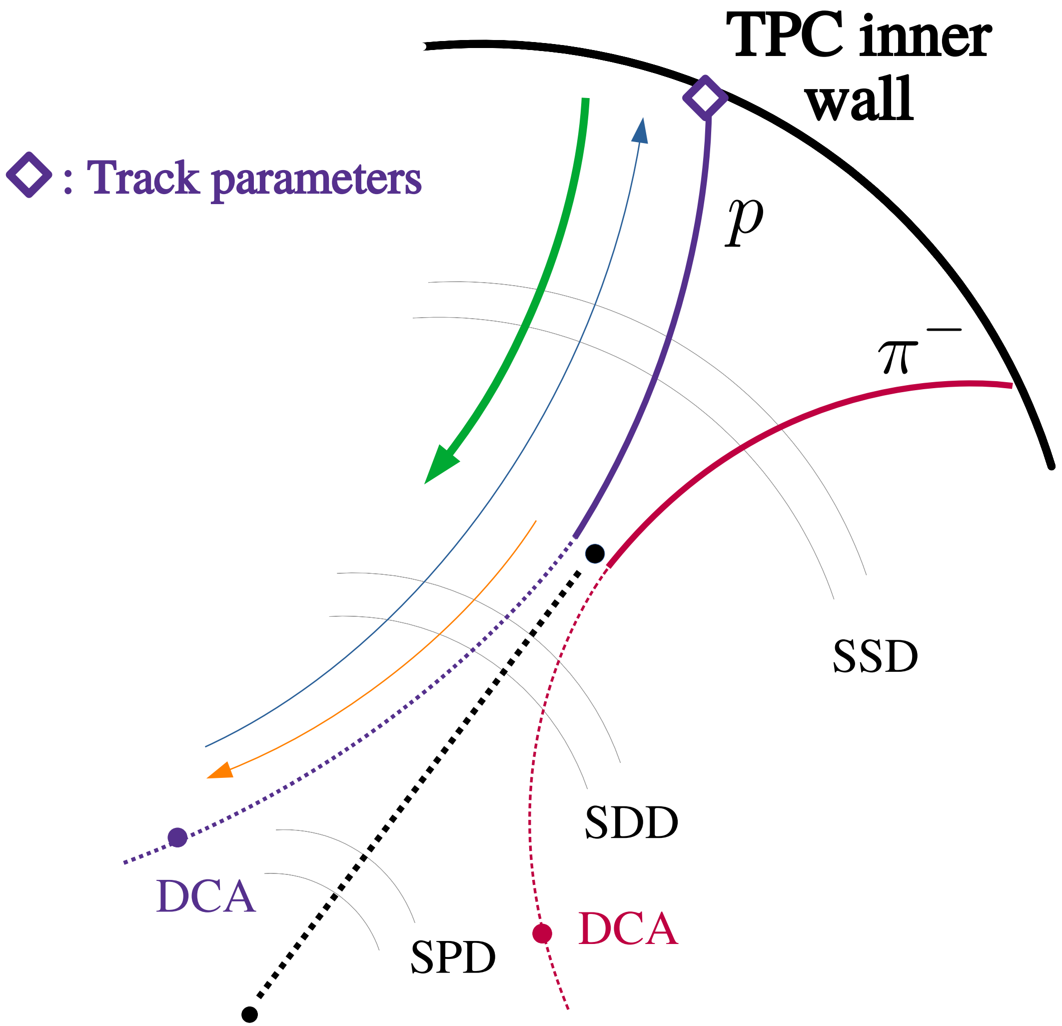

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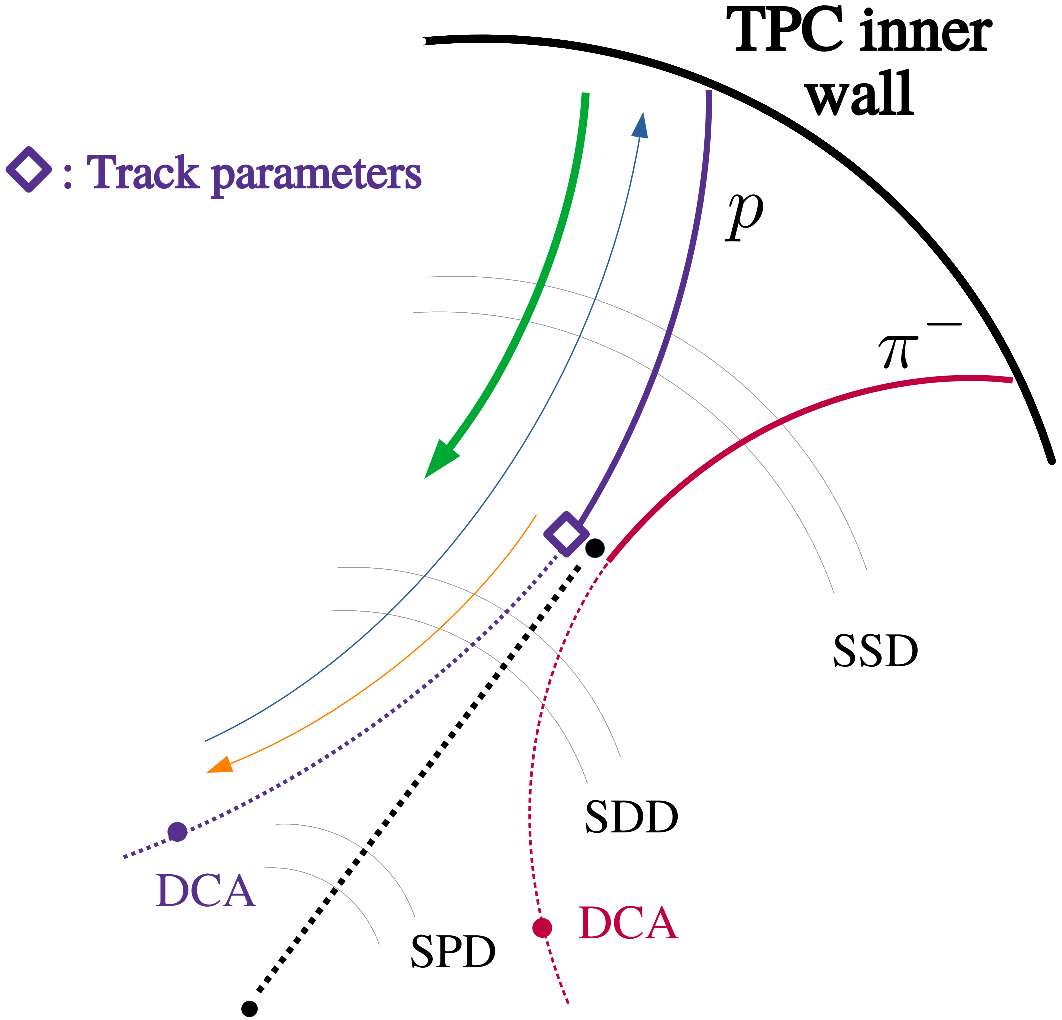

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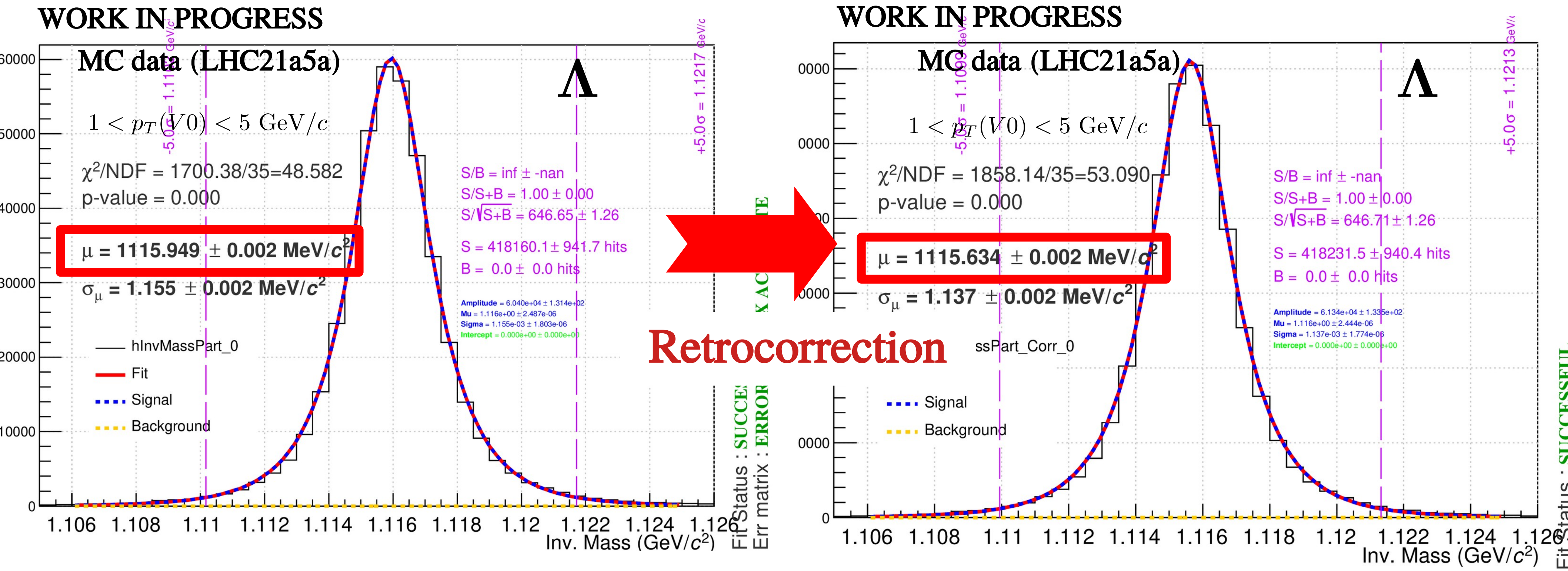
- 3rd step : propagate back to decay point **with** energy correction (hyp : correct PID)

Λ Invariant mass

- To get an idea whether or not these corrections are going in the right direction

  → look at the invariant mass

$$\mathbf{m_{PDG}(\Lambda) = 1115.683 \pm 0.006\ \mathrm{MeV}/c^2}$$



Retrocorrection

→ +266 keV/c^2 shift wrt to PDG mass (injected mass)

→ -49 keV/c^2 shift wrt to PDG mass (injected mass)

K0s Invariant mass

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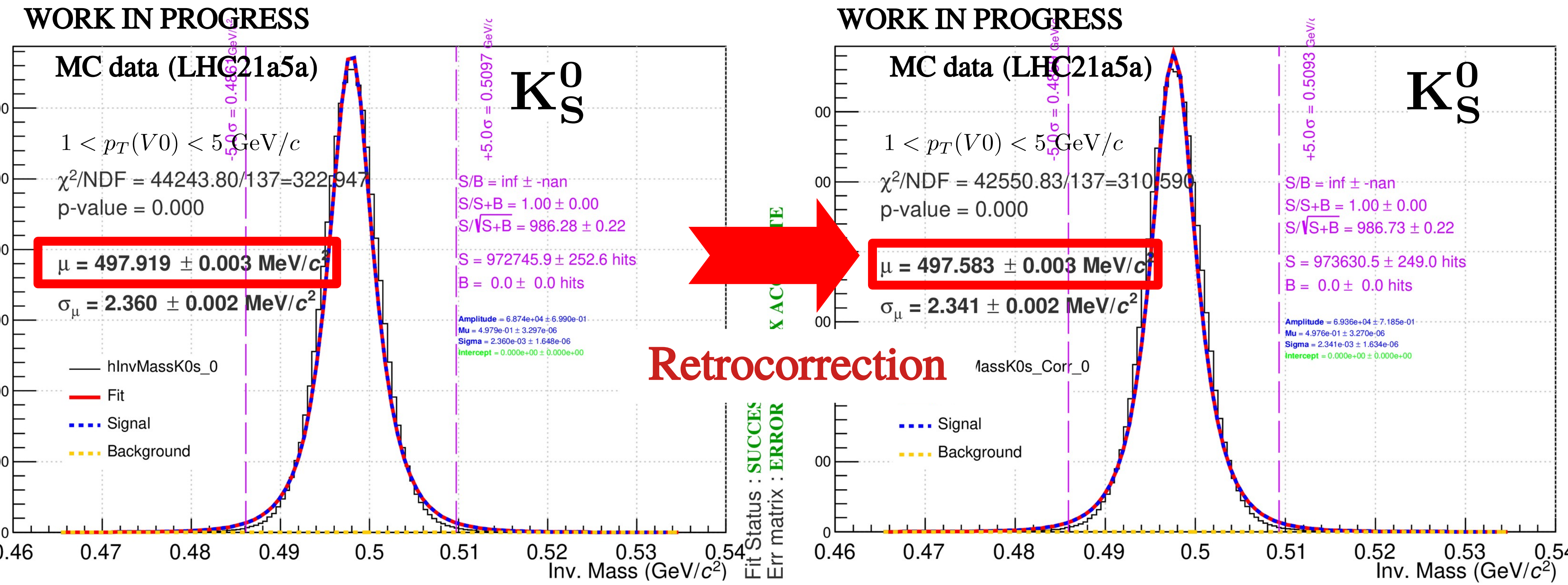
$$\mathbf{m_{PDG}(K^0_S) = 497.611 \pm 0.013\ \mathrm{MeV}/c^2}$$



→ +308 keV/c^2 shift wrt to PDG mass (injected mass)

→ -28 keV/c^2 shift wrt to PDG mass (injected mass)

I) Introduction

1. Motivations
2. The ALICE set-up

II) CPT symmetry test : mass measurements of the Ξ(dss) and Ω(sss)

1. Motivations
2. Analysis based on real data
3. Analysis based on MC data
4. Current status for Ξ(dss) and Ω(sss)

III) Correlated production of strangeness : yield ratio measurement of $\phi(s\bar{s})$ to Ω(sss)

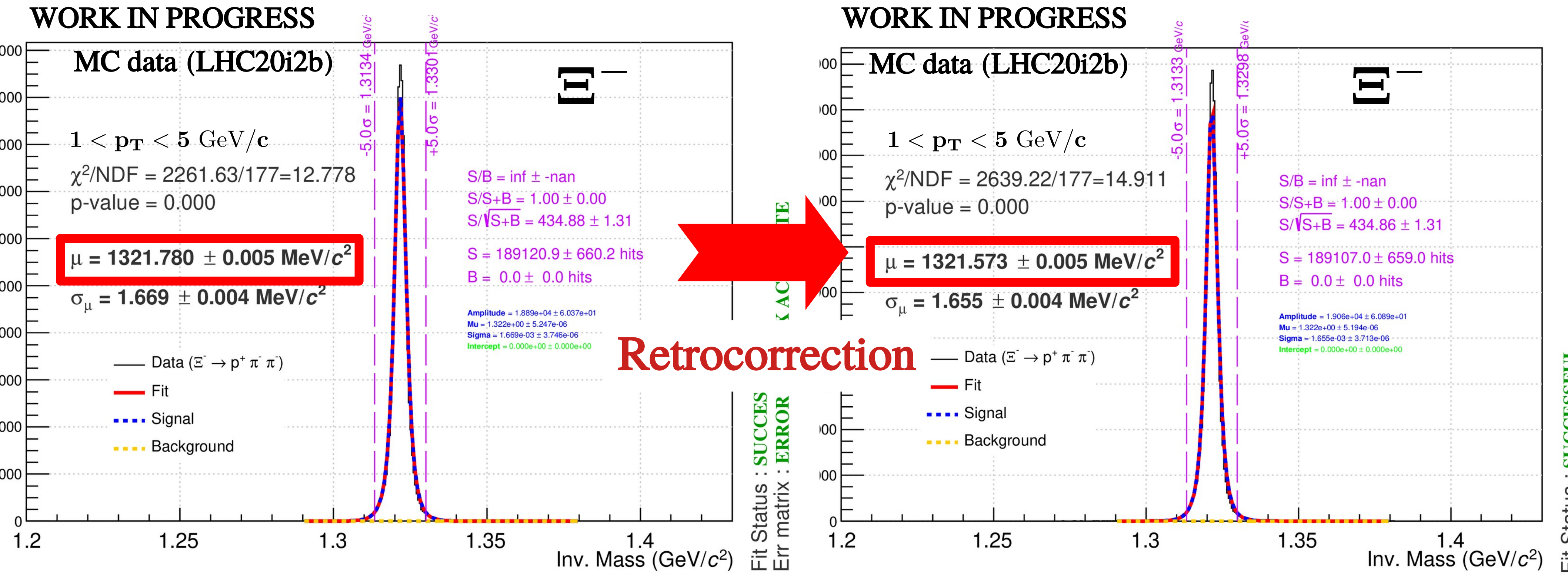
1. Motivations
2. Analysis details
3. A first glimpse on the complexity of such a measurement
4. Preliminary results

IV) Conclusion and other activities

Ξ Invariant mass

- Look at dE/dx retrocorrection applied on cascades
- **In MC data (LHC20i2b) :**

$$\mathbf{m_{PDG}(\Xi) = 1321.71 \pm 0.07\ \mathrm{MeV}/c^2}$$



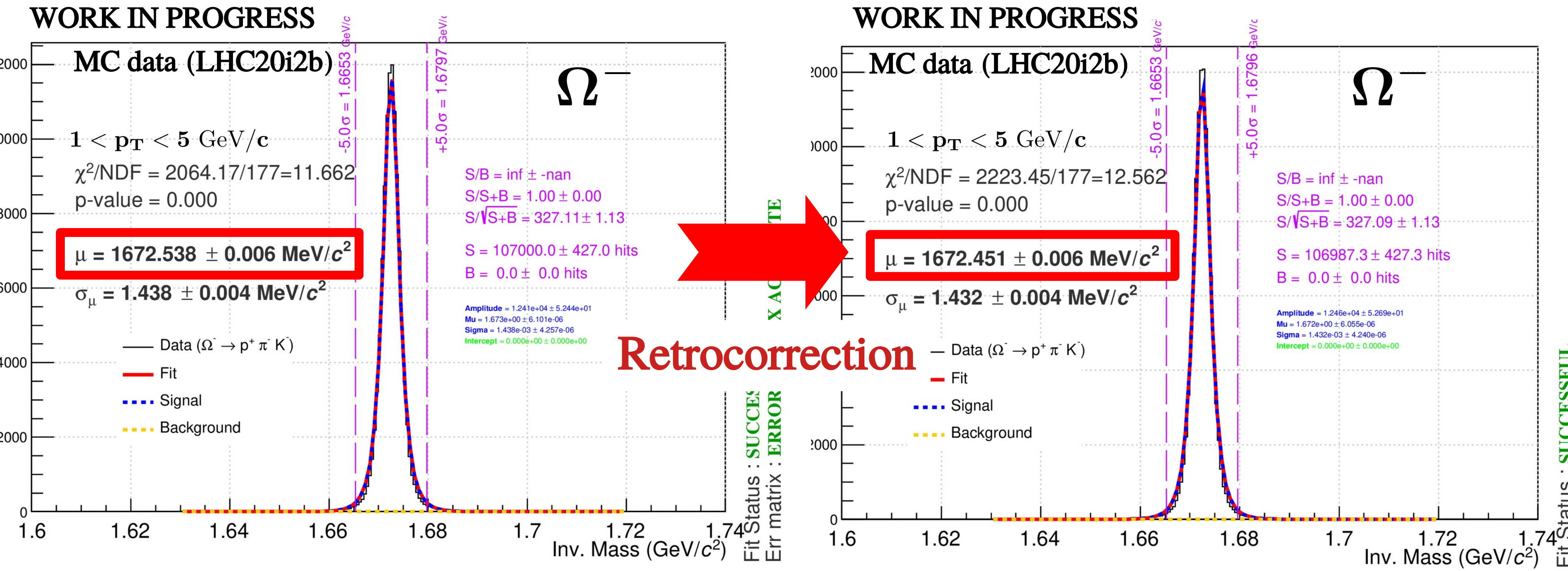
→ +70 keV/c^2 shift wrt to PDG mass (injected mass)

→ -137 keV/c^2 shift wrt to PDG mass (injected mass)

Ω Invariant mass

- Look at dE/dx retrocorrection applied on cascades
- **In MC data (LHC20i2b) :**

$$\mathbf{m_{PDG}(\Omega) = 1672.45 \pm 0.23 \ \mathrm{MeV/c^2}}$$



→ +88 keV/c^2 shift wrt to PDG mass (injected mass)

→ +1 keV/c^2 shift wrt to PDG mass (injected mass)

Conclusion

- On real data :
  - Improve PDG mass and mass difference values by at least a factor 5 and 3 respectively
  - Mass difference ~ 0 : CPT still valid but further constrained

- On MC data : a glimpse on the complexity of such a precision measurement
  - Our mass measurements have an offset wrt the PDG mass, whatever the particle of interest (K_S, Λ, Ξ, Ω)
  - This mass shift mainly comes from extra energy addition during V0/cascade finding → corrected now

- All the systematics are not done yet :

Source	TPC and topo. selections	B field precision	Choice of the fitting function	Choice of the fitting range	Material budget	Our energy loss correction
Status	Done	Done	Done	Done	To do	To do

- Next step :
  - Understand why our dE/dx retrocorrection works so well on Ω but not on Ξ

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Motivations

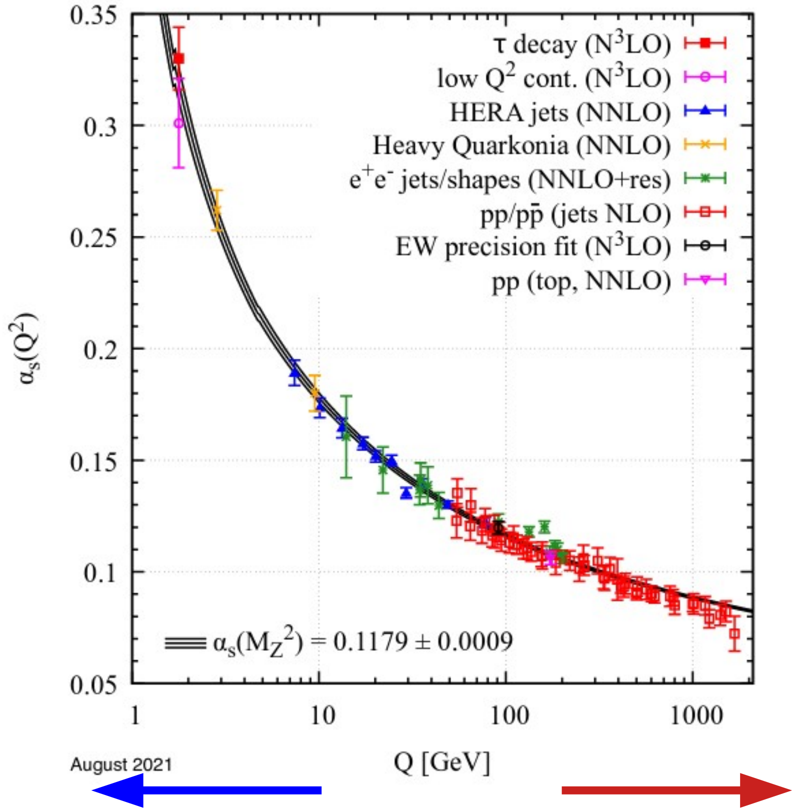
Quantum **C**hromo**D**ynamics **(QCD)** is the current quantum field theory describing the strong interaction of colored quarks and gluons

- Quark : fermion, carries only one (anti)color
- Gluon : vector boson of the strong interaction, carries one color and one anticolor

  → gluons can interact together

} **= partons**

Particle Data Group, Quantum Chromodynamics, Fig.9.3



Low energy/Large distance

High energy/Small distance

Two regimes :

- **Color confinement** at low energy

  → quarks and gluons are confined within hadrons
  → described by **lattice QCD (LQCD)** for example

- **Asymptotic freedom** at high energy

  → quarks and gluons are almost free
  → described by **perturbative QCD (pQCD)**

Motivations

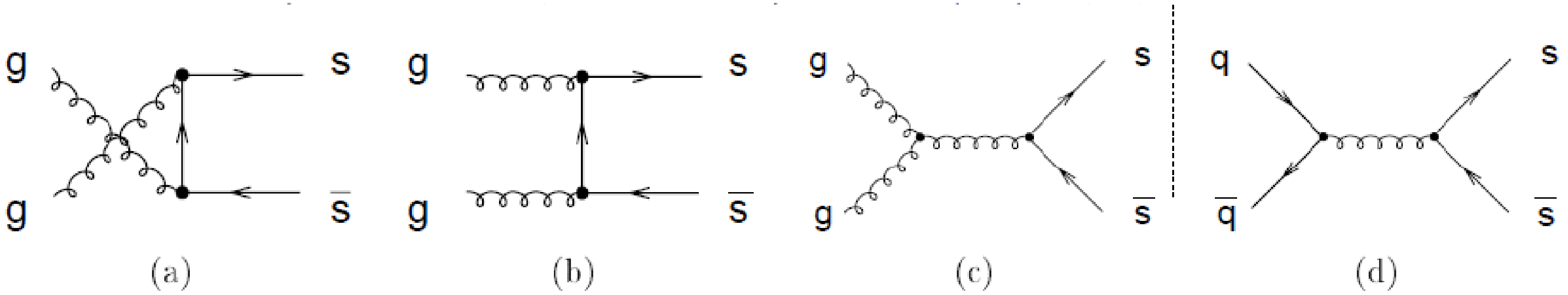
Lattice QCD predicts a phase transition from hadronic to partonic matter, i.e. a new phase of deconfined and thermalised partons

→ the Quark Gluon Plasma (QGP)

- Critical temperature > 155 MeV
- Critical energy density ~ 1 GeV/fm^3
- Thermalisation time ~ 10^{-24} sec

One of the key signatures of QGP is **strangeness enhancement**

- In the QGP, the mass of the strange quarks reduces to their bare mass, i.e. the mass coming from the Higgs mechanism → $m_s = 93\ \mathrm{MeV}/c^2 < \mathrm{T}_{\mathrm{QGP}}$

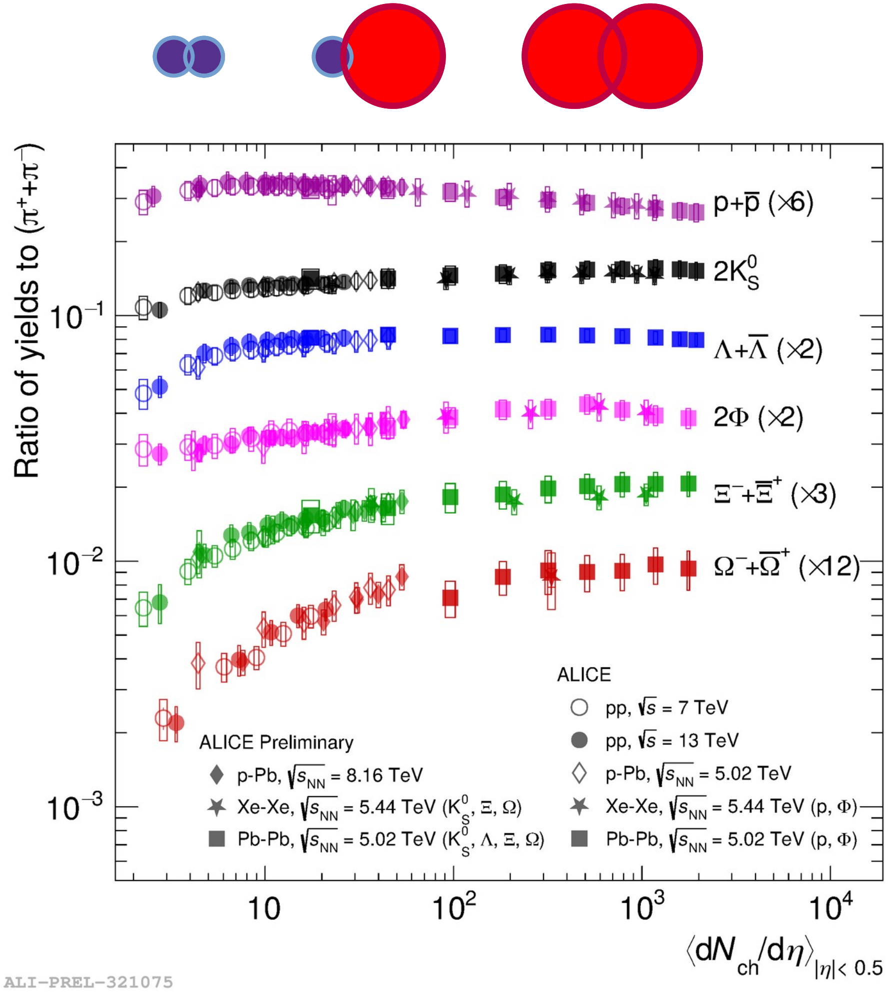


- The production of strange quarks is dominated by gluon fusion (reaction time shorter than $q\bar{q}$ annihilition, Phys. Rev. Lett. 56, 2334 (1986))
- **This excess of strange quarks should be reflected in the final hadron population**

Motivations

Strangeness enhancement is one of the key signatures of QGP :

Increase of the ratio of (multi-)strange to non-strange hadron yields with the multiplicity of charged particles produced in the collision



|S| = 0
|S| = 1
|S| = 1
|S| = 0
(hidden)
|S| = 2
|S| = 3

Strangeness enhancement in ALICE :

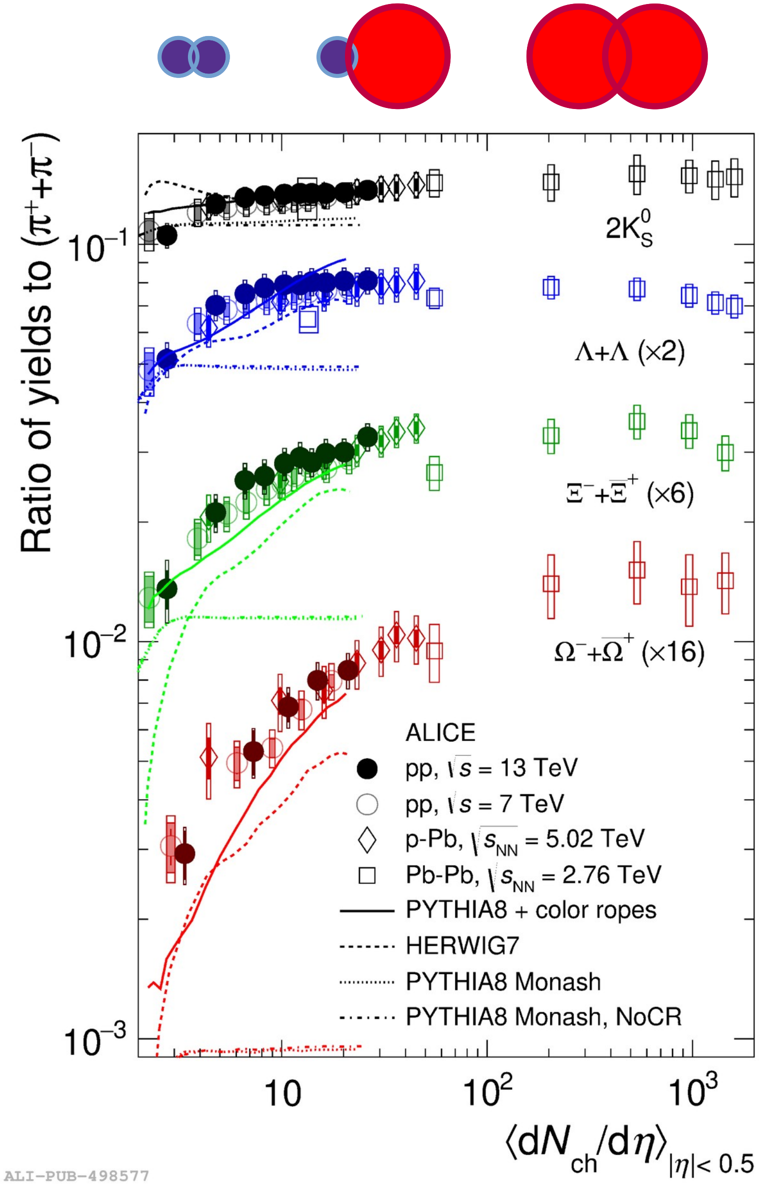
- **Smooth evolution** with the multiplicity of charged particles across different collision systems (**pp**, p-Pb, Pb-Pb)
- No dependence on the collision energy at LHC
- **More pronounced** for hadrons **with larger strangeness content**

$$E(\Omega) > E(\Xi) > E(\Lambda) \simeq E(\mathrm{K}^0_\mathrm{S})$$

with E = the observed enhancement with respect to $(\pi^+ + \pi^-)$

Nature Physics 13, 535-539 (2017)

Motivations



Eur. Phys. J. C 80 (2020) 693

Several phenomenological models qualitatively reproduce this effect, but **no unambiguous explanation yet**.

In order to get a better description of pp and AA collision dynamics :

- Perform multi-differential measurements
- Compare them with QCD-inspired MC models

The starting point of our analysis is a prediction from Pythia8 (with color rope and color shoving) :

- $\phi(s\bar{s})$ production increases in the presence of a $\Omega(sss)$
- The increase is greater when the $\phi(s\bar{s})$ is produced close to a $\Omega(sss)$

→ due to stat. limitations, **this will <u>first</u> be done with Ξ**

Correlation method

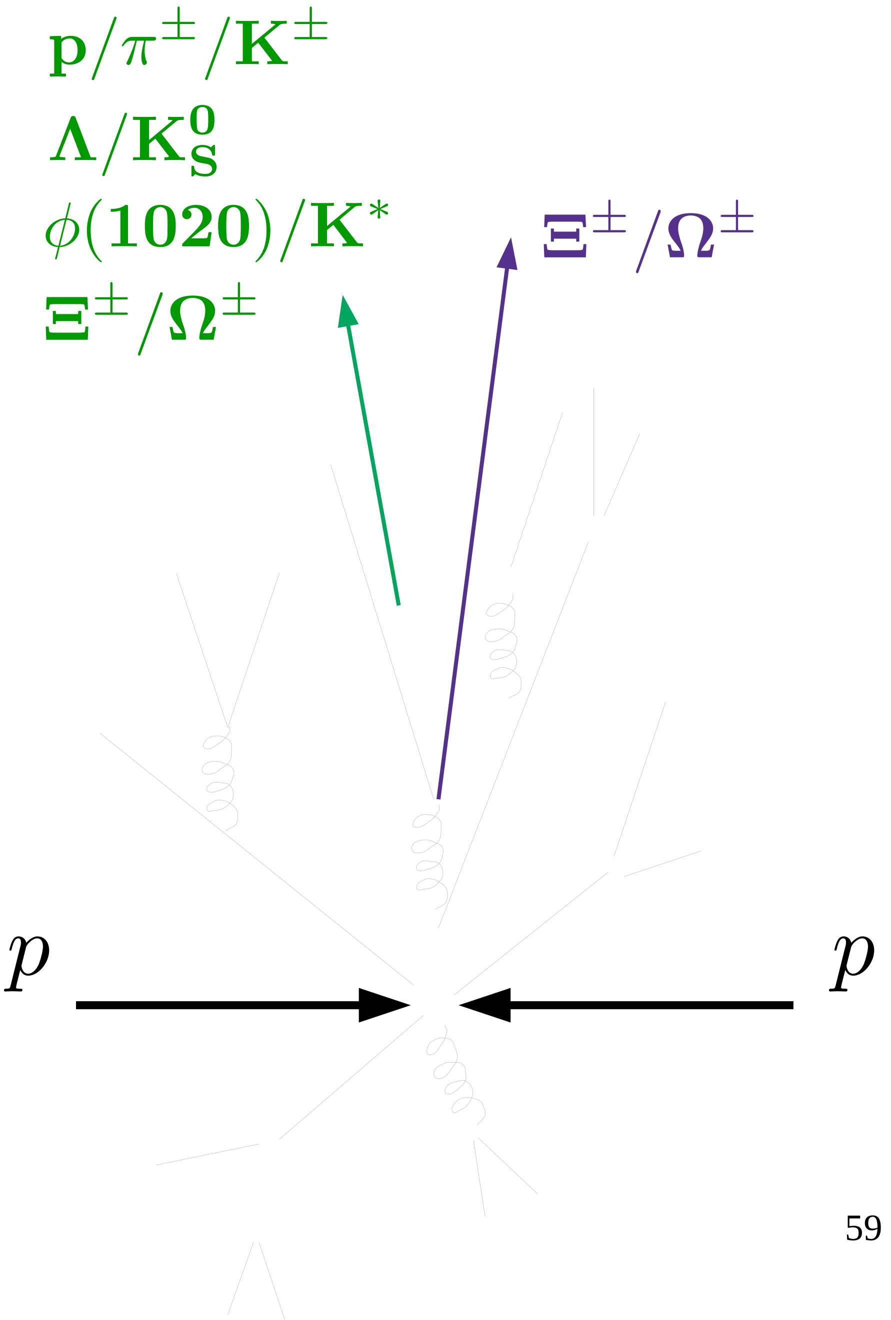
1) Selection of the **trigger particle(s)** : one Ξ or Ω cascade candidate

2) Identification of all the $\phi(1020)$ candidates (**associated particles**)

3) **Correlation** between the trigger particle(s) and the associated particles

$$\Delta y = y_{\Omega} - y_{\phi}$$

$$\Delta\varphi = \varphi_{\Omega} - \varphi_{\phi}$$



y = rapidity

φ = azimuthal angle

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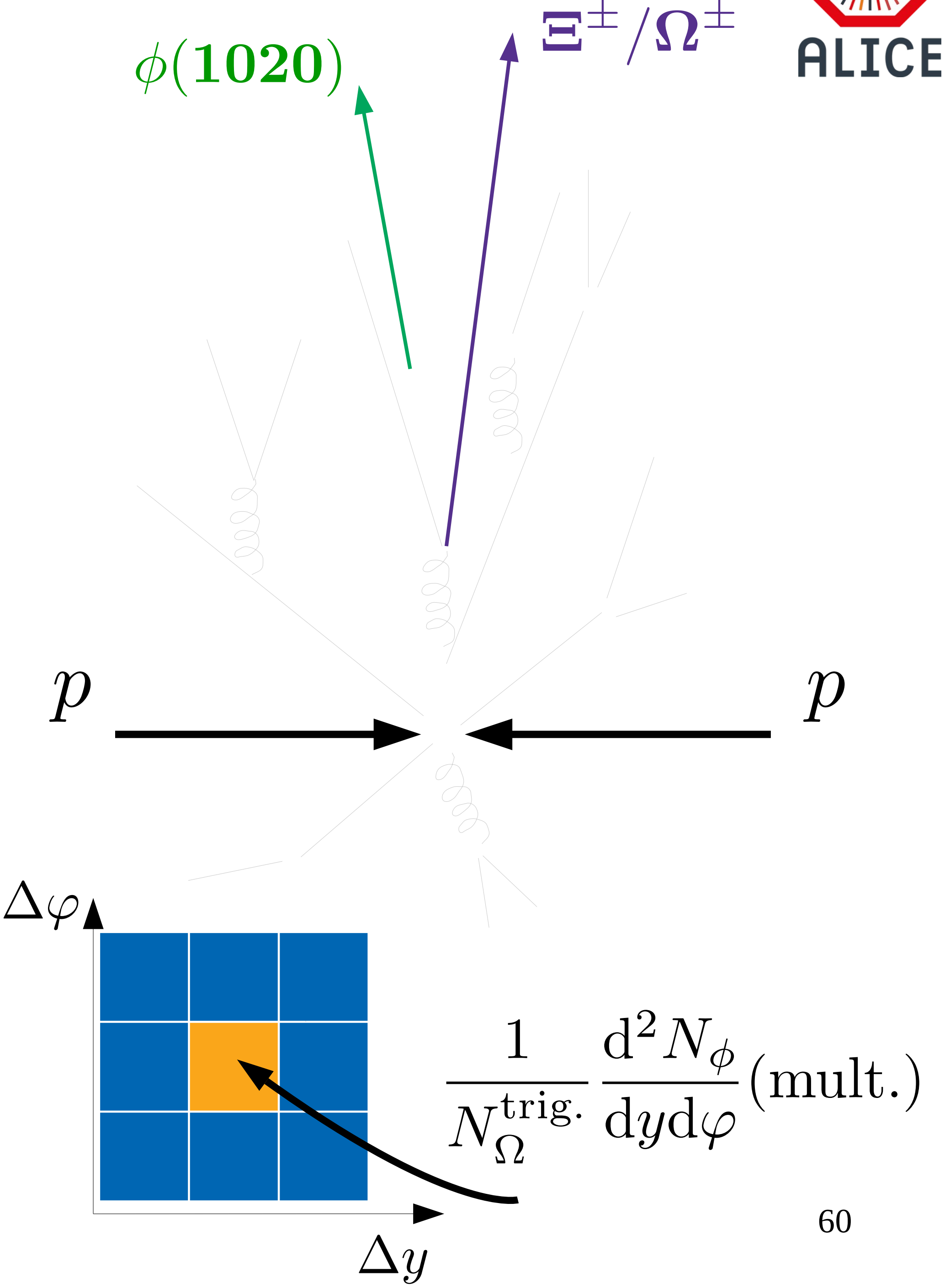


$$\frac{1}{N_{\Omega}^{\text{trig.}}}\frac{\mathrm{d}^2 N_{\phi}}{\mathrm{d}y\mathrm{d}\varphi}(\text{mult.})$$

y = rapidity
φ = azimuthal angle

The dataset

Objective : measure the $\phi(1020)$ yield as a fct($\Delta y = y_{\Omega}$-y_{ϕ}), using Run 2 data

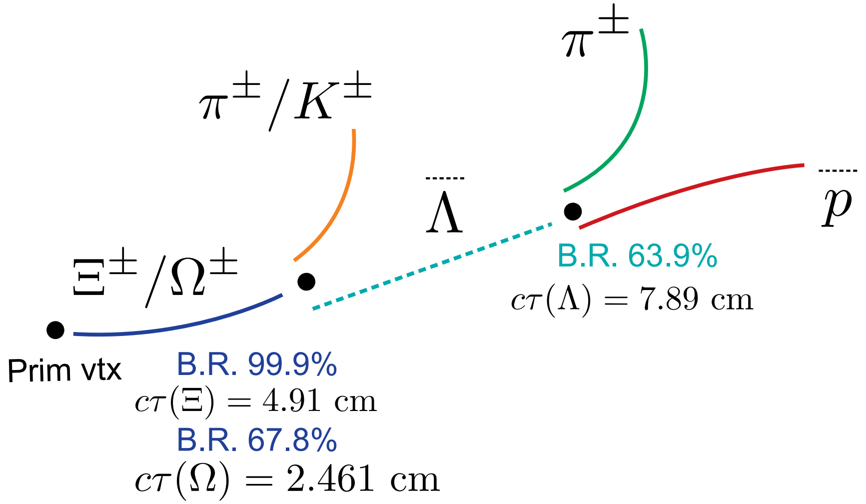
- Data : Analyzed $\pi^{\pm},\ p^{\pm},\ K^{\pm},\ \phi(1020),\ K^{*},\ K^{0}_{S},\ \Lambda,\ \Xi^{\pm},\ \Omega^{\pm}$
  - ~ 2.2×10^{9} pp collisions at $\sqrt{s} = 13$ TeV (LHC16 + LHC17 + LHC18)
  - Represents ~140×10^{6} cascade candidates
- Event Selection :
  - kINT7 = Minimum Bias (MB),
  - Remove in bunch (IB) and out-of-bunch (OOB) pile up
  - Primary vertex $|z_{vtx}| < 10$ cm
- Analysis task : https://github.com/alisw/AliPhysics/blob/master/PWGLF/STRANGENESS/Cascades/Run2/AliAnalysisTaskStrangeCascadesTriggerAODRun2

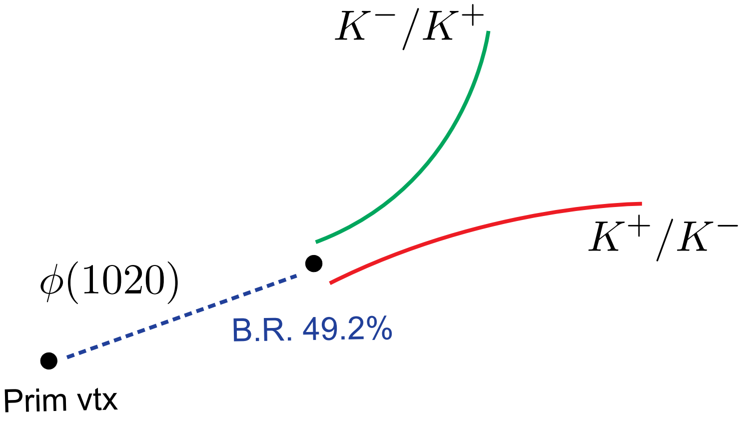
The analysis

- Ξ/Ω and $\phi(1020)$ will be studied in the following decay channel :

$$\begin{cases} \overline{\Xi}^{\pm} \rightarrow \overline{\Lambda}\ \pi^{\pm} \rightarrow \overline{p}\ \pi^{\pm}\ \pi^{\pm} \\ \overline{\Omega}^{\pm} \rightarrow \overline{\Lambda}\ K^{\pm} \rightarrow \overline{p}\ \pi^{\pm}\ K^{\pm} \end{cases}$$

$$\phi(1020) \rightarrow K^{+}K^{-}$$





$\phi(1020)$ **resonances** are reconstructed by pairing kaons, combinatorial background is subtracted using mixed events

Ξ/Ω are reconstructed using topological selections

- Analysis in multiplicity (using V0M estimator = multiplicity based on signal amplitude in the V0 detectors)

Multiplicity class	I	II	III	IV	V
$\sigma/\sigma_{\mathrm{INEL}>0}$	0-0.95%	0.95-4.7%	4.7-9.5%	9.5-14%	14-19%
$\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta \rangle$	21.3 ± 0.6	16.5 ± 0.5	13.5 ± 0.4	11.5 ± 0.3	10.1 ± 0.3
Multiplicity class	VI	VII	VIII	IX	X
$\sigma/\sigma_{\mathrm{INEL}>0}$	19-28%	28-38%	38-48%	48-68%	68-100%
$\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta \rangle$	8.45 ± 0.25	6.72 ± 0.21	5.40 ± 0.17	3.90 ± 0.14	2.26 ± 0.12

Phys. Rev. C 99, 024906 (2019)

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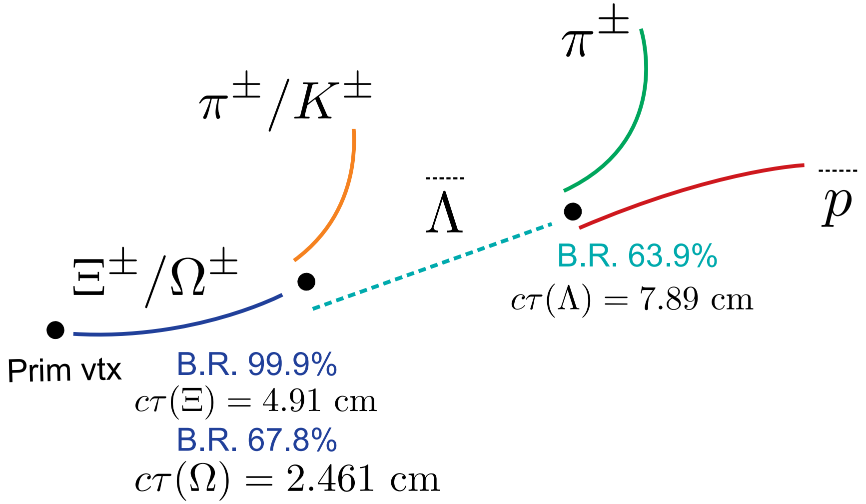

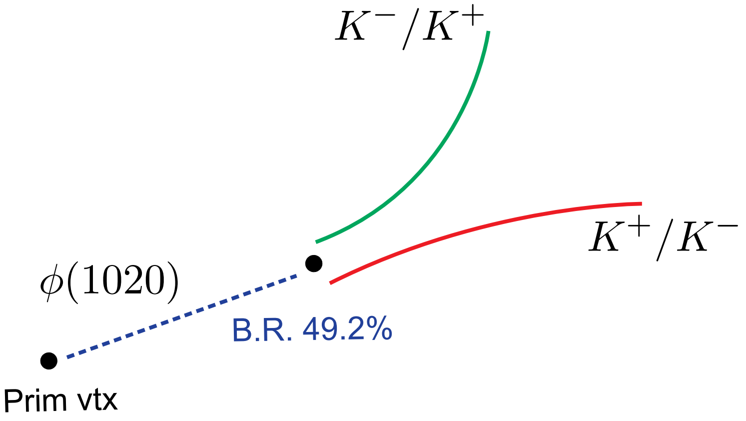

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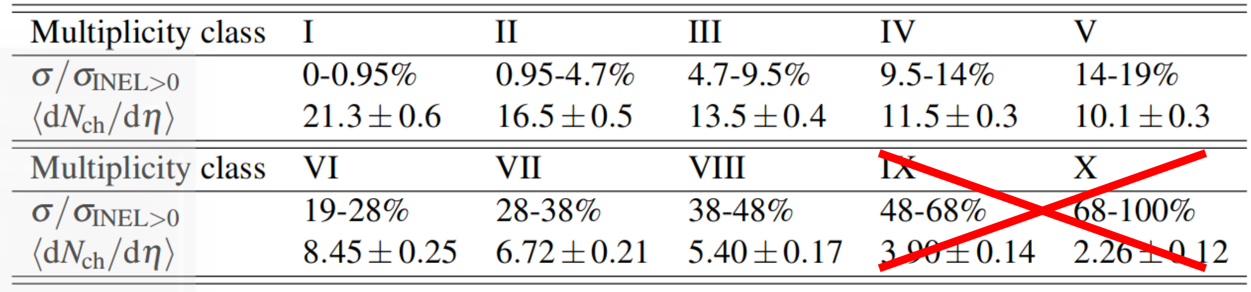


Multiplicity class	I	II	III	IV	V	VI	VII	VIII	IX	X
$\sigma/\sigma_{\mathrm{INEL}>0}$	0-0.95%	0.95-4.7%	4.7-9.5%	9.5-14%	14-19%	19-28%	28-38%	38-48%	~~48-68%~~	~~68-100%~~
$\langle dN_{ch}/d\eta \rangle$	21.3 ± 0.6	16.5 ± 0.5	13.5 ± 0.4	11.5 ± 0.3	10.1 ± 0.3	8.45 ± 0.25	6.72 ± 0.21	5.40 ± 0.17	~~3.90 ± 0.14~~	~~2.26 ± 0.12~~

Phys. Rev. C 99, 024906 (2019)

Ξ selections

- Ξ are reconstructed using topological selections

Ξ	Cut value
|y|	< 0.5
p_T (GeV/*c*)	[0.6, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.5, 2.9, 3.4, 4,5, 6.5]

- Cascade selections

DCA Bach To PV	> 0.04 cm
DCA Casc daughters	< 1.3 σ
Casc Radius	> 0.6 cm
Casc Cos PA	> 0.999
Proper Lifetime	> 3 x 4.91 cm

- V0 selections

On-the-fly V0	NO
DCA V0 to PV	> 0.04 cm
DCA Pos to PV	> 0.03 cm
DCA Neg to PV	> 0.03 cm
DCA V0 daughters	< 1.5 σ
V0 Radius	> 1.2 cm
V0 Cos PA	> 0.97
|V0 Mass - Λ Mass|	< 0.008 GeV/c²

- Track selections :
  - $|\eta| < 0.8$
  - TPC refit
  - TPC Nbr Crossed Rows > 70
  - TPC PID Nsigma < 3

Ω selections

- Ω are reconstructed using topological selections

Ω	Cut value
|y|	< 0.5
p_T (GeV/*c*)	[0.6, 1.0, 1.4, 1.8, 2.3, 2.8, 3.3, 3.8, 4.8, 6.5]

- Cascade selections

DCA Bach To PV	> 0.04 cm
DCA Casc daughters	< 1.6 σ
Casc Radius	> 0.5 cm
Casc Cos PA	> 0.997
|Casc Mass - Ξ Mass|	> 0.008 GeV/c^2
Proper Lifetime	> 3 x 2.46 cm

- V0 selections

On-the-fly V0	NO
DCA V0 to PV	> 0.04 cm
DCA Pos to PV	> 0.03 cm
DCA Neg to PV	> 0.03 cm
DCA V0 daughters	< 1.6 σ
V0 Radius	> 1.1 cm
V0 Cos PA	> 0.97
|V0 Mass - Λ Mass|	< 0.008 GeV/c²

- Track selections :
  - $|\eta| < 0.8$
  - TPC refit
  - TPC Nbr Crossed Rows > 70
  - TPC PID Nsigma < 4

$\phi(1020)$ selections

- Track selections :
  - Standard cuts 2011 →
  - TPC PID Nsigma < 2
  - TOF PID Nsigma < 3 (only if track matches a hit in the TOF)
  - $|\eta| < 0.8$
  - $0.15 < p_{\mathrm{T}}(\mathrm{track}) < 20\ \mathrm{GeV}/c$

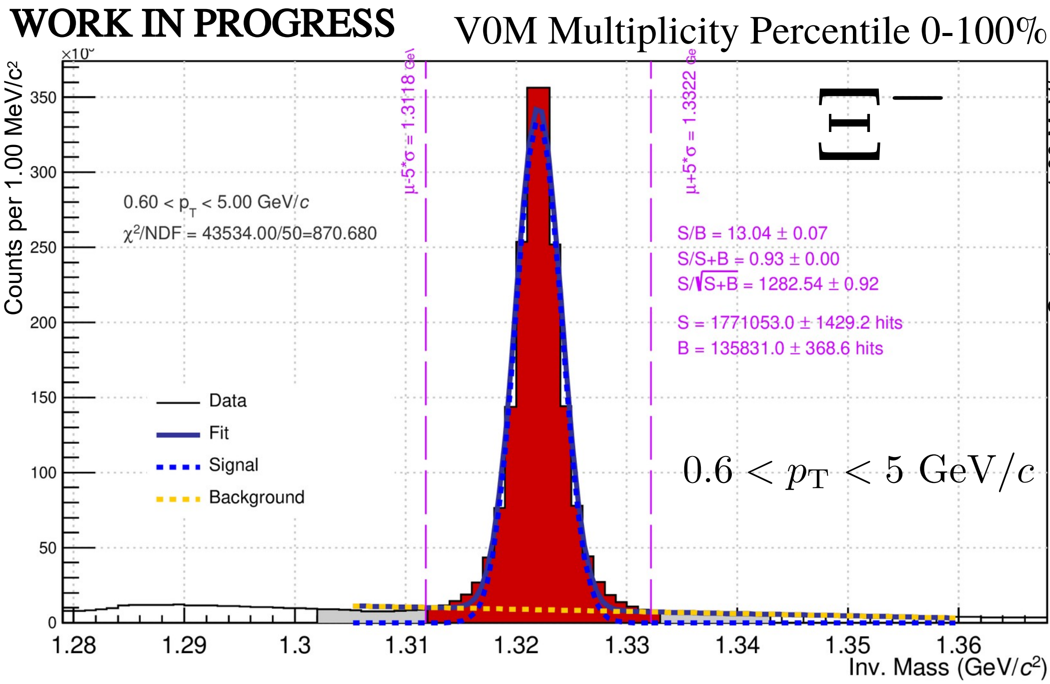
Kink topology	NO
TPC Nbr Crossed Rows	> 70 cm
TPC Ncr/Nfindable	>= 0.8
χ_{TPC}^{2}	< 4
Status	kITSrefit & kTPCrefit
Nbr Clusters in SPD	>= 1
DCAxy	$<0.0105 + 0.035\ p_{T}^{-1.01}$
DCAz	< 2cm
SetDCAToVertex2D	kFALSE
SetRequireSigmaToVertex	kFALSE
$\chi_{TPC\text{-}CG}^{2}$	< 36
χ_{ITS}^{2}	< 36

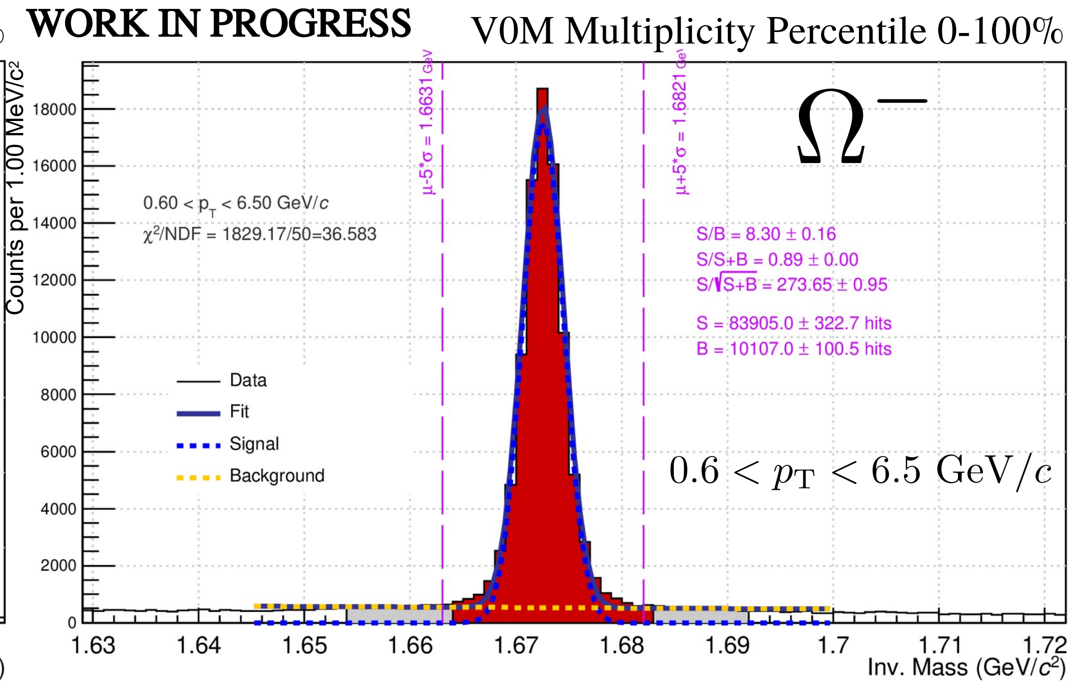
- $\phi(1020)$ selections:

$\phi(1020)$	Cut value
|y|	< 0.5
p_T (GeV/c)	[0.4, 0.8, 1.2, 1.8, 2.6, 3.4, 4.2, 5, 11]

Ξ and Ω signal extraction

- Background substraction for inv. mass analysis :
  - Fit with a *modified* gaussian + linear function (sigma and mean value used as reference for bin counting)
  - Signal region between $\pm 5\sigma$; background region between $[-10\sigma; -5\sigma] \cup [+5\sigma; +10\sigma]$





$\phi(1020)$ signal extraction

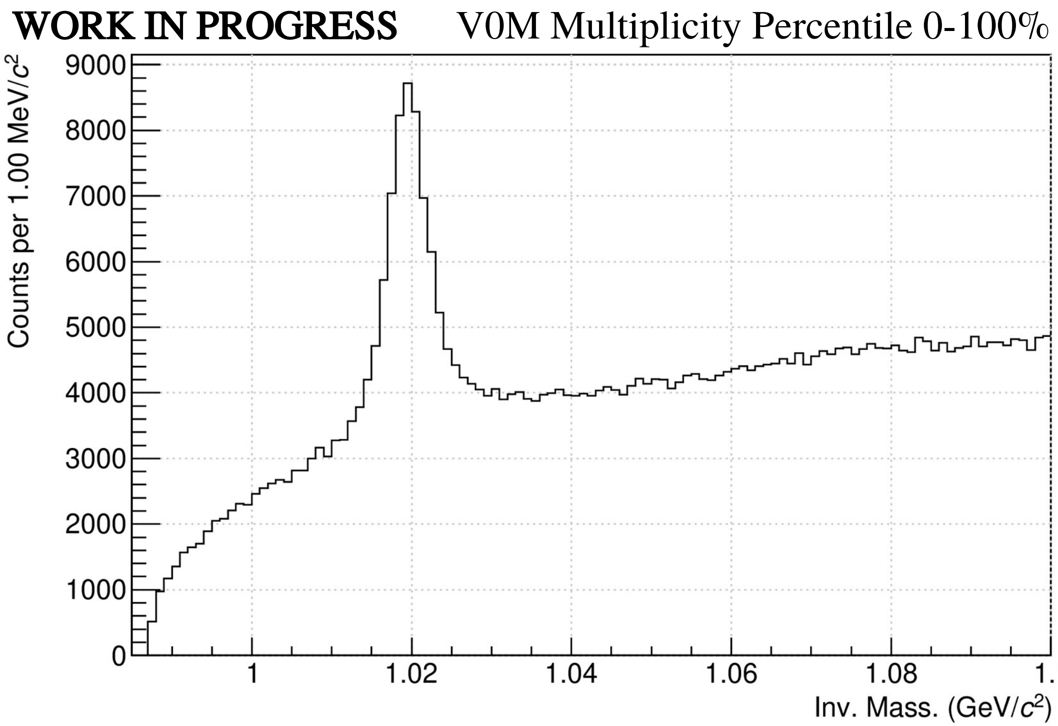
- Two ways to compute background and substract it from the inv. mass :

Mixing pairs from 5 other different events
(**Event Mixing**)

$$\begin{cases} |\Delta \mathrm{PV}_z(\mathrm{Evt}_A,\ \mathrm{Evt}_B)| < 1\ \mathrm{cm} \\ |\Delta \mathrm{V0M\ Percentile}(\mathrm{Evt}_A,\ \mathrm{Evt}_B)| < 10\ \% \end{cases}$$

Rotate the pairs from the same event
(Rotating)

Take one of kaons and rotate it by 180 degrees to break the correlation

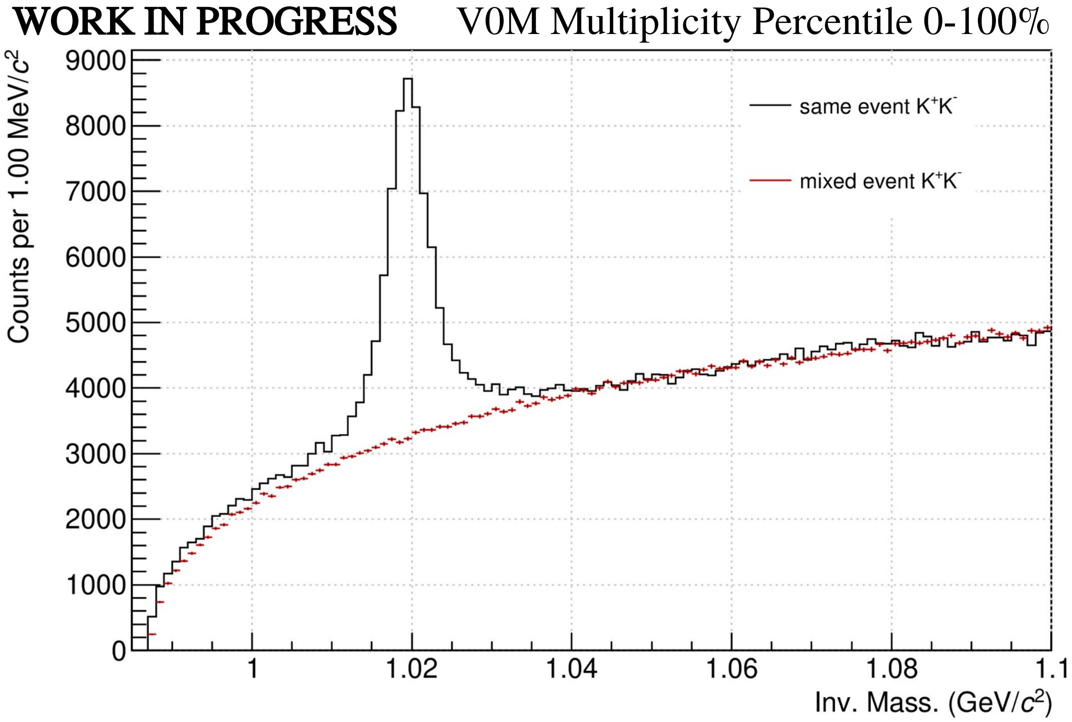


$\phi(1020)$ signal extraction

- Two ways to compute background and substract it from the inv. mass :

Mixing pairs from 5 other different events
(**Event Mixing**)

$$\begin{cases} |\Delta \mathrm{PV}_z(\mathrm{Evt}_A,\ \mathrm{Evt}_B)| < 1 \text{ cm} \\ |\Delta \mathrm{V0M\ Percentile}(\mathrm{Evt}_A,\ \mathrm{Evt}_B)| < 10\ \% \end{cases}$$



Rotate the pairs from the same event
(Rotating)

Take one of kaons and rotate it by 180 degrees to break the correlation

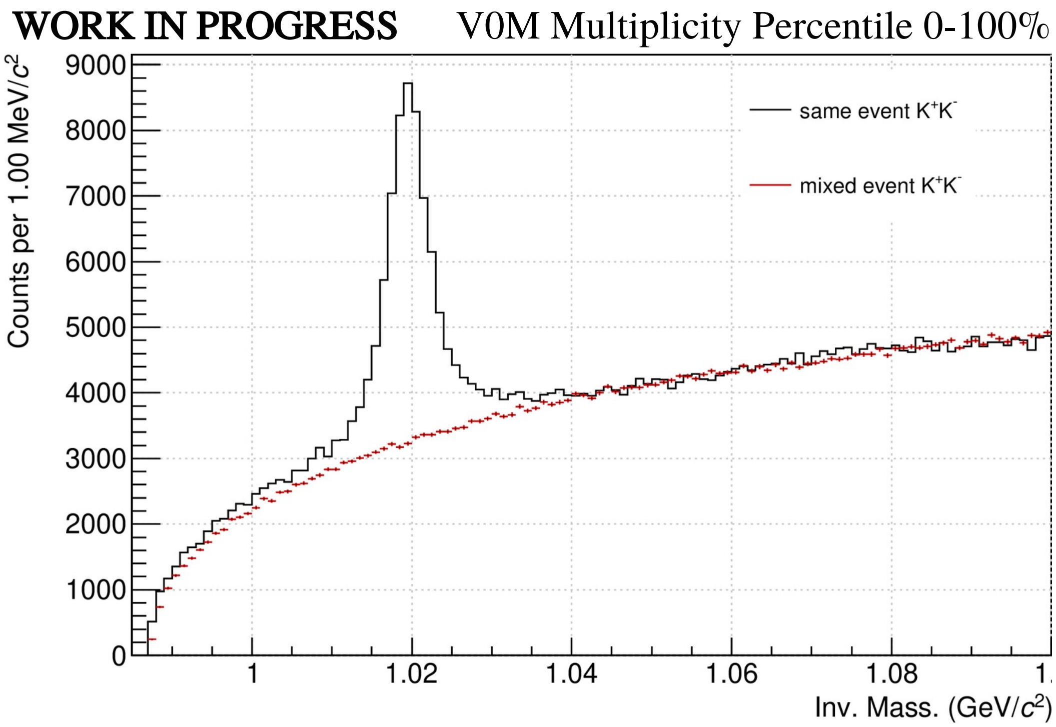
$\phi(1020)$ signal extraction

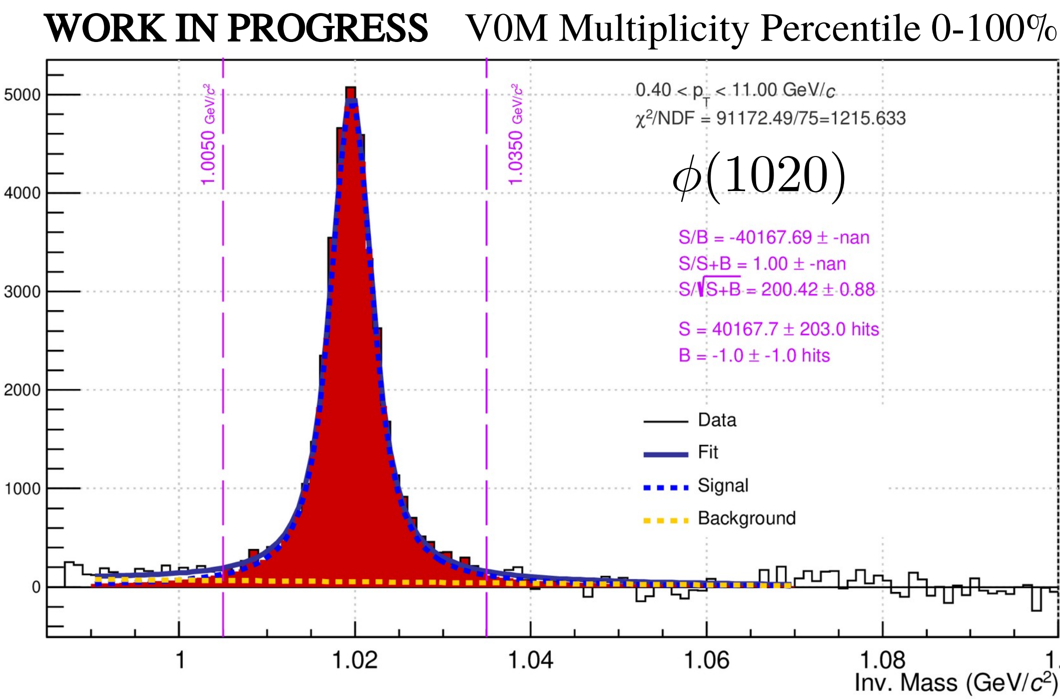
- Compute background :

Mixing pairs from 5 other different events (**Event Mixing**)

$$\begin{cases} |\Delta PV_z(\mathrm{Evt}_A,\ \mathrm{Evt}_B)| < 1\ \mathrm{cm} \\ |\Delta \mathrm{V0M\ Percentile}(\mathrm{Evt}_A,\ \mathrm{Evt}_B)| < 10\ \% \end{cases}$$

- Residual background substraction :
  - ◆ Fit with Voigt + 1st order polynomial functions
  - ◆ Signal given by the sum of
    - bin counting in $[1.005; 1.035]\ \mathrm{GeV}/c^2$
    - integral of the Voigt function on the rest of the invariant mass





Correct for Ξ/Ω background-ϕ pairs

1) Selection of the **trigger particle(s)** : one Ξ or Ω cascade candidate

2) Identification of all the **ϕ(1020)** candidates (**associated particles**)

3) **Correlation** between the trigger particle(s) and the associated particles

$$\Delta y = y_{\Omega} - y_{\phi}$$

$$\Delta \varphi = \varphi_{\Omega} - \varphi_{\phi}$$

y = rapidity
φ = azimuthal angle

Correct for Ξ/Ω background-ϕ pairs

1) Selection of the **trigger particle(s)** : one Ξ or Ω cascade candidate

$\Xi^{\pm}/\Omega^{\pm}$ → Signal (**S**) / Background (**B**)

2) Identification of all the ϕ**(1020)** candidates (**associated particles**)

3) **Correlation** between the trigger particle(s) and the associated particles

$$\Delta y = y_{\Omega} - y_{\phi}$$

$$\Delta \varphi = \varphi_{\Omega} - \varphi_{\phi}$$

$y =$ rapidity

$\varphi =$ azimuthal angle

Correct for Ξ/Ω background-ϕ pairs

1) Selection of the **trigger particle(s)** : one $\boldsymbol{\Xi}$ or $\boldsymbol{\Omega}$ cascade candidate

$\Xi^{\pm}/\Omega^{\pm}$ { Signal ($\mathbf{S}$) / Background ($\mathbf{B}$)

2) Identification of all the $\boldsymbol{\phi}$**(1020)** candidates (**associated particles**)

$\phi(\mathbf{1020})$ { Signal ($\mathbf{S}$) / Background ($\mathbf{B}$)

3) **Correlation** between the trigger particle(s) and the associated particles

$$\Delta y = y_{\Omega} - y_{\phi}$$

$$\Delta \varphi = \varphi_{\Omega} - \varphi_{\phi}$$

$y =$ rapidity

$\varphi =$ azimuthal angle

Correct for Ξ/Ω background-ϕ pairs

1) Selection of the **trigger particle(s)** : one **Ξ** or **Ω** cascade candidate

$\Xi^{\pm}/\Omega^{\pm}$ Signal (**S**)
Background (**B**)

2) Identification of all the **ϕ(1020)** candidates (**associated particles**)

ϕ(**1020**) Signal (**S**)
Background (**B**)

3) **Correlation** between the trigger particle(s) and the associated particles

$$\Delta y = y_{\Omega} - y_{\phi}$$

$$\Delta\varphi = \varphi_{\Omega} - \varphi_{\phi}$$

		ϕ(1020)	
		S	**B**
$\Xi^{\pm}/\Omega^{\pm}$	**S**	**S-S**	**S-B**
	B	**B-S**	**B-B**

y = rapidity
φ = azimuthal angle

Correct for Ξ/Ω background-ϕ pairs

1) Selection of the **trigger particle(s)** : one **Ξ** or **Ω** cascade candidate

→ $\Xi^{\pm}/\Omega^{\pm}$ { Signal (**S**) / Background (**B**)

2) Identification of all the **ϕ(1020)** candidates (**associated particles**)

→ $\phi(\mathbf{1020})$ { Signal (**S**) / Background (**B**)

3) **Correlation** between the trigger particle(s) and the associated particles

$$\Delta y = y_{\Omega} - y_{\phi}$$

$$\Delta \varphi = \varphi_{\Omega} - \varphi_{\phi}$$

		ϕ(1020)	
		S	**B**
$\Xi^{\pm}/\Omega^{\pm}$	**S**	**S-S**	**S-B**
	B	**B-S**	**B-B**

} Need to remove these candidates

y = rapidity

φ = azimuthal angle

Correct for Ξ/Ω background-ϕ pairs

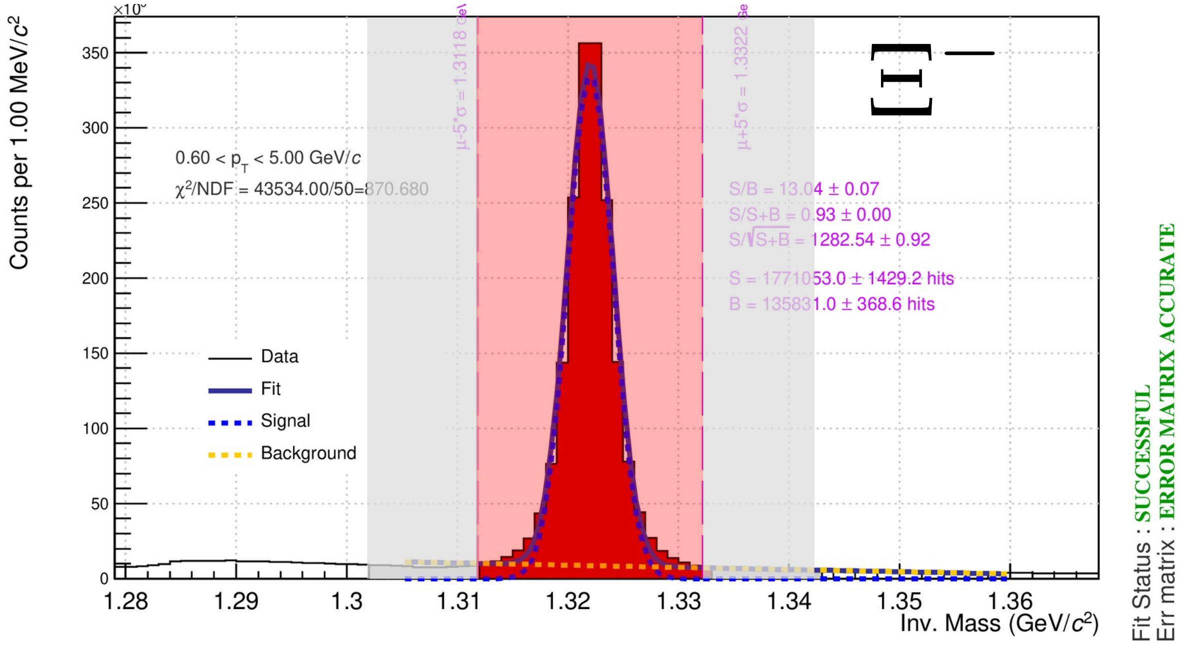
$\Xi^{\pm}/\Omega^{\pm}$ $\begin{cases} \text{Signal } (\mathbf{S}) \\ \text{Background } (\mathbf{B}) \end{cases}$

$\phi(1020)$ $\begin{cases} \text{Signal } (\mathbf{S}) \\ \text{Background } (\mathbf{B}) \end{cases}$

		$\phi(1020)$	
		S	**B**
$\Xi^{\pm}/\Omega^{\pm}$	**S**	**S-S**	**S-B**
	B	**B-S**	**B-B**

Need to remove these candidates

WORK IN PROGRESS



Correct for Ξ/Ω background-ϕ pairs

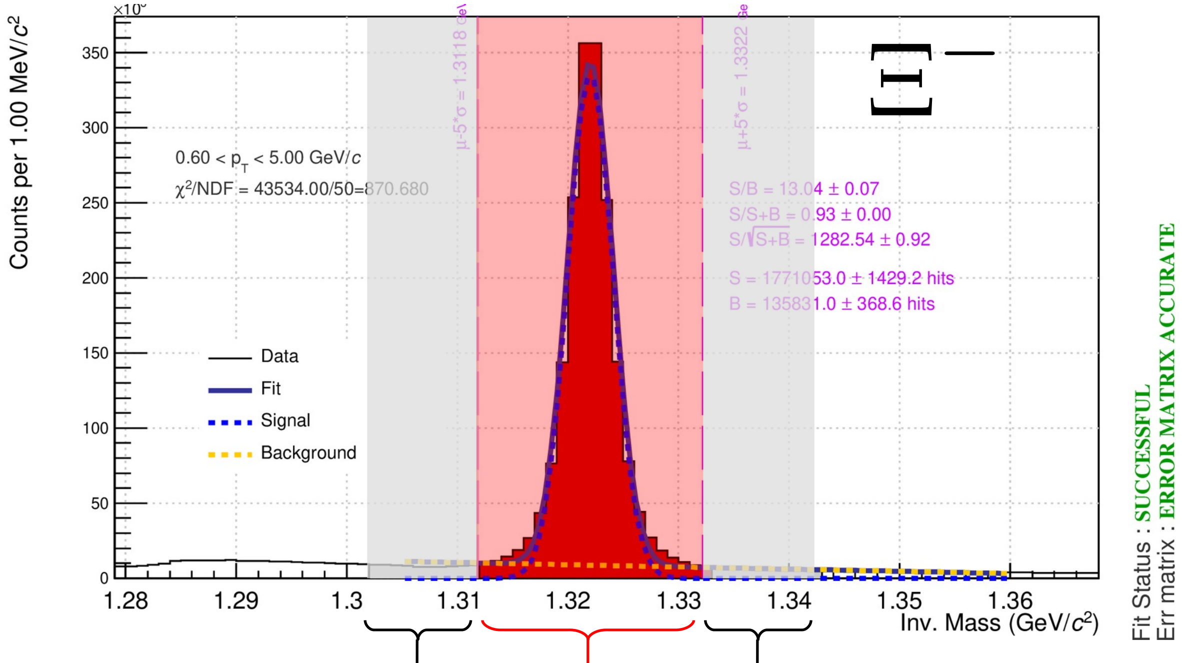
$\Xi^{\pm}/\Omega^{\pm}$
- Signal (**S**)
- Background (**B**)

$\phi(1020)$
- Signal (**S**)
- Background (**B**)

		$\phi(1020)$	
		S	**B**
$\Xi^{\pm}/\Omega^{\pm}$	**S**	**S**-**S**	**S**-**B**
	B	**B**-**S**	**B**-**B**

Need to remove these candidates

WORK IN PROGRESS



Correlate $\Xi^{\pm}/\Omega^{\pm}$ with a $\phi(1020)$ cand.

Correlate $\Xi^{\pm}/\Omega^{\pm}$ with a $\phi(1020)$ cand.

Correct for Ξ/Ω background-ϕ pairs

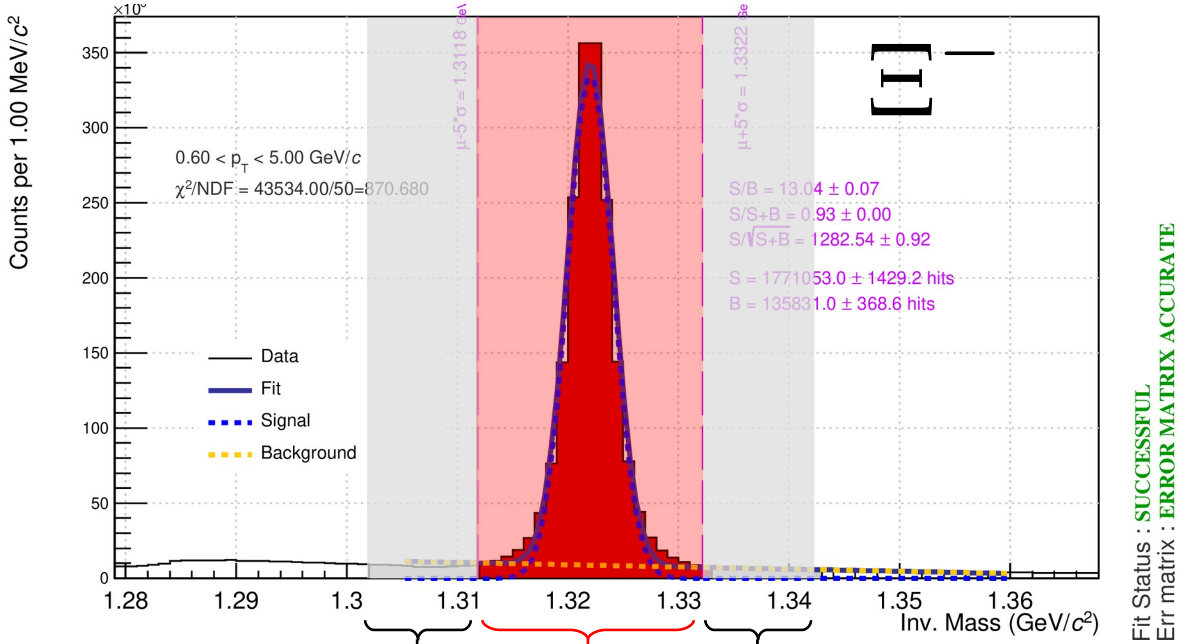
$\Xi^{\pm}/\Omega^{\pm}$ { Signal (**S**), Background (**B**) }

ϕ(**1020**) { Signal (**S**), Background (**B**) }

		$\phi(1020)$	
		S	**B**
$\Xi^{\pm}/\Omega^{\pm}$	**S**	**S-S**	**S-B**
	B	**B-S**	**B-B**

Need to remove these candidates

WORK IN PROGRESS



Inv. mass of $\phi(1020)$ to be fitted =

Inv. mass of $\phi(1020)$ correlated with a **signal** $\Xi^{\pm}/\Omega^{\pm}$

−

Inv. mass of $\phi(1020)$ correlated with a **background** $\Xi^{\pm}/\Omega^{\pm}$

Correlate $\Xi^{\pm}/\Omega^{\pm}$ with a $\phi(1020)$ cand.

Correlate $\Xi^{\pm}/\Omega^{\pm}$ with a $\phi(1020)$ cand.

Efficiency correction

- The quantity of interest is :

$$\underbrace{\frac{1}{N_{\mathrm{trig.}}}\frac{\mathrm{d}^2 N_{\phi}}{\mathrm{d}y\mathrm{d}\varphi}}_{\substack{\text{What we are interested in}\\ \textbf{corrected quantity}}} = \underbrace{\frac{1}{N^{\mathrm{raw}}_{\mathrm{trig.}}}\frac{\mathrm{d}^2 N_{\phi}(\mathrm{raw})}{\mathrm{d}y\mathrm{d}\varphi}}_{\substack{\text{What we measure}\\ \textbf{raw quantity}}} \times (A \times \epsilon \times \mathrm{B.R.})_{\mathrm{trig.}} \times \frac{1}{(A \times \epsilon \times \mathrm{B.R.})_{\phi}}$$

Efficiency correction

- The quantity of interest is :

$$\frac{1}{\underset{\substack{\uparrow \\ N_{\Xi} \text{ or } N_{\Omega}}}{N_{\text{trig.}}}}\frac{\mathrm{d}^2 N_{\phi}}{\mathrm{d}y\mathrm{d}\varphi} = \frac{1}{\underset{\substack{\uparrow \\ N_{\Xi} \text{ or } N_{\Omega}}}{N_{\text{trig.}}^{\text{raw}}}}\frac{\mathrm{d}^2 N_{\phi}(\text{raw})}{\mathrm{d}y\mathrm{d}\varphi} \times (A \times \epsilon \times \text{B.R.})_{\text{trig.}} \times \frac{1}{(A \times \epsilon \times \text{B.R.})_{\phi}}$$

Efficiency correction

- The quantity of interest is :

$$\frac{1}{N_{\mathrm{trig.}}}\frac{\mathrm{d}^2 N_{\phi}}{\mathrm{d}y\mathrm{d}\varphi} = \frac{1}{N^{\mathrm{raw}}_{\mathrm{trig.}}}\frac{\mathrm{d}^2 N_{\phi}(\mathrm{raw})}{\mathrm{d}y\mathrm{d}\varphi} \times (A \times \epsilon \times \mathrm{B.R.})_{\mathrm{trig.}} \times \frac{1}{(A \times \epsilon \times \mathrm{B.R.})_{\phi}}$$

N_{Ξ} or N_{Ω}

N_{Ξ} or N_{Ω}

$1/\epsilon_{\mathrm{eff.}}(\Xi)$ or $1/\epsilon_{\mathrm{eff.}}(\Omega)$

$\epsilon_{\mathrm{eff.}}(\phi)$

Efficiency correction

- The quantity of interest is :

$$\frac{1}{N_{\rm trig.}}\frac{\mathrm{d}^2 N_\phi}{\mathrm{d}y\mathrm{d}\varphi} = \frac{1}{N^{\rm raw}_{\rm trig.}}\frac{\mathrm{d}^2 N_\phi(\mathrm{raw})}{\mathrm{d}y\mathrm{d}\varphi} \times (A \times \epsilon \times \mathrm{B.R.})_{\rm trig.} \times \frac{1}{(A \times \epsilon \times \mathrm{B.R.})_\phi}$$

N_Ξ or N_Ω

N_Ξ or N_Ω

$1/\epsilon_{\rm eff.}(\Xi)$ or $1/\epsilon_{\rm eff.}(\Omega)$

$\epsilon_{\rm eff.}(\phi)$

- **For each p_T bin**, compute $\mathrm{acceptance} \times \mathrm{efficiency} \times \mathrm{B.R.}$ correction factors :

$$\epsilon_{\rm eff}(\Xi) = \frac{N_{\rm reco}(\Xi^-) + N_{\rm reco}(\Xi^+)}{N_{\rm gen}(\Xi^-) + N_{\rm gen}(\Xi^+)} \qquad \epsilon_{\rm eff}(\phi) = \frac{N_{\rm reco}(\phi)}{N_{\rm gen}(\phi)} \quad \Bigg\} \begin{array}{l} |y_{\rm reco}| < y_{max} \\ |y_{\rm gen}| < y_{max} \end{array}$$

- Numerator = Nbr of reconstructed particle associated to a generated one
  - From the reconstruction, as if it was with data
- Denominator = Nbr of generated particle
  - From the MC truth, perfect information

MC dataset

- Two MC datasets :
  - Pythia 8, tune : Monash 2013
  - 700×10^6 pp collisions at $\sqrt{s} = 13$ TeV (GP)
    (anchored on all the periods of 2016+17+18)
  - 12×10^6 pp collisions at $\sqrt{s} = 13$ TeV enriched in Ξ and Ω
    (Only two periods : LHC17j + LHC18i)

- Event Selection :
  - Same as in real data
  - kINT7 = Minimum Bias (MB),
  - Primary vertex $|z_{vtx}| < 10$ cm
- Analysis task :
  https://github.com/alisw/AliPhysics/blob/master/PWGLF/STRANGENESS/Cascades/Run2/AliAnalysisTaskStrangeCascadesTriggerAODRun2MC

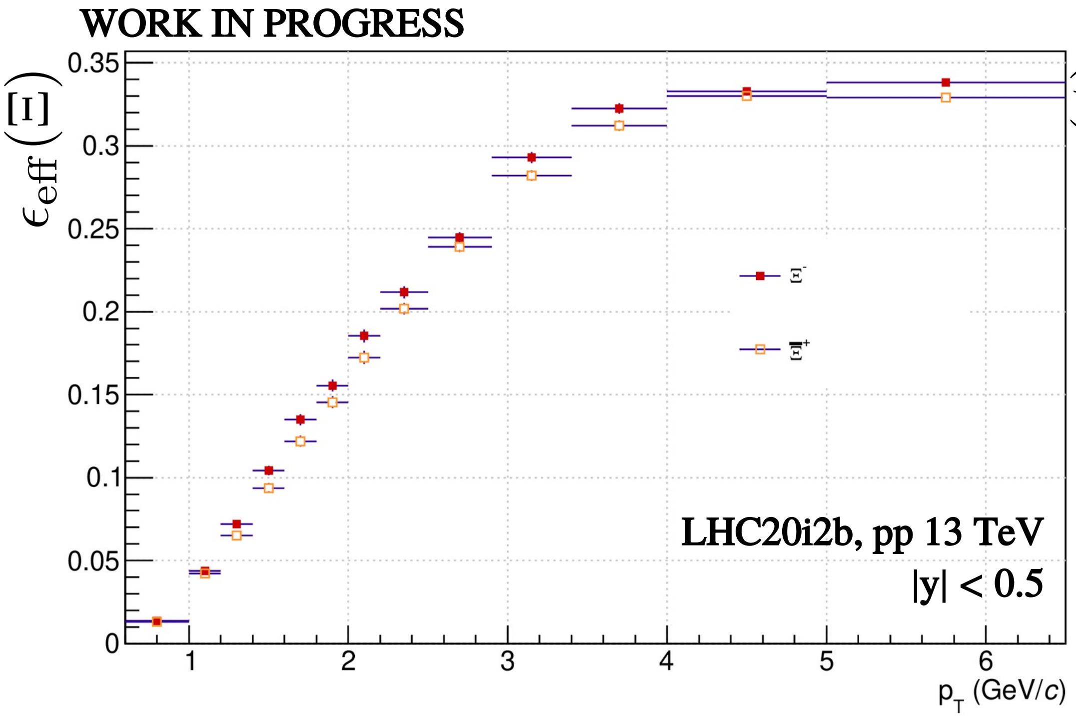
Ξ and $\phi(1020)$ efficiency

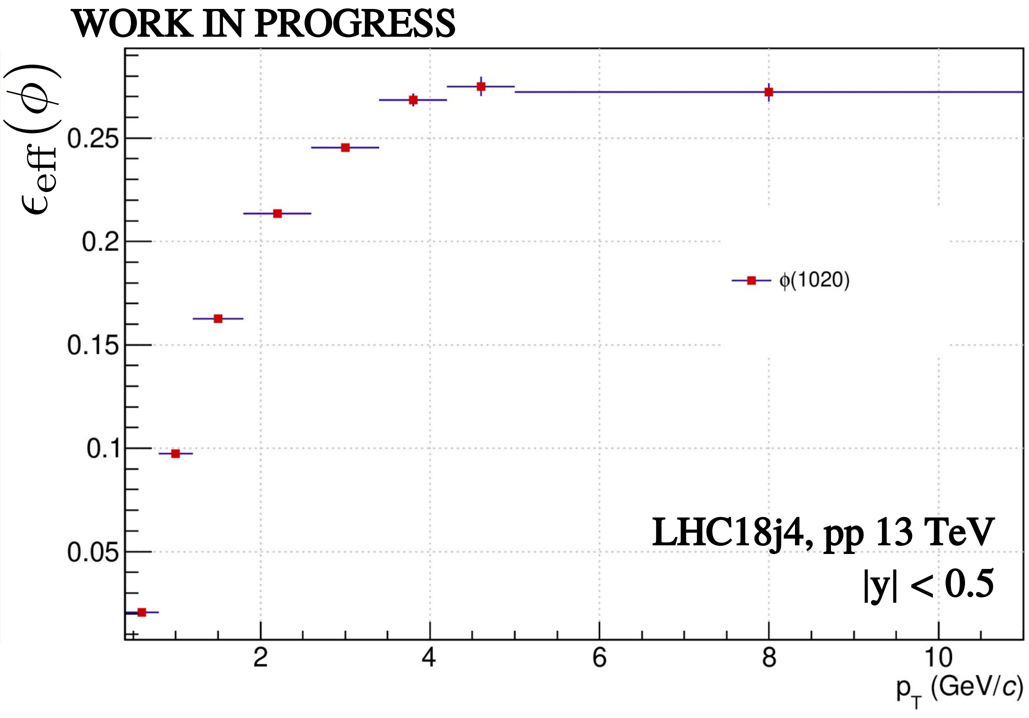
Ξ efficiency (Enriched)

$$\epsilon_{\mathrm{eff}}(\Xi) = \frac{N_{\mathrm{reco}}(\Xi^{-}) + N_{\mathrm{reco}}(\Xi^{+})}{N_{\mathrm{gen}}(\Xi^{-}) + N_{\mathrm{gen}}(\Xi^{+})}$$

$\phi(1020)$ efficiency (GP)

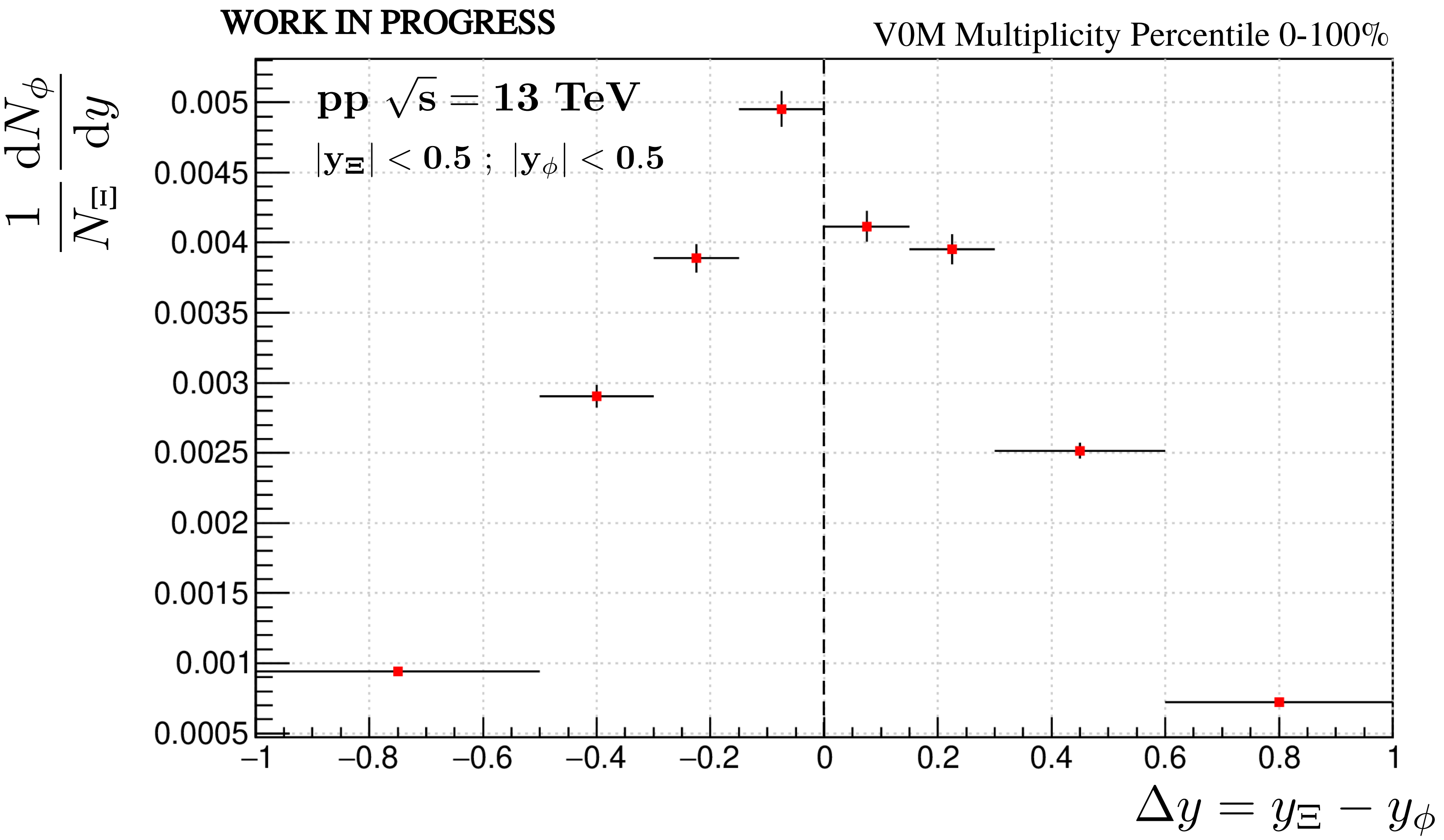
$$\epsilon_{\mathrm{eff}}(\phi) = \frac{N_{\mathrm{reco}}(\phi)}{N_{\mathrm{gen}}(\phi)}$$





First-stage results with Ξ ?

- The yield of $\phi(1020)$ in events containing at least one Ξ, a function of Δy
  - increases as the gap in rapidity wrt the Ξ, Δy, reduces
  - Reaches a maximum at Δy~0



Pair acceptance correction

- In this analysis, we make **correlation** between Ξ/Ω and $\phi(1020)$

  BUT not all the pairs are physically correlated !

  → we also form pairs of uncorrelated : Ξ/Ω and $\phi(1020)$

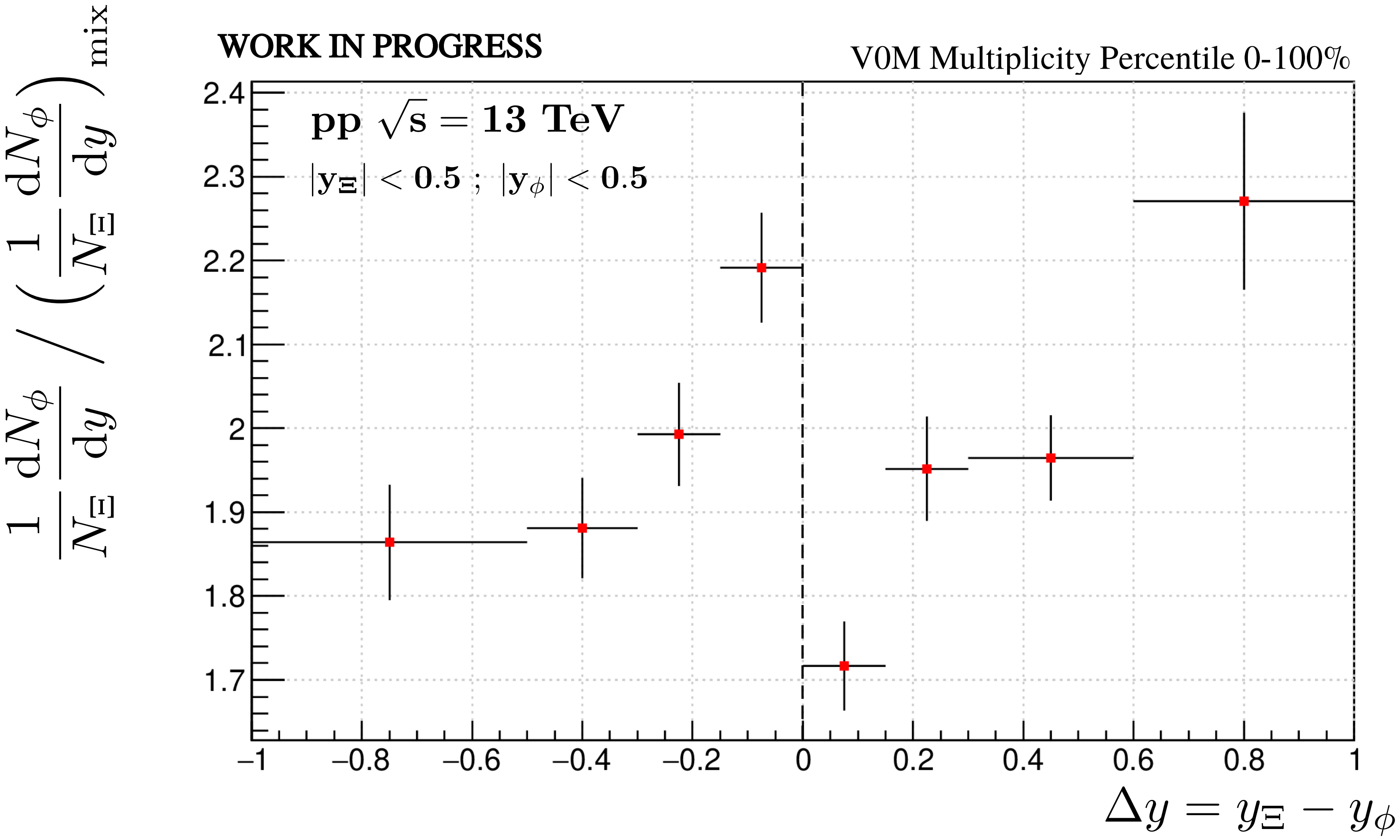
- To assess the contribution of uncorrelated pairs of Ξ/Ω–$\phi(1020)$, use an event mixing technique :
  - **Same mixing as for the resonances** (i.e. same pool of matching events)
  - Redo all the steps presented previously but with a Ξ/Ω and $\phi(1020)$ coming from two separate events

- Divide the previous yield ratio (i.e. Ξ/Ω-$\phi(1020)$ same event)

  by this distribution (i.e. Ξ/Ω-$\phi(1020)$ from mixed events)

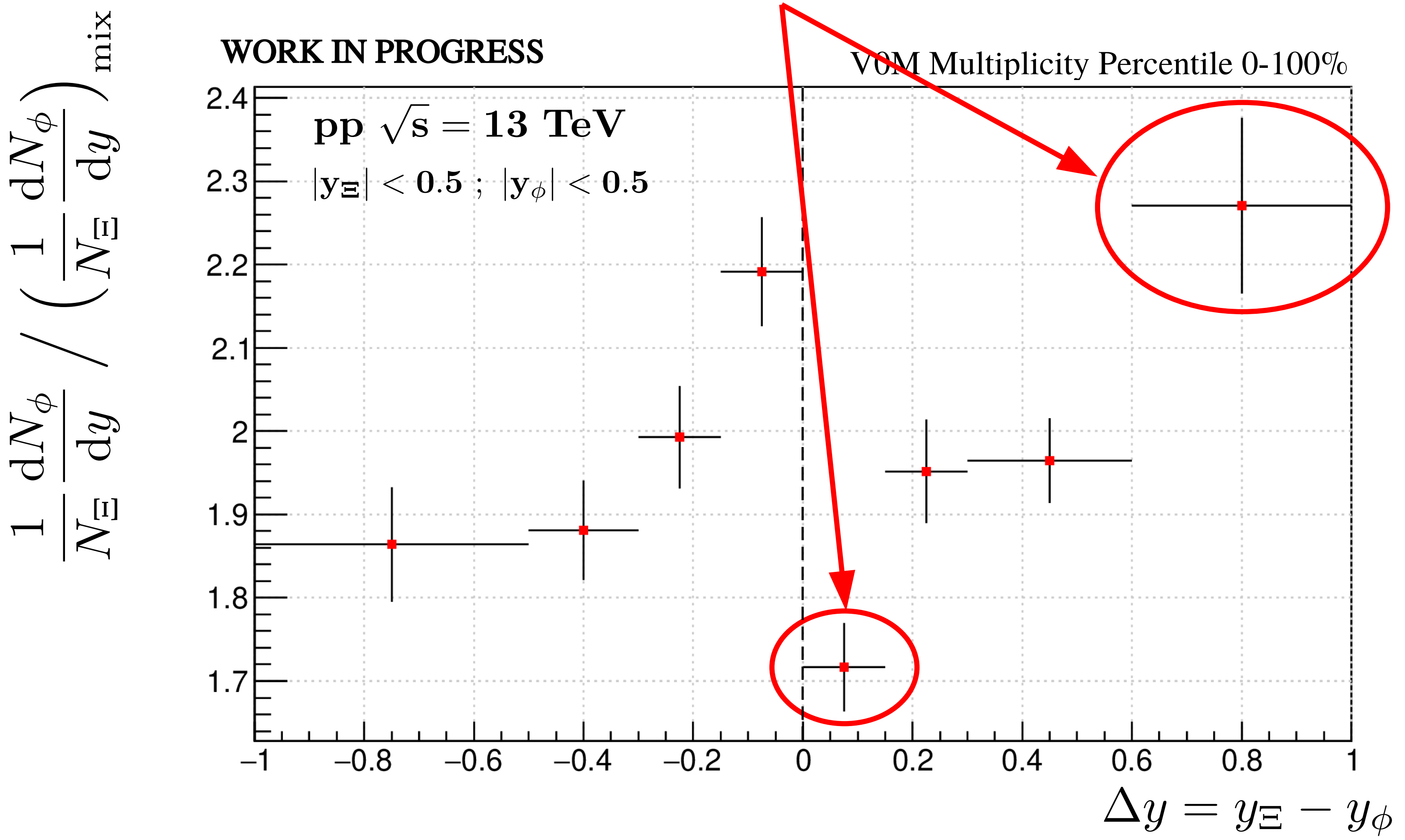
Corrected results with Ξ

- The **corrected** yield of $\phi(1020)$ in events containing at least one Ξ, a function of Δy
  - increases as the gap in rapidity wrt the Ξ, Δy, reduces, for negative Δy
  - Reaches a maximum at Δy~0, for negative Δy



Corrected results with Ξ

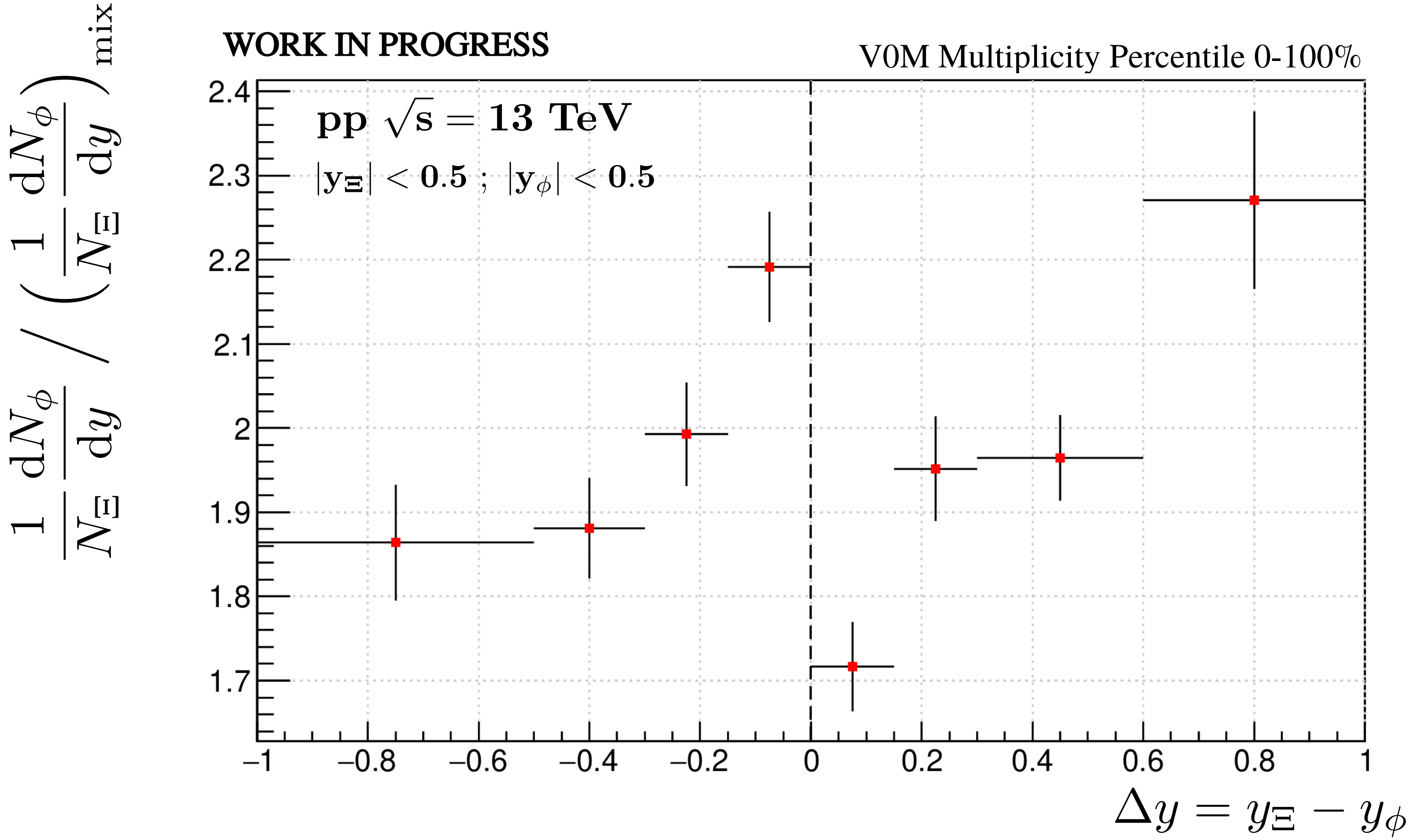
- The **corrected** yield of $\phi(1020)$ in events containing at least one Ξ, a function of Δy
  - increases as the gap in rapidity wrt the Ξ, Δy, reduces, for negative Δy
  - Reaches a maximum at Δy~0, for negative Δy
  - Not sure what happened in **these bins**, still under investigation



Corrected results with Ξ

- The **corrected** yield of ϕ(1020) in events containing at least one Ξ, a function of Δy
  - increases as the gap in rapidity wrt the Ξ, Δy, reduces, for negative Δy
  - Reaches a maximum at Δy~0, for negative Δy

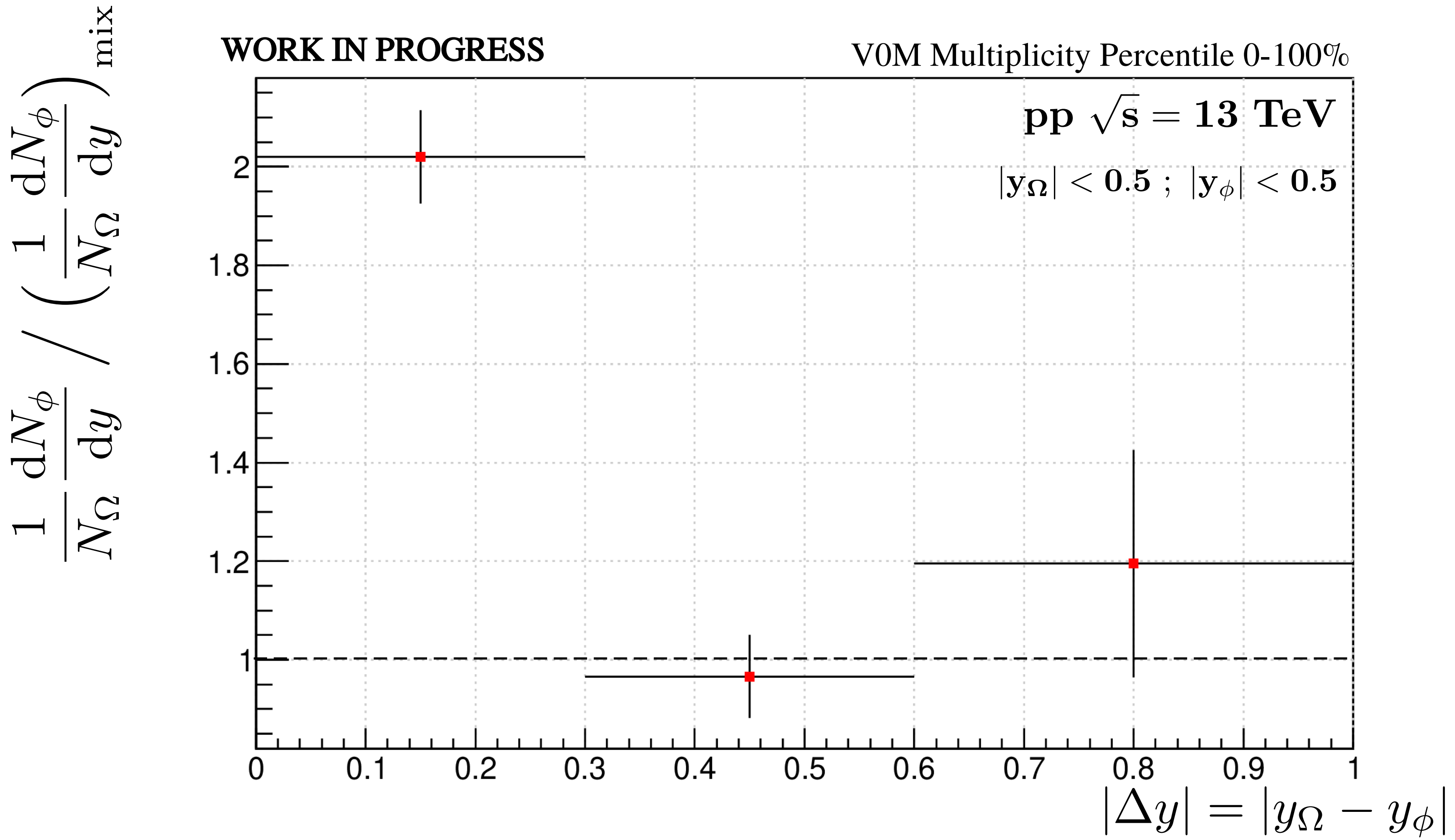
→ **When a Ξ is produced, the yield of ϕ(1020) is enhanced by almost a factor 2!**



Corrected results with Ω

- The **corrected** yield of ϕ(1020) in events containing at least one Ω, a function of Δy
  - **Is enhanced for |Δy| ~ 0**
  - Compatible with unity at large Δy

→ The yield of ϕ(1020) is doubled, when produced close in rapidity to an Ω!



Conclusion

- **Goal :** Measure the yield of $\phi(1020)$, focusing on events with at least one Ω
  - This measurement has been done using Ξ
    → demonstrates the feasibility of such a measurement
  - $\phi(1020)$ production is enhanced when produced close to an Ω

- The analysis is currently at the preliminary stage, **very preliminary results**
  - Pair acceptance correction ✓
  - Efficiency correction ✓
  - Comparison with published individual $\mathrm{d}N/\mathrm{d}p_{\mathrm{T}}$ MB results ~✓

- **Next steps :**
  - Implement other corrections ($\phi(1020)$ yield down to 0 p_{T})
  - Estimate the systematic uncertainties
  - Prepare the tools (Rivet) to make the comparison with MC models

Other activities

- Service task
  - Pre-alignement of the Inner Tracking System (ITS-2) (December 2021-June 2022)

    → Provide the (half-)layers and (half-)staves positions before going for the full alignement with the Millepede method

- Two analysis notes :
  - Testing CPT theorem via the mass differences between anti-hyperons and hyperons with data of LHC run II [link] – Work in progress
  - Study of correlated production of strangeness via the measurement of the yield ratio of Ω and $\phi(1020)$ with pp data of LHC run II [link] – Work in progress

- Article
  - Proceedings for Strangeness in Quark Matter 2022

    → Publication by November 2022

Other activities

- Regular presentations
  - PWG-LF or PAG-LF every 3-4 months
  - Weekly meeting among international authors (Iouri Belikov, David Chinellato, Antonin Maire, **Romain Schotter**, Kai Schweda, **Georgijs Skorodumovs**)

- Presentations at conferences
  - “A multi-differential investigation of strangeness production in pp collisions with ALICE” – Strangeness in Quark Matter (Busan, South Korea – June 2022), **invitation**
  - “CPT Symmetry Test : Mass measurements of the Ξ(dss) and Ω(sss) with pp data collected with the ALICE detector during the LHC run II” – Assemblée Générale du GDR QCD (Ile d’Oléron, France – Mai 2022), **invitation**
  - “CPT Symmetry Test : Mass measurements of the Ξ(dss) and Ω(sss) with pp data collected with the ALICE detector during the LHC run II” – Rencontres QGP France (Tours, France – Mai 2022)
  - “Correlated production of strangeness : Measurement of the yield ratio of Ω(sss) and (ss) with pp data of LHC run II” – Rencontres QGP France (Etretat, France – Juillet 2021)
  - “CPT Symmetry Test : Mass measurements of the Ξ(dss) and Ω(sss) with pp data collected with the ALICE detector during the LHC run II” – Rencontres QGP France (Etretat, France – Juillet 2021)

Other activities

- Communication
  - Etonnante Chimie (IPHC, Strasbourg, France – 20 Mai 2022)
- ALICE Collaboration
  - **French junior ambassador** since the 15/09/2021
- IPHC
  - Soon **member of the Bureau Des Doctorants**
- Teaching duties : **2 contracts of monitoring** (2 x 64 hours)
  - TD Biophysique (L1 biologie – September-December 2020)
  - TP Biophysique (L1 biologie – January-April 2021)
  - Introduction à Python (L2 Physique – September-November 2021)
  - TP : Programming & Numerical Simulations (M1 Physique – September-November 2021)
  - Projects : Programming & Numerical Simulations (M1 Physique – January-May 2022)

Other activities

- Disciplinary trainings : **1/3**
  - Introduction to Quantum Science and Technology – 2021 ✓
  - Lectures Group Theory - The 34th International Colloquium on Group Theoretical Methods in Physics – July 2022 ✗
  - To be defined… ✗

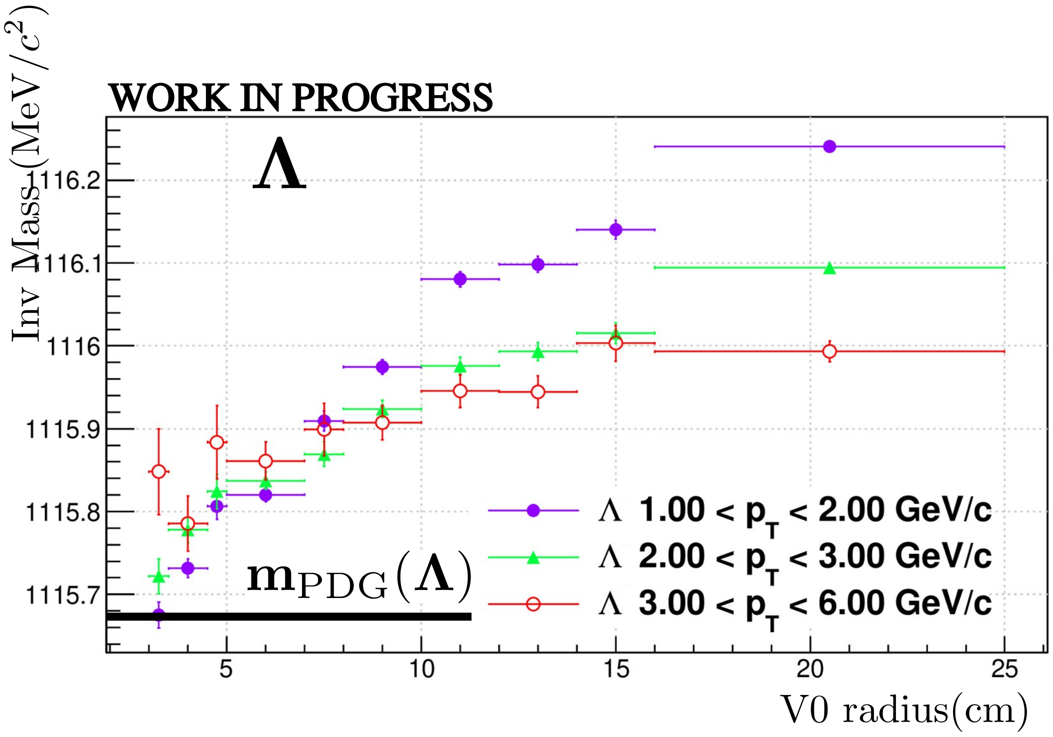
- Transversal trainings : **53/54h**
  - Assemblée générale des doctorants 2020 : 2h
  - Charte de déontologie des métiers de la Recherche : 3h
  - Calcul Parallèle : 21h
  - Econometrics of treatment effects and program evaluation : 9h
  - MOOC Intégrité scientifique dans les métiers de la recherche : 10h
  - Recruitment in academia: how to get a researcher or professor position in France : 1h30
  - Vaccines in a Pandemic: From the Lab to the Jab : 1h30
  - Congrès des doctorants ED182 : 5h

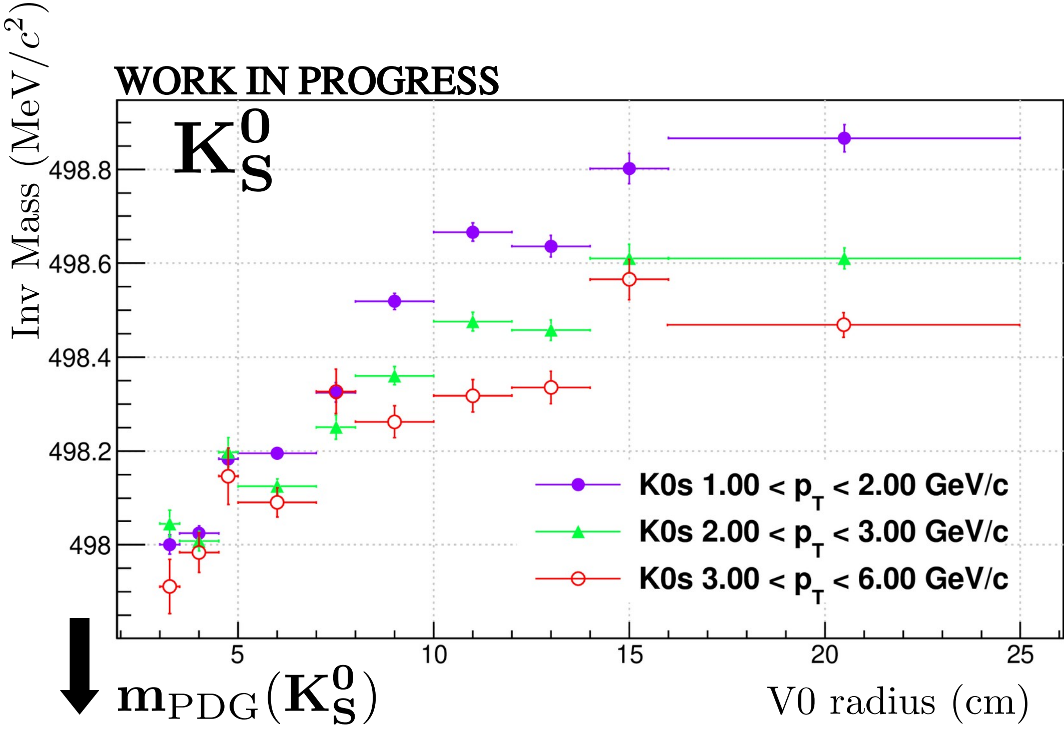
Backup slides

Dependence of the mass shift

- The gap between the extracted mass and the PDG mass seems to depend on :
  - Radial position of the decay point
  - The transverse momentum

$$\mathbf{m_{\mathrm{PDG}}(\Lambda) = 1115.683 \pm 0.006}\ \mathrm{MeV}/\mathbf{c^2} \quad \mathbf{m_{\mathrm{PDG}}(K^0_S) = 497.611 \pm 0.013}\ \mathrm{MeV}/\mathbf{c^2}$$



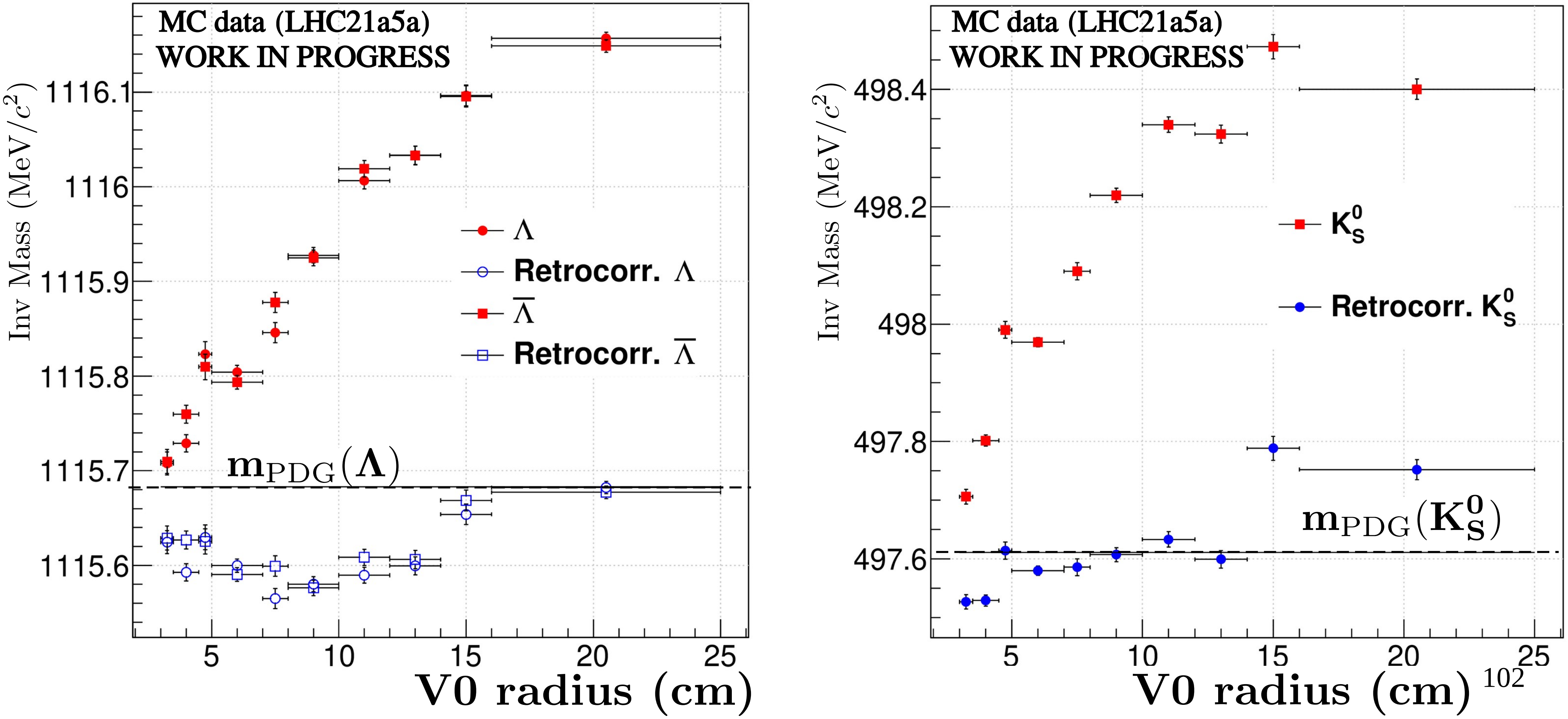


Invariant mass Vs radius

- The mass shift is dependent on the radial position of the V0

  → with retrocorrections, we'd expect the trend to be less pronounced

$\mathbf{m_{PDG}(\Lambda) = 1115.683 \pm 0.006}$ MeV/$\mathbf{c^2}$ $\mathbf{m_{PDG}(K^0_S) = 497.611 \pm 0.013}$ MeV/$\mathbf{c^2}$



Cascade selections

- Ω are reconstructed using topological selections

Ξ/Ω	Cut value
|y|	< 0.5
pT	[1 ; 5] GeV/c

- V0 selections for Ξ (Ω)

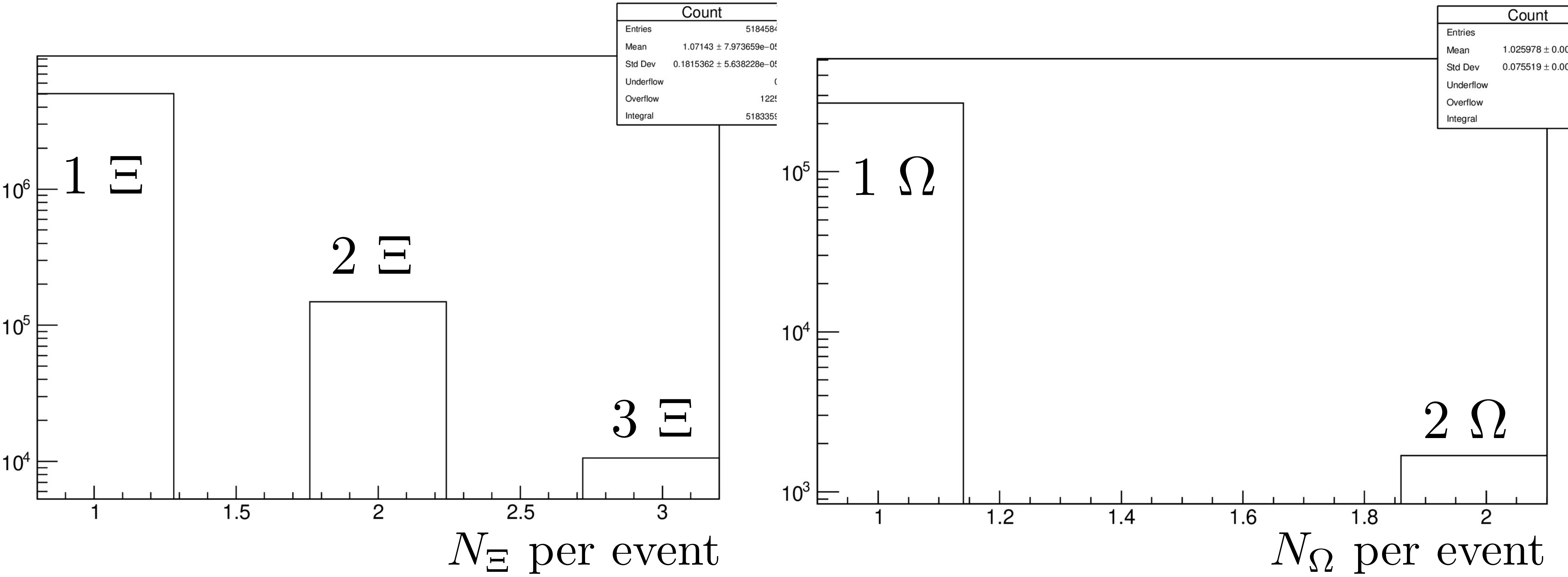
DCA V0 to PV	> 0.07 cm
DCA Pos to PV	> 0.04 (0.03) cm
DCA Neg to PV	> 0.04 (0.03) cm
DCA V0 daughters	< 1.6 cm
V0 Radius	> 1.4 cm
V0 Cos PA	> 0.97
|V0 Mass - Λ Mass|	< 0.006 GeV/c²

- Cascade selections

DCA Bach To PV	> 0.05 cm
DCA Casc daughters	< 1.6 cm
Casc Radius	> 0.8 cm
Casc Cos PA	> 0.97
|Casc Mass(Ξ) – Ξ Mass|	< 0.010 GeV/c2
|Casc Mass(Ω) – Ω Mass|	< 0.010 GeV/c2
Fast detector signal	>= 1 daughter with ITS refit OR TOF signal
Comp. casc rejection (only Ω)	> 0.008 GeV/c2

- Track selections :
  - $|\eta| < 0.8$
  - TPC refit + has TPC PID
  - TPC Nbr Crossed Rows > 70
  - TPC PID Nsigma < 4

Nbr of cascades per event



- Events with more than 1 Ξ represent ~ 2% of the total amount of events
- Events with more than 1 Ω represent ~ 0.5% of the total amount of events

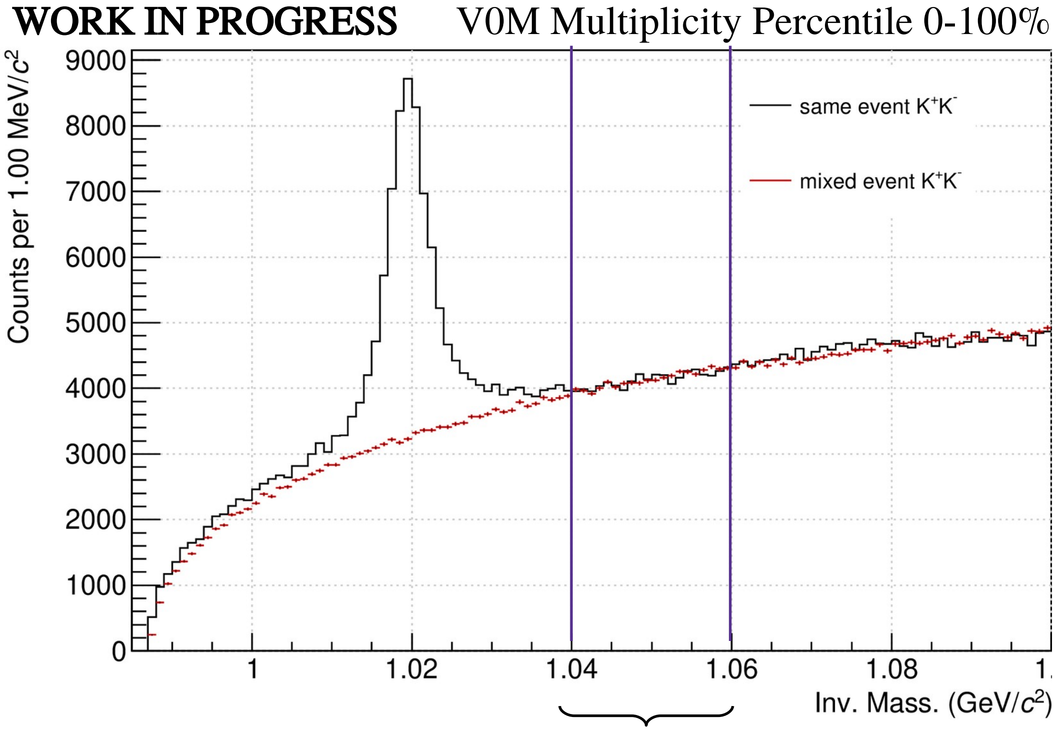
$\phi(1020)$ signal extraction

- Compute background :

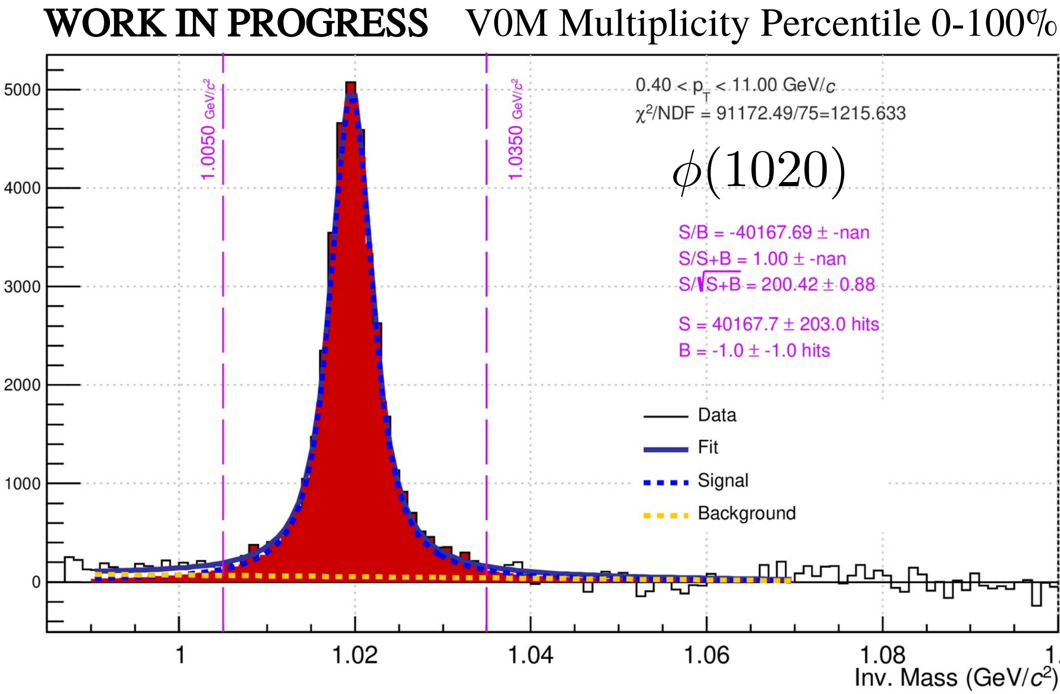
Mixing pairs from 5 other different events (**Event Mixing**)

$$\begin{cases} |\Delta PV_z(\mathrm{Evt}_A,\ \mathrm{Evt}_B)| < 1\ \mathrm{cm} \\ |\Delta \mathrm{V0M\ Percentile}(\mathrm{Evt}_A,\ \mathrm{Evt}_B)| < 10\ \% \end{cases}$$

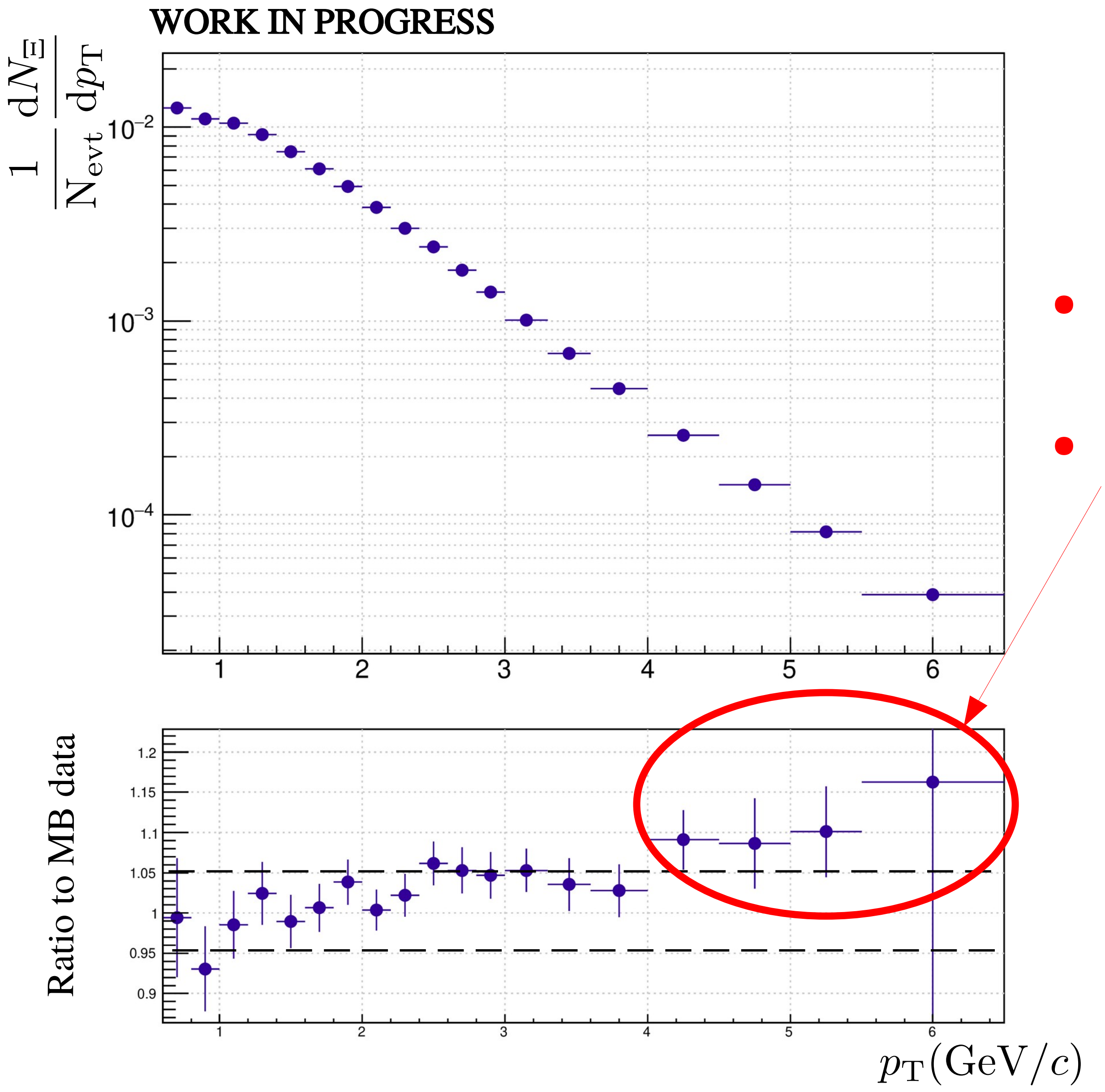
- Residual background substraction :
  - Fit with Voigt + 1^{st} order polynomial functions
  - Signal given by the sum of
    - bin counting in $[1.005; 1.035]\ \mathrm{GeV}/c^2$
    - integral of the Voigt function on the rest of the invariant mass



Scaling region



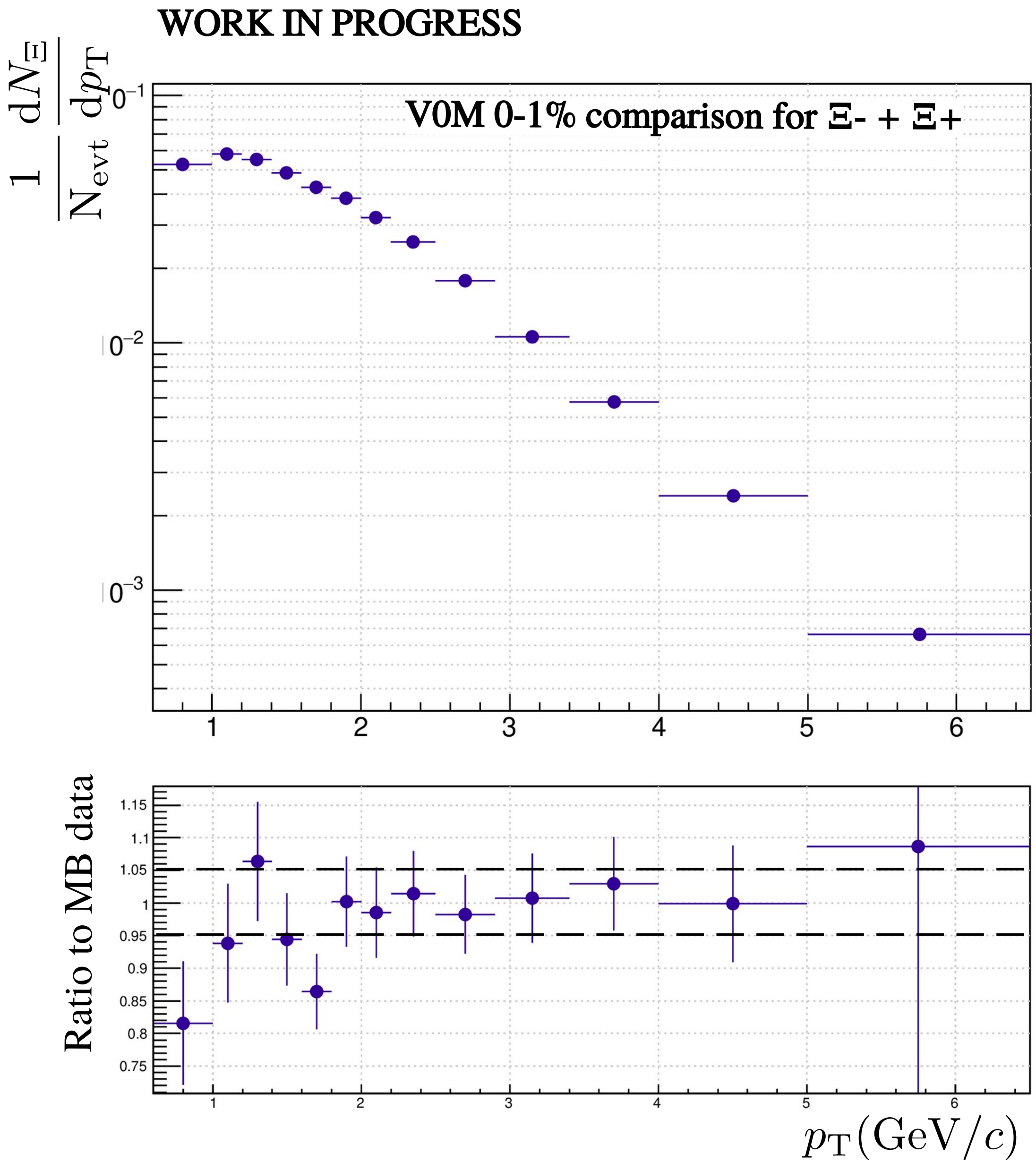
Check : Ξ MB spectra



- Our **corrected** spectra and the MB one are compatible within ± 5%
- **Above ± 5% at high p_T**

→ Also observed in other analysis

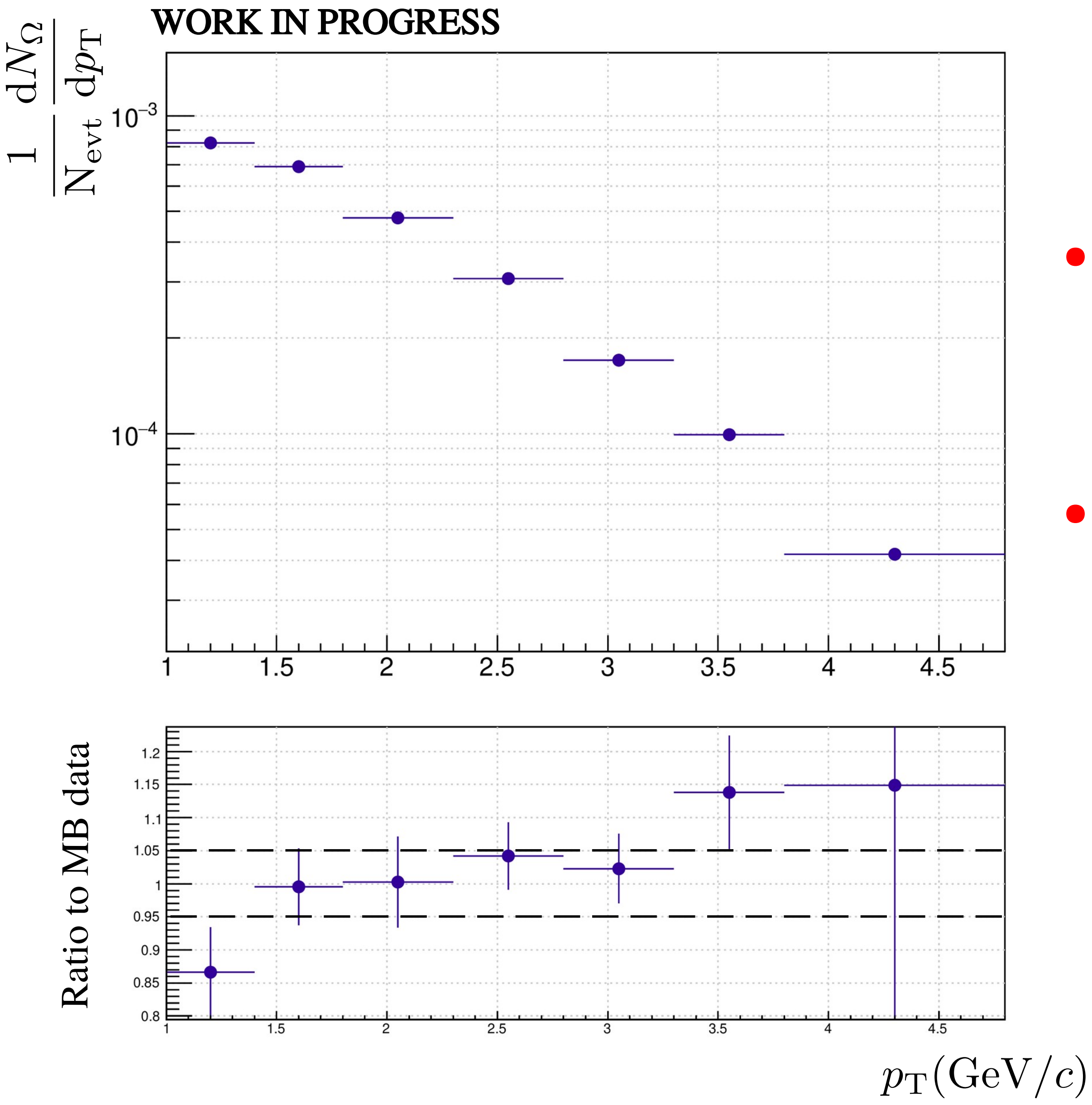
Check : Ξ MB spectra high multiplicity



- Our **corrected** spectra and the MB one are compatible within ± 5%
- **The deviation at high p_T disappears when going to high multiplicity events**

→ Also observed in other analysis

Check : Ω MB spectra



- Our **corrected** spectra and the MB one are compatible within +/- 5% (for most bins)
- There are deviations but this is certainly coming from the official results, that used a more limited data sample in Ω than us