Hidden over open beauty production in pp collisions $\sqrt{s}$ = 13.6 TeV at forward rapidity with ALICE

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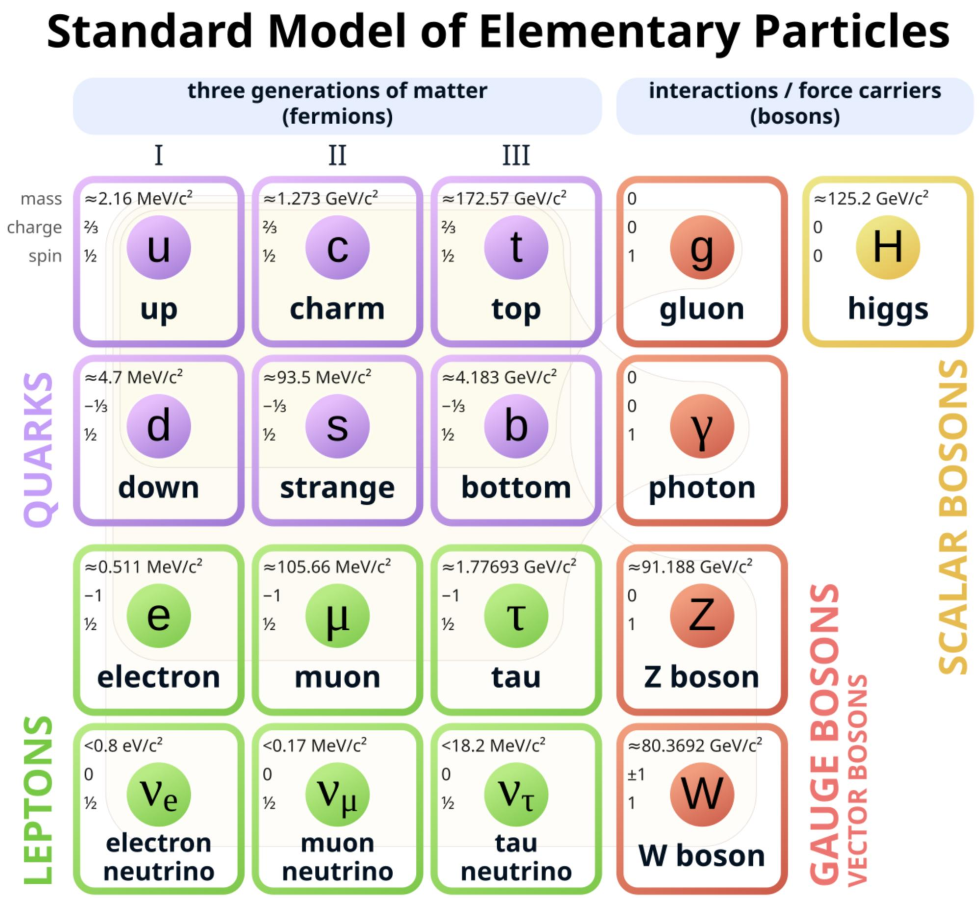
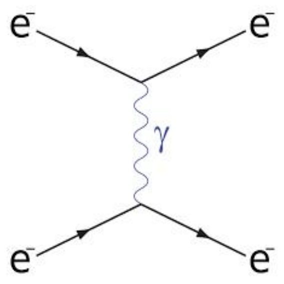
The Standard Model of particles

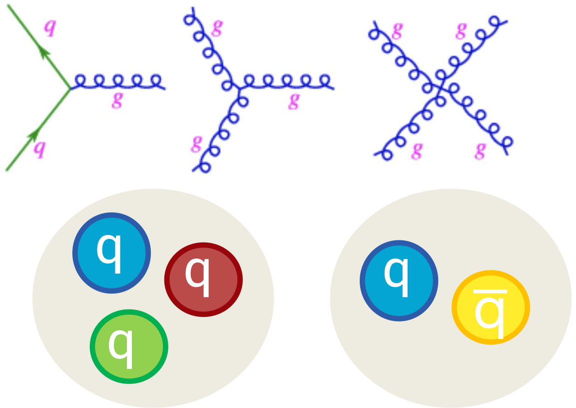
- Matter built from set of **elementary particles**
- **Quarks** and **gluons** feel the **strong interaction**
  - 6 quark flavours; the heavy **charm** & **beauty** are precious probes
  - Gluons carry the strong force (as photons carry electromagnetism)
- Quarks are **never seen free** : always bound inside **hadrons** (p, n, …)
- The strong force is described by **Quantum Chromodynamics (QCD)**



Quantum Electrodynamics :



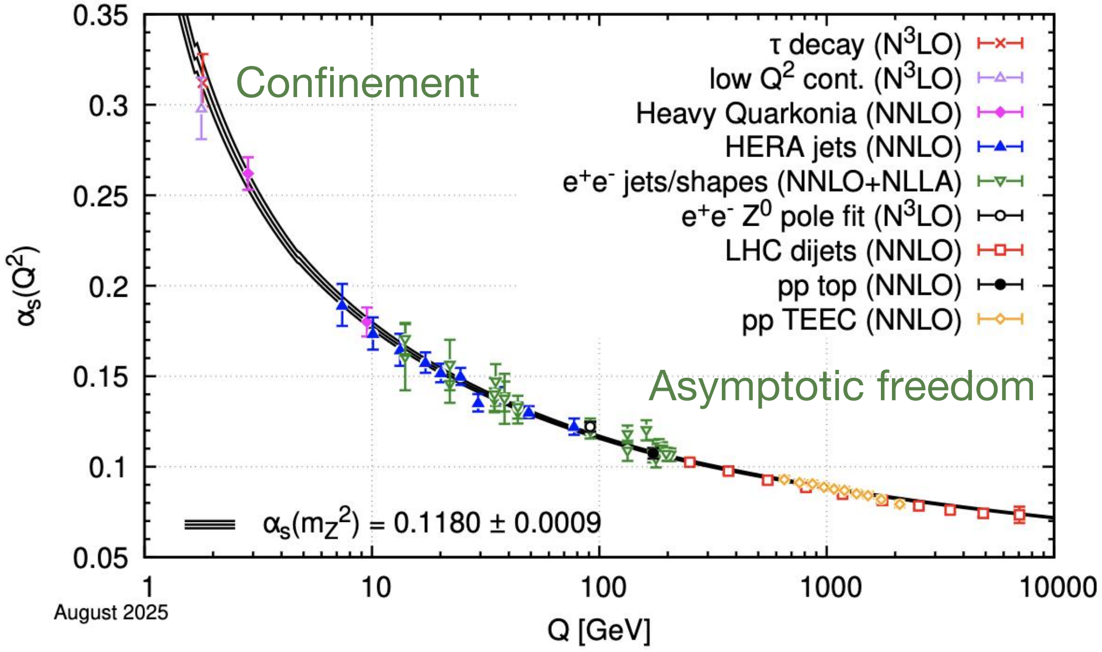
QCD (in short) :

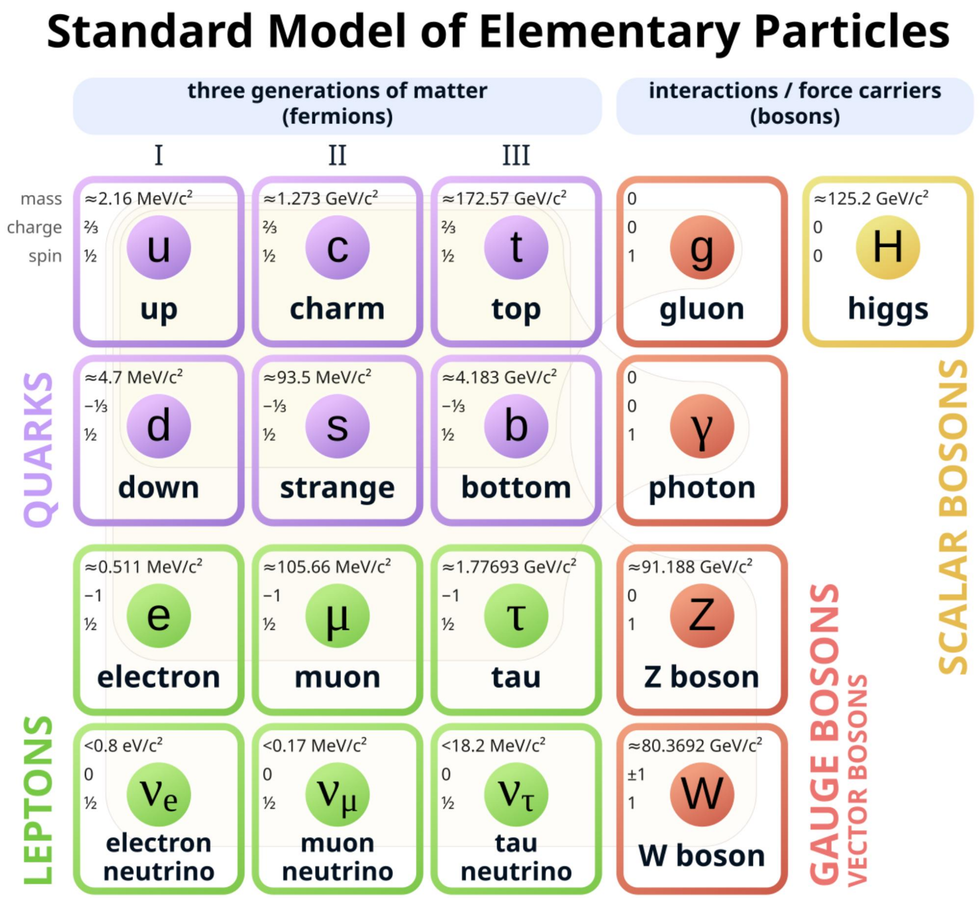


baryon meson

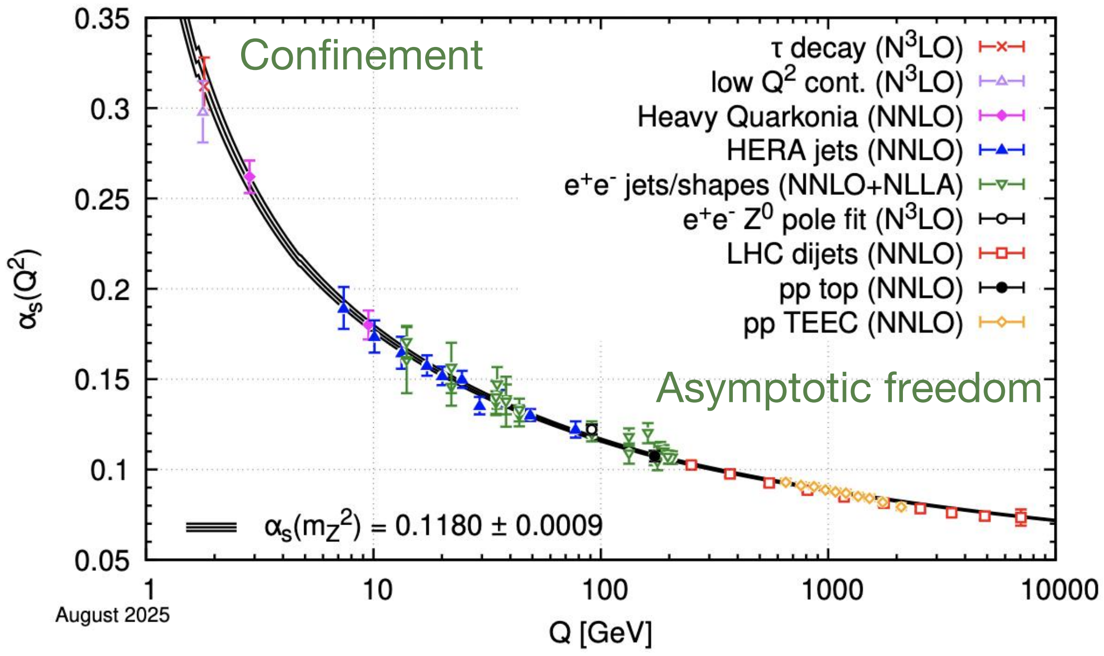
The Standard Model of particles

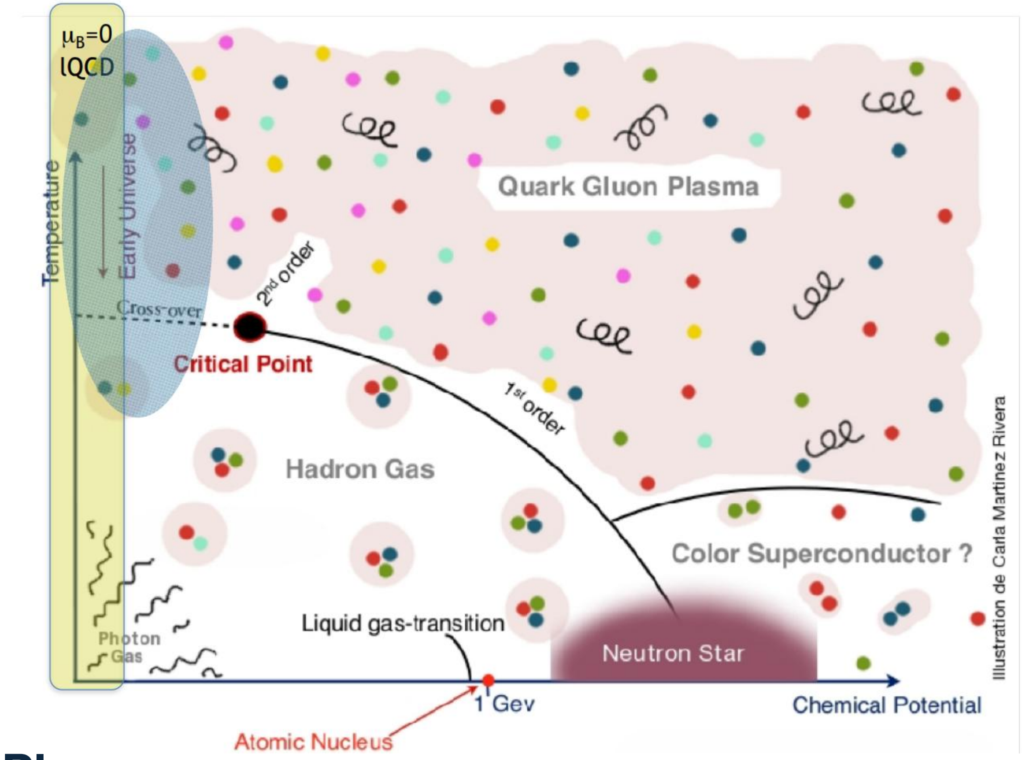
- **Confinement:** at low energy α_s **is large,** pulling quarks apart costs ever more energy → no free quark
- **Asymptotic freedom:** at high energy / short distance the coupling α_s **is small,** quarks act almost free





Deconfinement: the QCD phase diagram



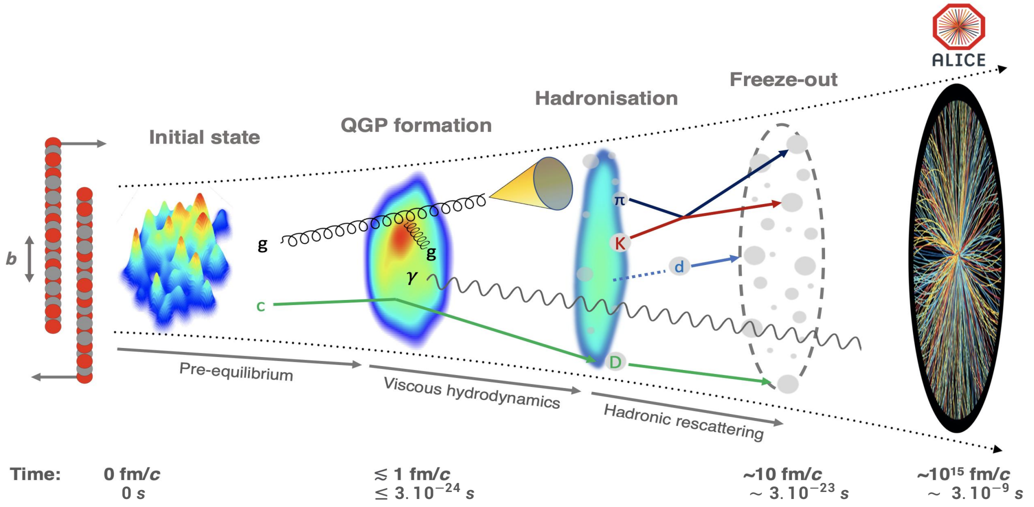


At high temperature or density : formation of a Quark Gluon Plasma

- quarks and gluons **deconfinement**
- $\mu_B \approx 0$ (@ LHC) & $T_C \approx 155$ MeV (LQCD)
- like a nearly perfect fluid

Quarkonia production in heavy-ion collisions

- $M_{c,b} \gg \Lambda_{QCD}$ (pQCD)
- $c\bar{c}$ & $b\bar{b}$ pairs are created at the **initial state** ($\tau \sim 1/m_Q$) of the collision
- **Sensitive** to medium evolution :
  - heavy-flavor ($q\bar{c}$, $\bar{q}c$, $q\bar{b}$, $\bar{q}b$, $c\bar{c}$, $b\bar{b}$) are probes



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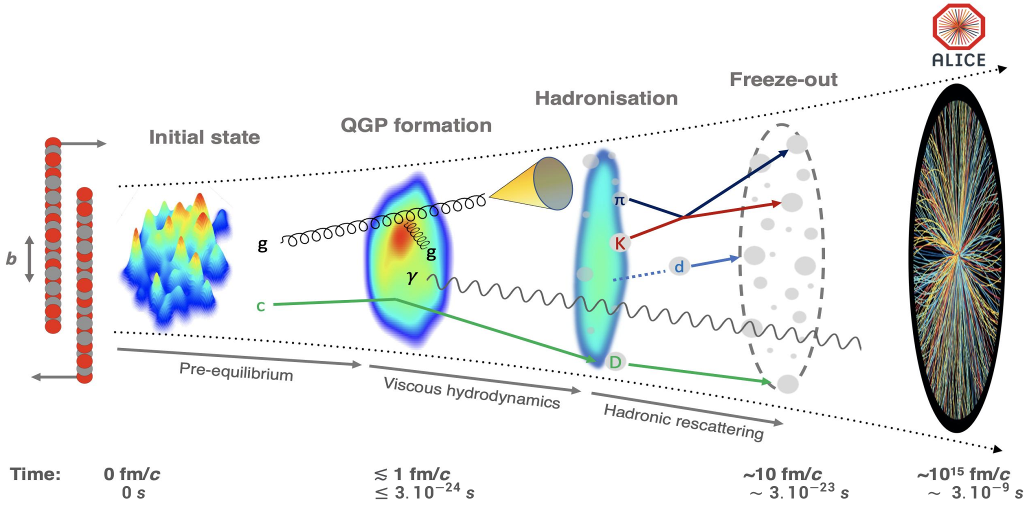
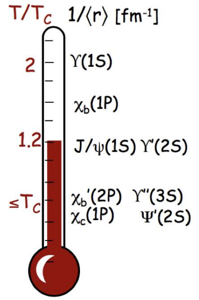
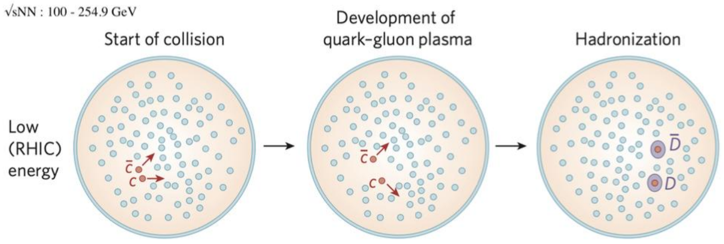


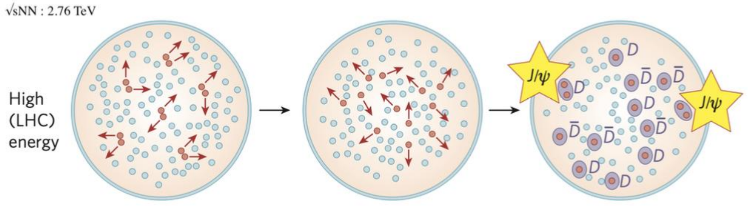
- **Suppression** (Debye's color screening effect)





[T. Matsui and H. Satz, [PLB 178 (1986) 416]

- @ LHC energy → $c\bar{c}$ pair (uncorrelated) **recombination**



[P. Braun-Munzinger, J. Stachel, Nature 448 (2007) 302]

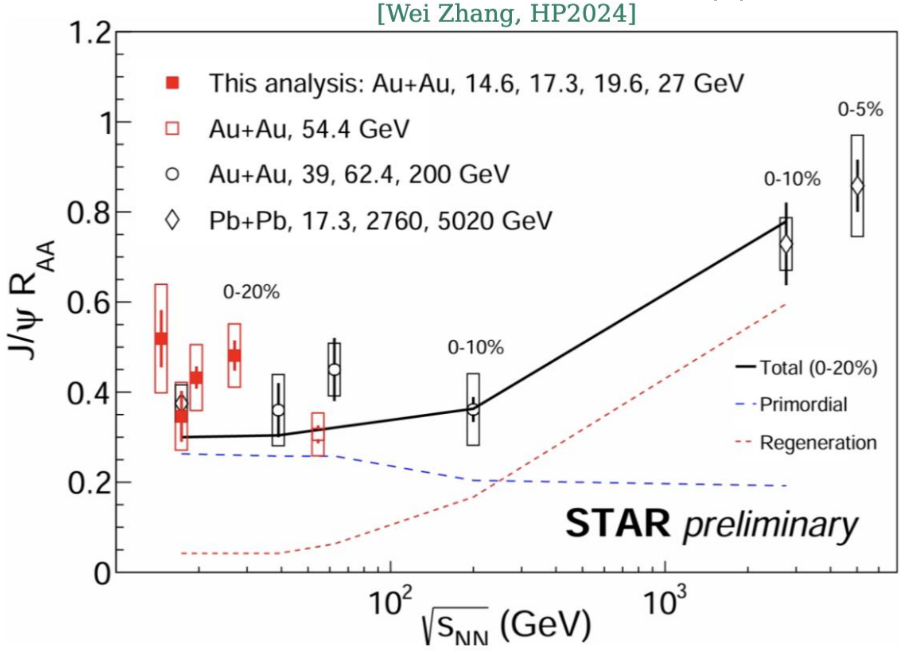
→ *dynamic approach of $Q\overline{Q}$ production* [Jiaxing Zhao SQM 2024]

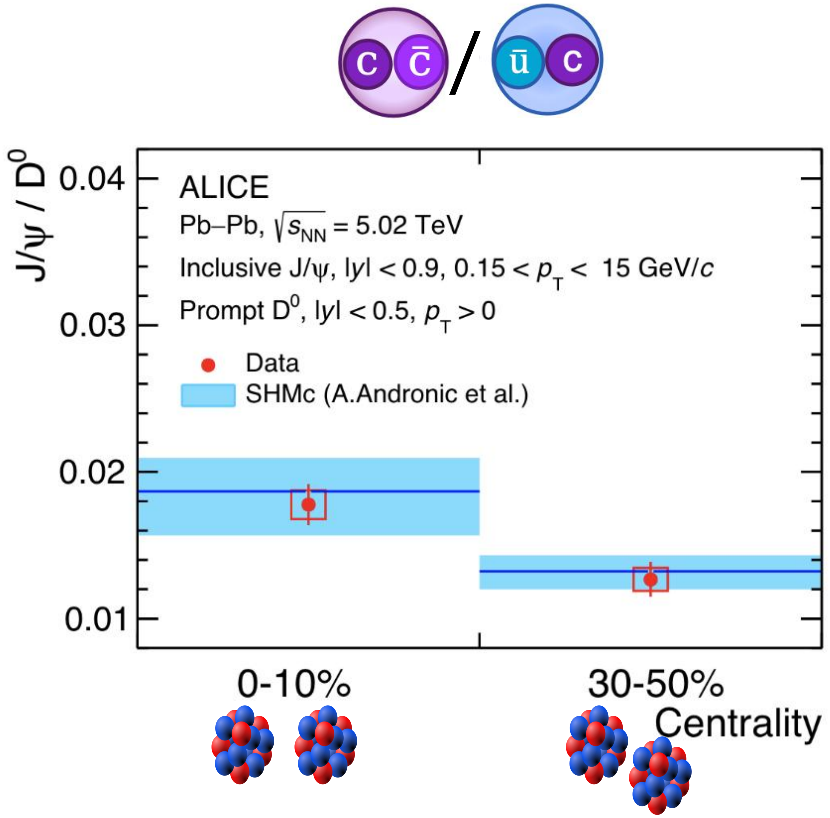
Hidden vs Open charm production

- Mesure of **suppression** of charmonia & bottomonia / **regeneration** of charmonia
  → p/A-A system : Affected by **Hot Matter** effect and/or by **Cold Nuclear Matter** effects (CNM)
  → p-p system (baseline) : Sensitive to hadronisation

$$R_{AA} = \frac{N_{AA}}{\langle N_{coll} \rangle N_{pp}}$$

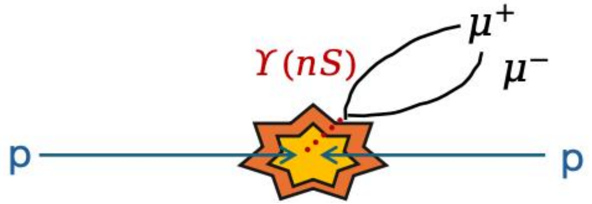
[Wei Zhang, HP2024]





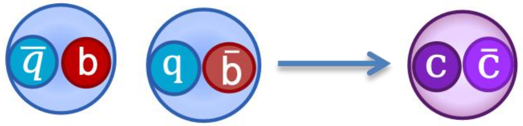
Hidden vs Open beauty production

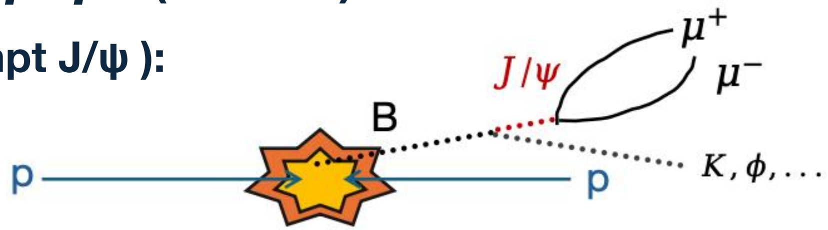
- **Hidden beauty** : Υ **resonance states** $\rightarrow \boldsymbol{\mu^+\mu^-}$



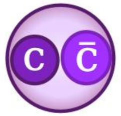
- **Open beauty** : via **non-prompt J/ψ** $\rightarrow \boldsymbol{\mu^+\mu^-}$ **(indirect)**

Open beauty (Non-prompt J/ψ):

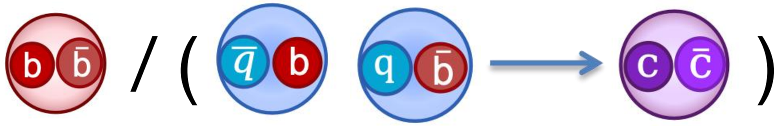




Prompt J/ψ contamination :

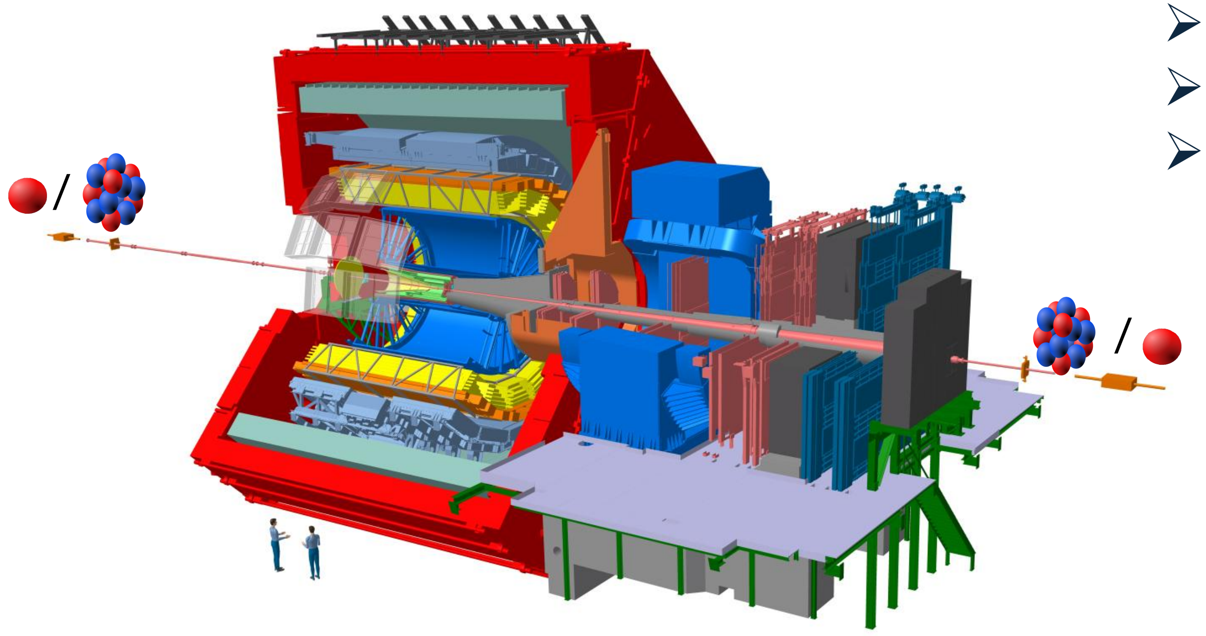


- Measuring Y and non-prompt J/ψ **together** → hidden/open ratio + reduce some systematics terms

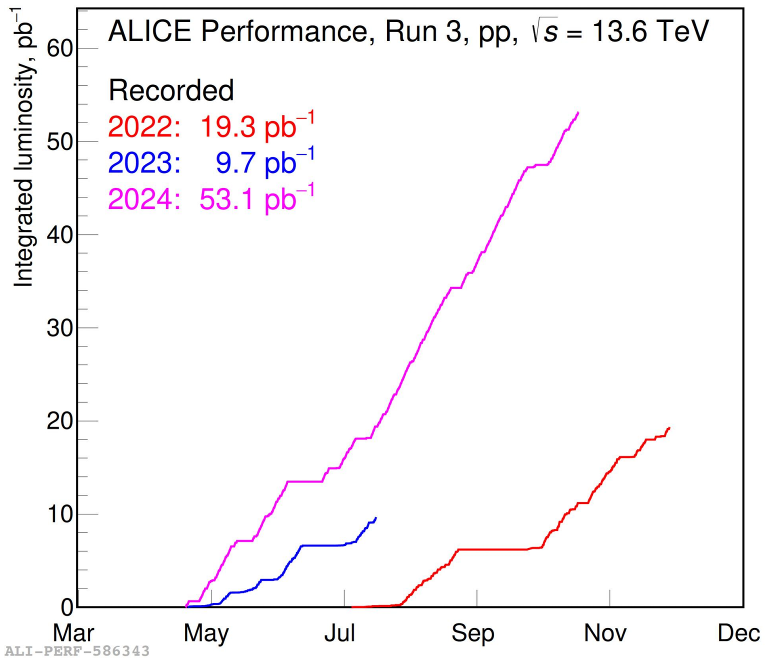


→ do first in pp as baseline for Pb-Pb measurement

A Large Ion Collider Experiment (ALICE) - Run 3



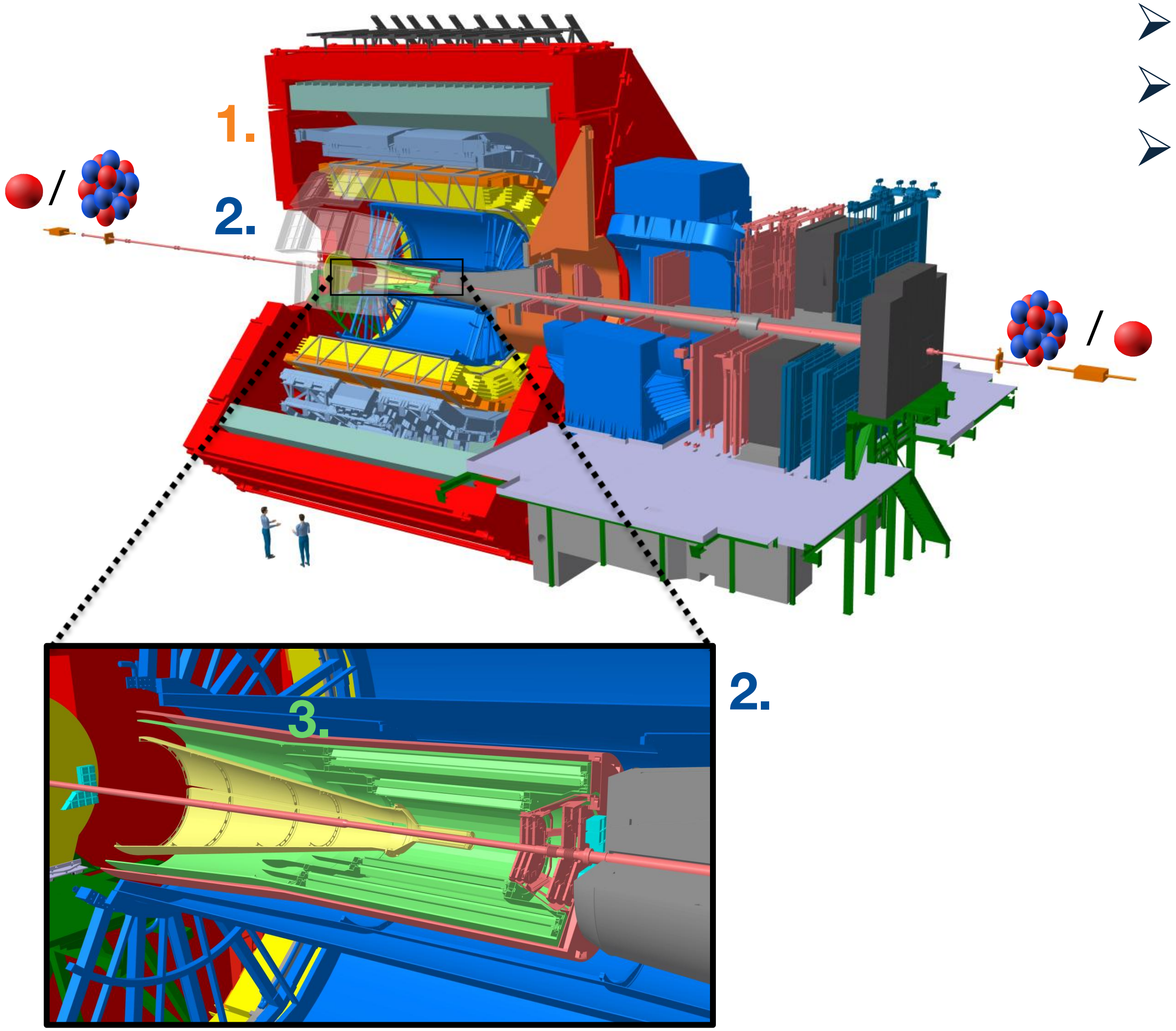
- One of the 4 major experiment @ CERN
- Dedicated to the QGP properties
- Hadrons can be **measured down to $p_T = 0$** and for 2 rapidity regions :



- **Higher luminosity :**
  - pp : 200 KHz → 500 KHz - 1 MHz
  - PbPb : 8 KHz → 50 KHz

- **Upgrade Run 2 → Run 3 :**
  - New detectors
  - « Triggering » → Continuous data taking

A Large Ion Collider Experiment (ALICE) - Run 3



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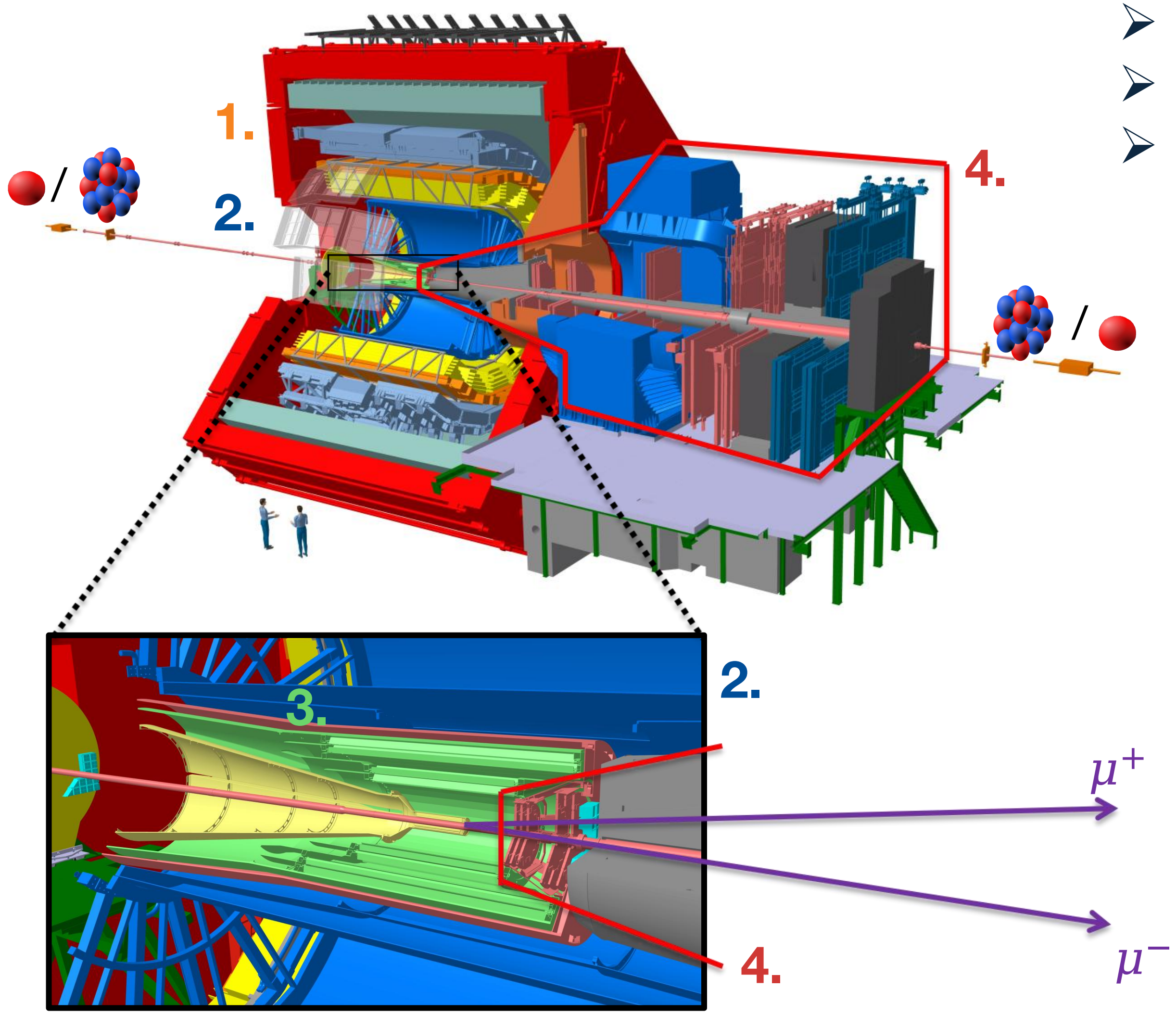
- Hadrons can be **measured down to $p_T = 0$** and for 2 rapidity regions :
  - **Central rapidity** : $|y| < 0.9$

    1. TOF – Time **O**f **F**light detector
    Particles identification

    2. TPC – Time **P**rojection **C**hamber
    PID, tracking

    3. ITS – Inner **T**racking **S**ystem
    Primary Vertex reconstruction, tracking

A Large Ion Collider Experiment (ALICE) - Run 3



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    1. TOF – Time Of Flight detector

    Particles identification

    2. TPC – Time Projection Chamber

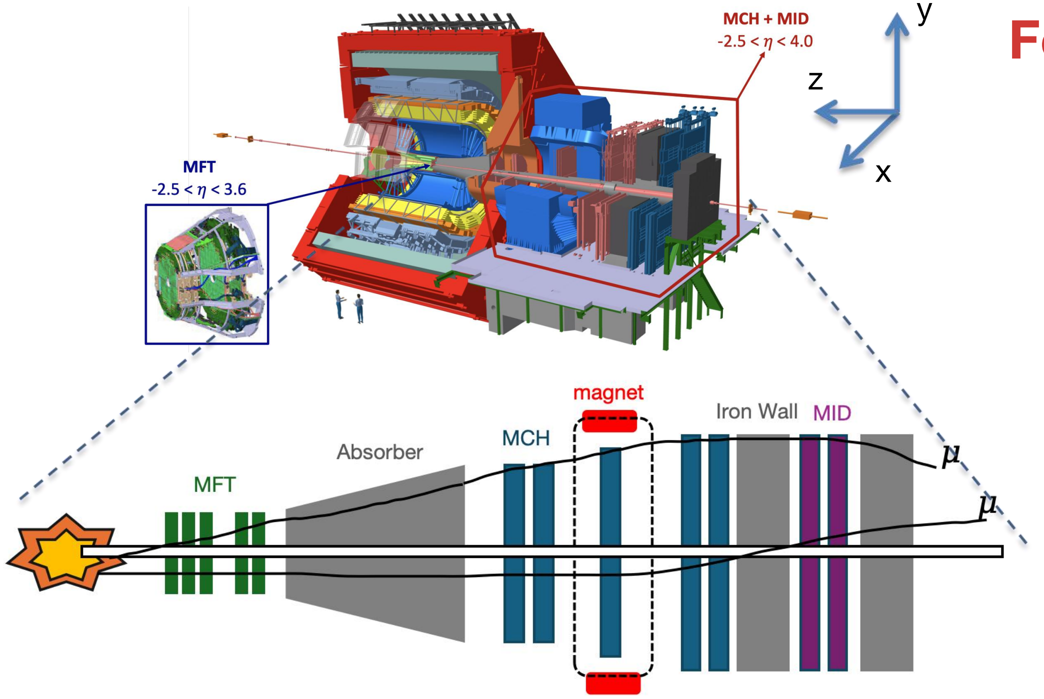
    PID, tracking

    3. ITS – Inner Tracking System

    Primary Vertex reconstruction, tracking
  - **Forward rapidity** : $2.5 < |y| < 4.0$ (or 3.6)

    4. Muon spectrometer + Muon Forward Tracker

ALICE - Muon Forward Tracker + Muon Spectrometer



- Tracks reconstruction :

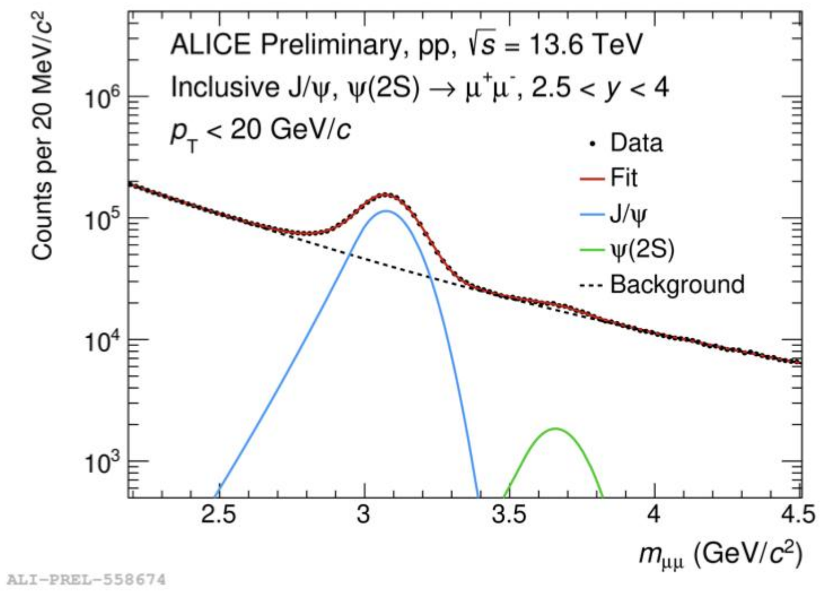
  Global : MFT + MCH + MID

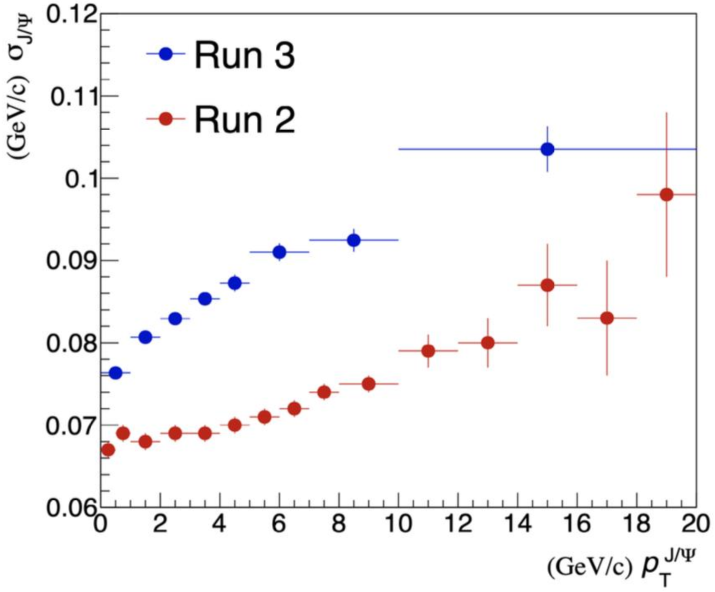
  Standalone : MCH + MID

Forward rapidity detector :

- **Muon Forward Tracker (MFT):** $2.5 < |y| < 3.6$
  5 silicons planes pixel detector in front of the absorber → allow prompt/non-prompt separation
- **Muon Spectrometer :** $2.5 < |y| < 4.0$
  - **Absorber :**
    Stop and reduce muons flux from π, K decay by 2 order of magnitude
  - **Muon CHambers (MCH):**
    MultiWire Proportional Chambers
    5 stations → 10 chambers
  - **Iron Wall :**
    Stop remaining hadrons & low momentum muon
  - **Muon IDentifier (MID):**
    Resistive Plate Chambers
    2 stations → 4 chambers

ALICE - Run 3 Muon Spectrometer response function





Invariant mass resolution of J/ψ for differents $p_T^{J/\psi}$ bins from ALICE

- Studies :

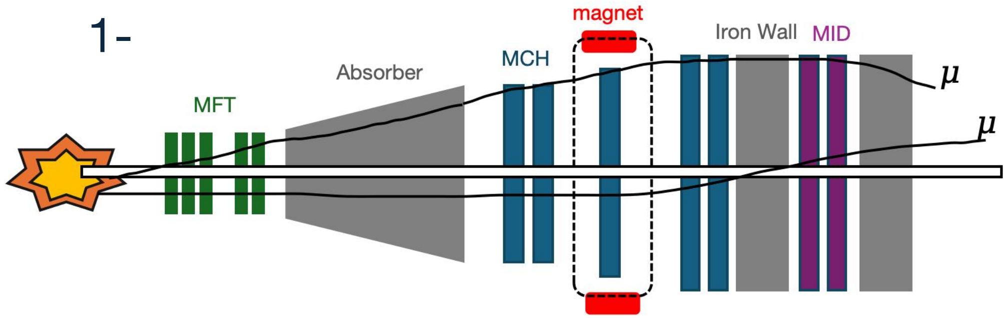
1. Response function of the Muon Spectrometer chambers

2. Tuning detector response & noise in Monte-Carlo simulations (impact on signal shape for analysis in particular for upsilon)

3. Improve resolution

Muon Spectrometer - Tracking and reconstruction

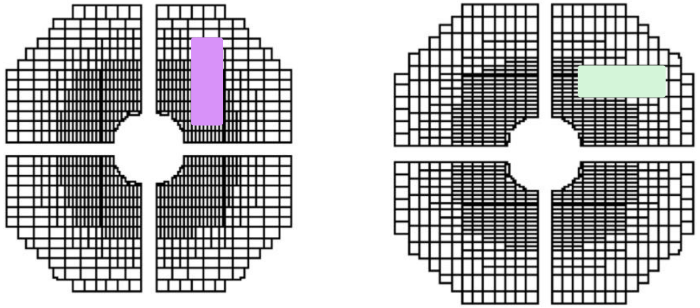
1-



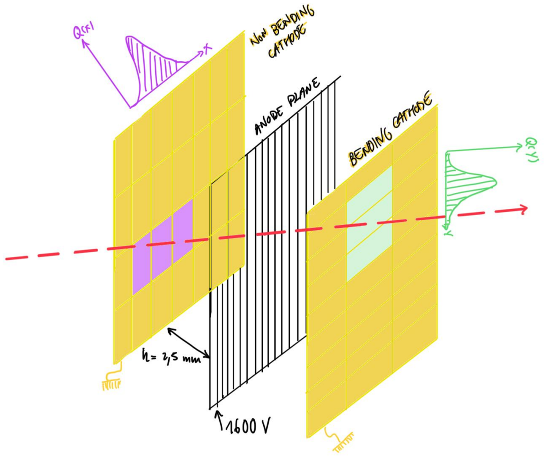
2-

Non-Bending (NB)

Bending (B)

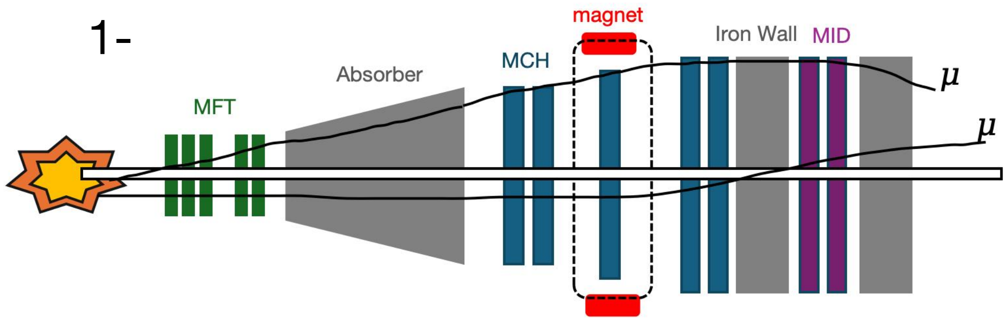


3-

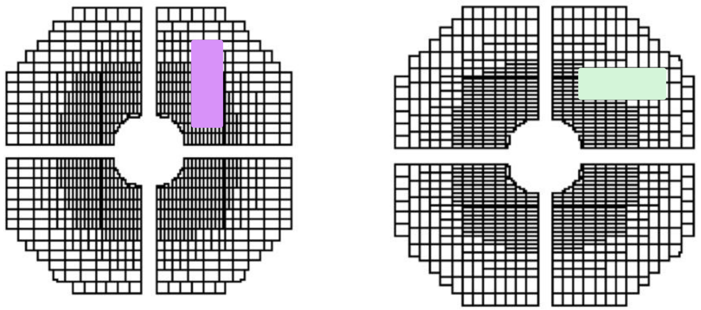


Muon Spectrometer - Tracking and reconstruction

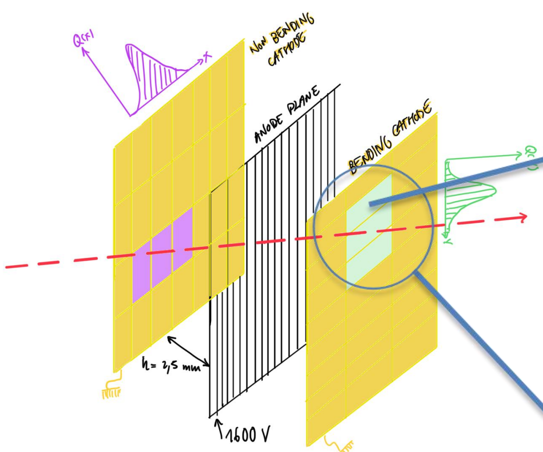
1-



2-

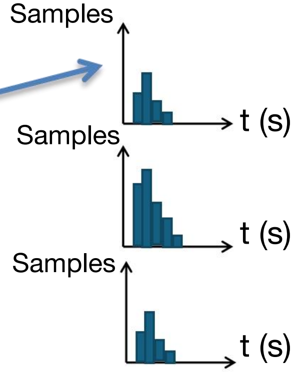


3-



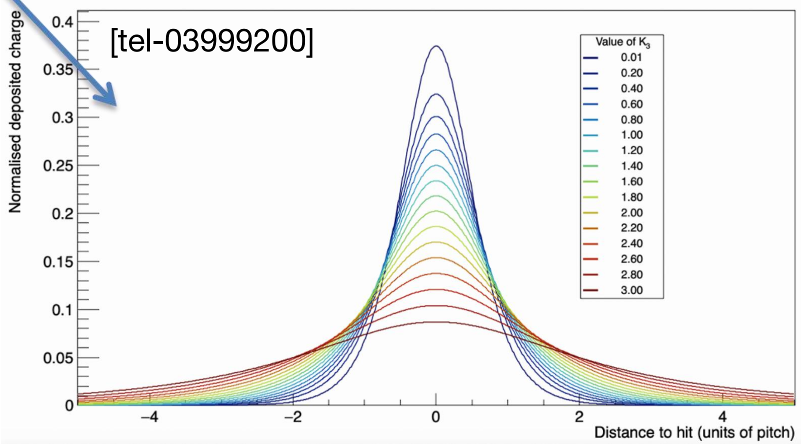
- Time distribution (pad):

pad charge ADC = $\sum_i Samples_i$

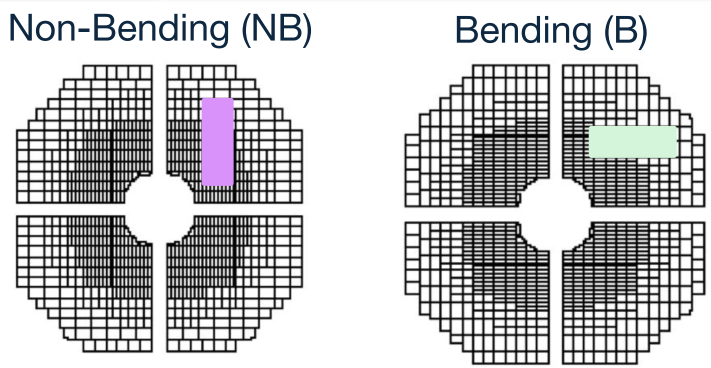


- Spatial distribution (cluster) :

Mathieson-Gatti distribution

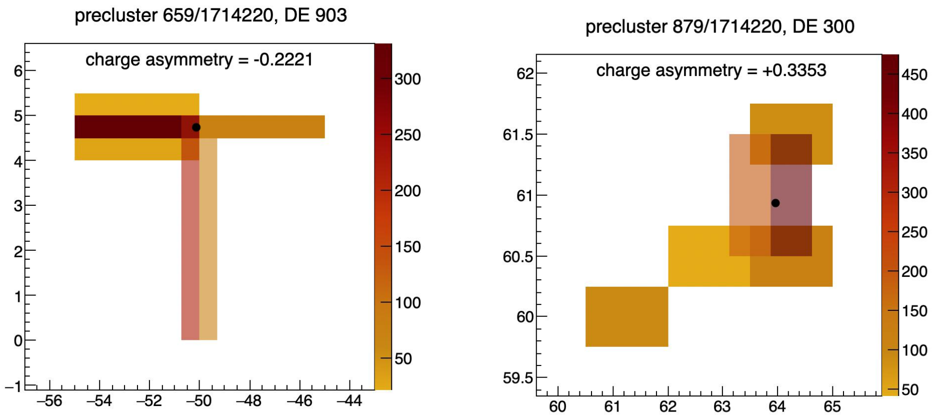


Muon Spectrometer - Strategy



- **Tuning detector response & noise in MC simulations from data :**
  - ➢ Pad charge resolution (i.e noise)
  - ➢ Bending and Non-Bending charge asymmetry

- **Run 3 preclusters :**



Muon Spectrometer - Strategy

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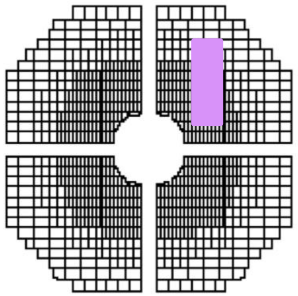
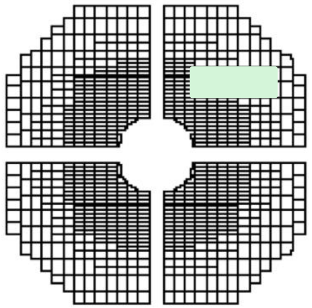


Bending (B)



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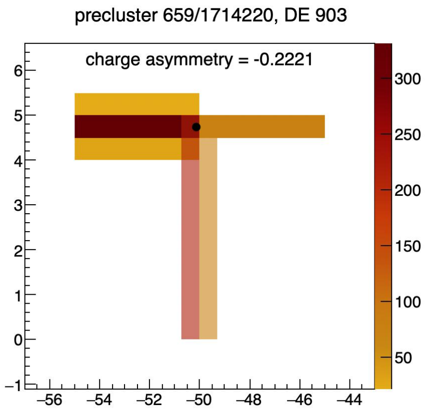
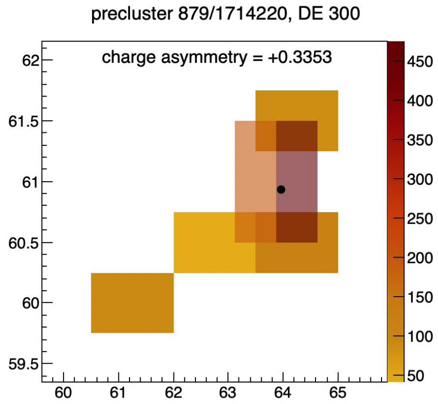




- **Tuning detector response & noise in MC simulations from data :**
  - Pad charge resolution (i.e noise)
  - Bending and Non-Bending charge asymmetry

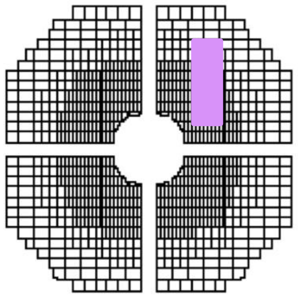
- **Tools :** MC & DATA (Run 3) selections :
  - Clusters attached to muon tracks
  - Single clusters
  - Bending & Non-Bending plane hit
  - Discard preclusters that are made of <u>disjoint</u> pads

<u>Toy MC</u> : 1. more flexible for adjusting the noise and asymmetry
2. use real cluster (position, charge) as input

I - Compare MC and Toy-MC (closure test)
II - Compare DATA (Run 3) and Toy-MC

Muon Spectrometer - Monte-Carlo residuals

Non-Bending (NB)



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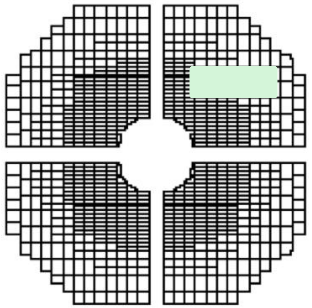
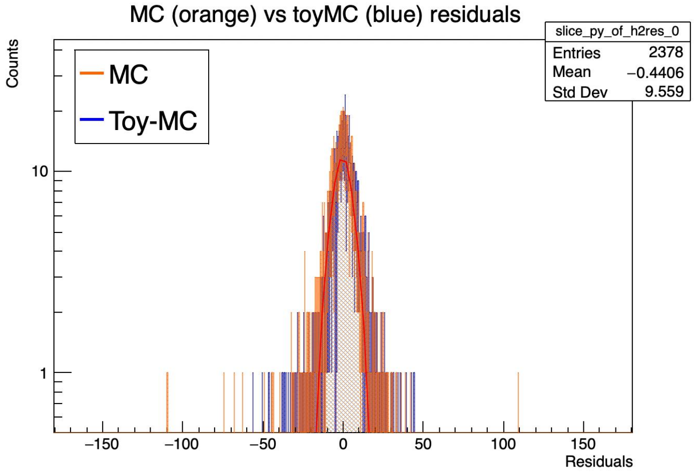
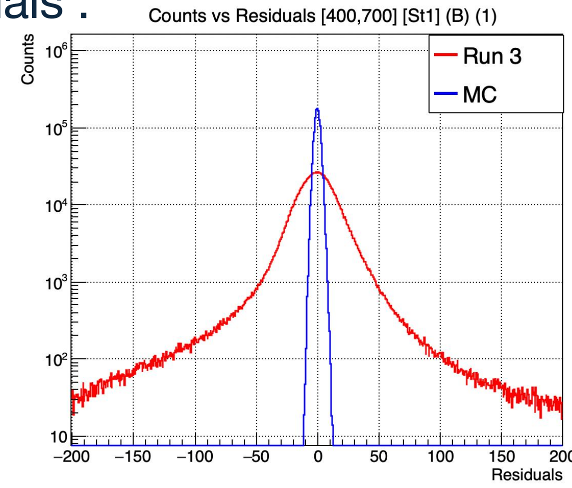


- MC vs Toy-MC residuals :



- MC vs Run 3 residuals :



➢ Closure test valid :
MC and Toy-MC input noise :

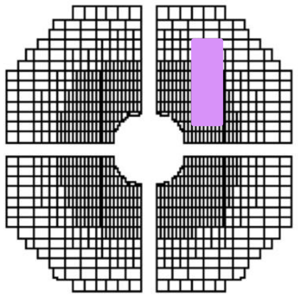
$$\text{All St.} \rightarrow \mathcal{N}\left(0\,,\ 0.5 * ADC^{\frac{1}{3}}\right)$$

➢ MC do not reproduce Run 3 residuals → noise is under estimated, correction :

$$\sigma^{th.}_{DATA} = \sigma^{th.}_{TMC}\ (\ \sigma^{mes.}_{DATA}\ /\ \ \sigma^{mes.}_{TMC})$$

Muon Spectrometer - Monte-Carlo residuals

Non-Bending (NB)



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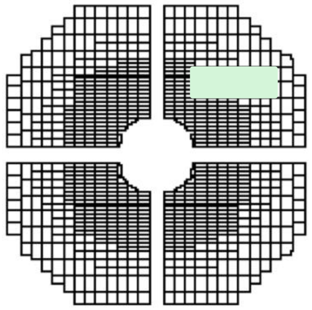
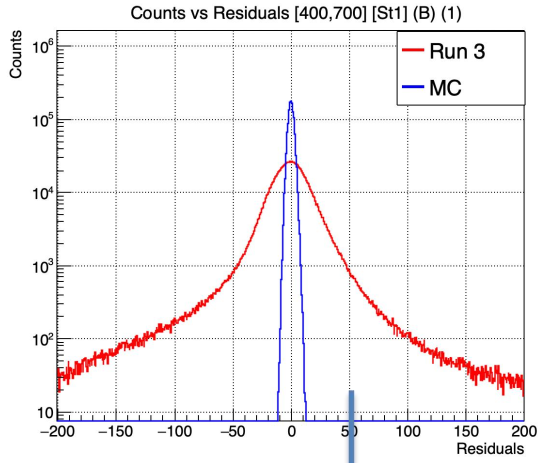


- MC vs Run 3 residuals :

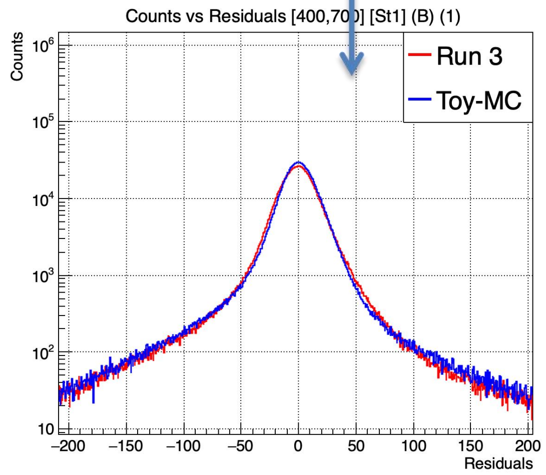


➢ New input noise fall within 10-20% accuracy :

$$\text{St. 1 (B)} \rightarrow \mathcal{N}\left(0\,,\ 1.3\sqrt{ADC} - 0.085\sqrt{ADC^2} + 0.004\sqrt{ADC^3}\right)$$

→ different tunning for different stations and cathodes

- Toy-MC vs Run 3 residuals :

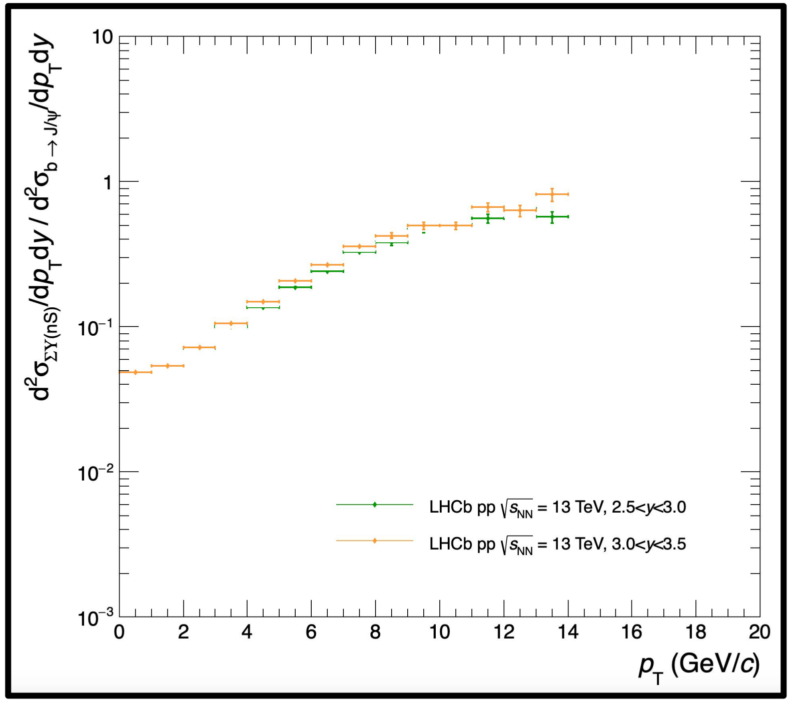


➢ **To do :** implement this tunning in official MC simulation

Analysis — Hidden over Open beauty production

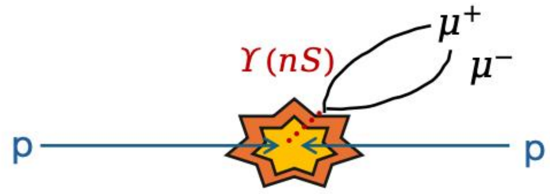
Goal : $\frac{d\sigma_{\Upsilon(nS)}}{dp_T dy} / \frac{d\sigma_{np-J/\psi}}{dp_T dy} \propto \sum_{n=1}^{3} N_{\Upsilon(nS)} \; / \; N_{np-J/\psi}$

** Branching ratios and Acceptance-Effiency correction hidden in ∝*



Hidden Beauty :

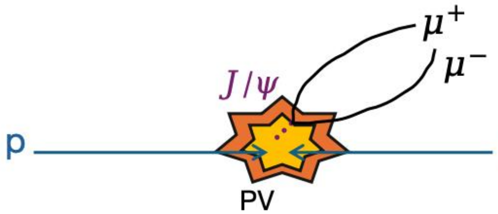
$$\sum_{n=1}^{3} N_{\Upsilon(nS)}$$

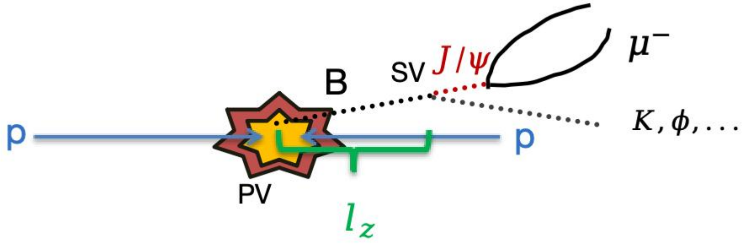


Open Beauty :

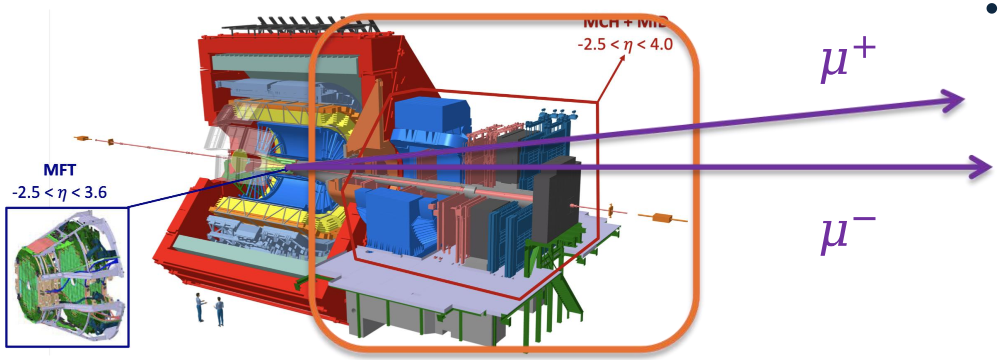
$$N_{np-J/\psi} = f_B N_{incl-J/\psi}$$

$$f_B = \frac{N_{np-J/\psi}}{N_{np-J/\psi} + N_{p-J/\psi}}$$



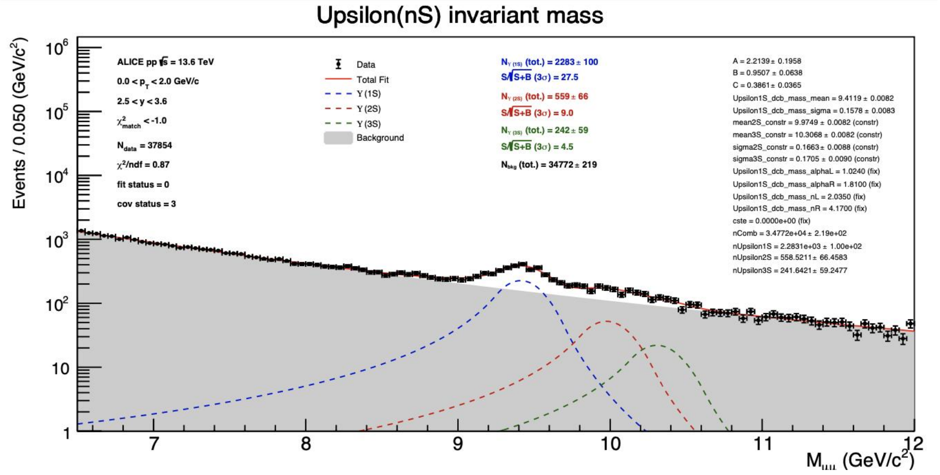


Analysis — Upsilon production

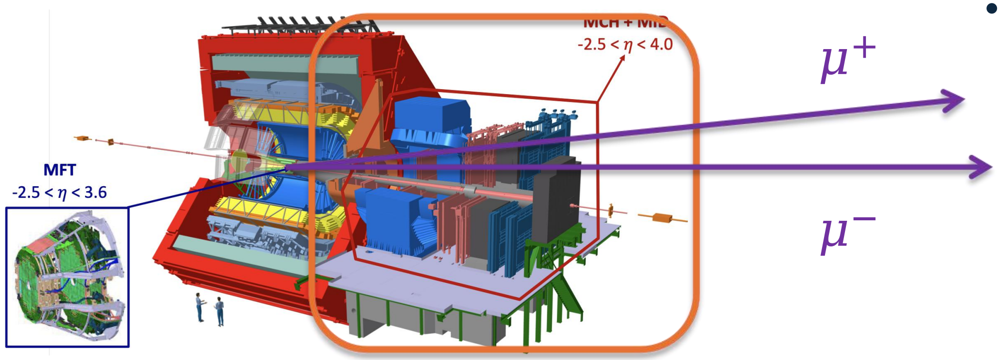


Detectors used: MCH + MID = Standalone

- **Invariant mass fit $M_{\mu\mu} = \sqrt{2p_{-}p_{+}(1 - cos(\theta_{-+}))}$:**

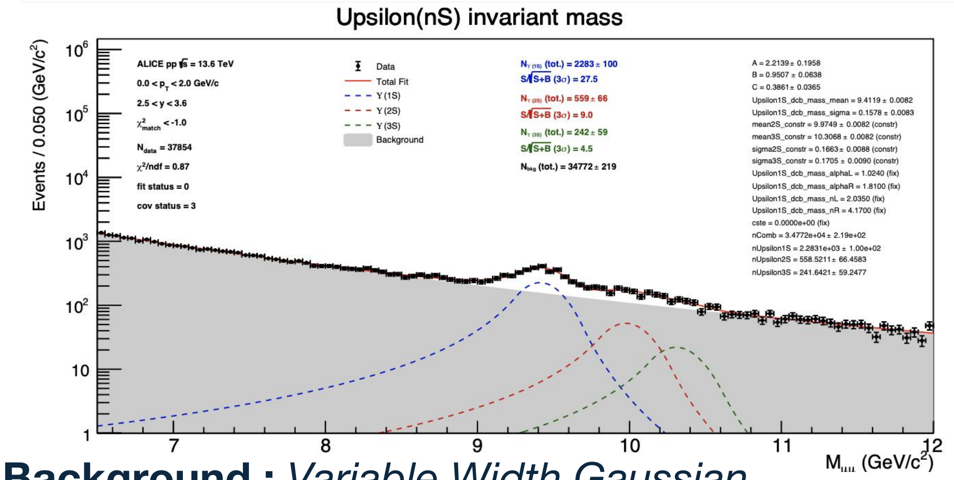


Analysis — Upsilon production



Detectors used: MCH + MID = Standalone

- **Invariant mass fit $M_{\mu\mu} = \sqrt{2p_-p_+(1-cos(\theta_{-+}))}$:**

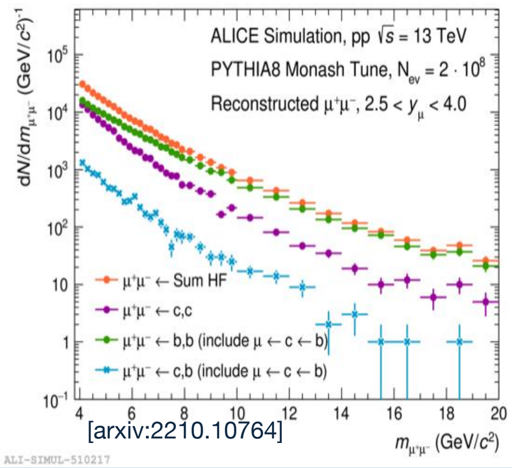


- **Signal :** *Double-Crystal ball, ...*

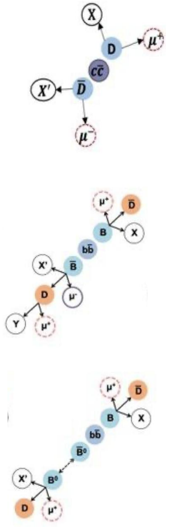
Υ(1S), Υ(2S), Υ(3S)

- **Background :** *Variable Width Gaussian, ...*

Heavy-Flavour decay

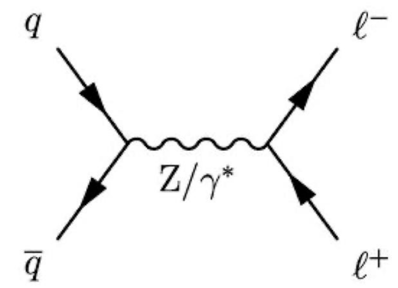


[arxiv:2210.10764]

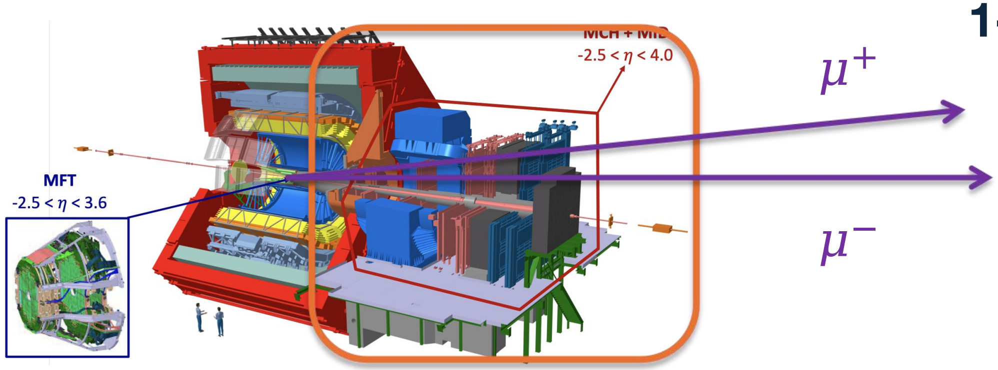


>>

Drell-Yan mechanism

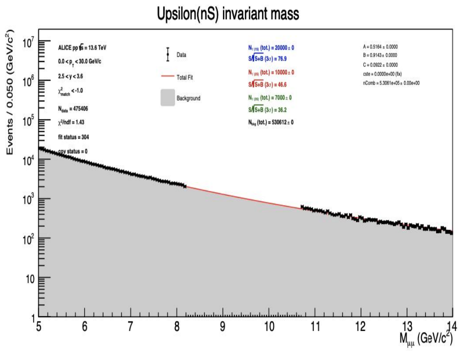


Analysis — Upsilon production

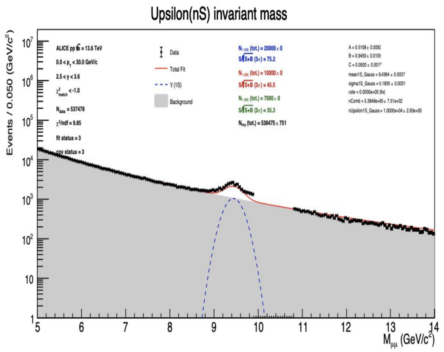


Detectors used: MCH + MID = Standalone

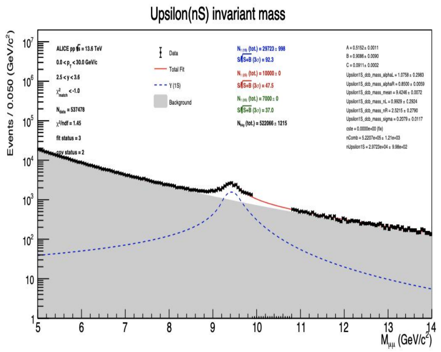
1-



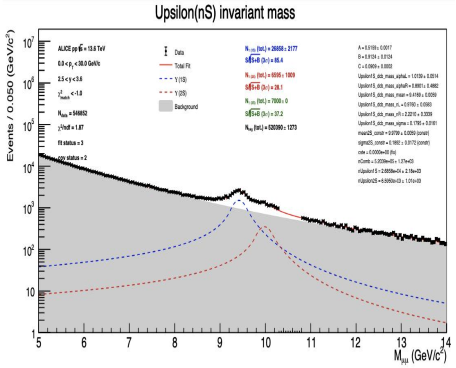
2-



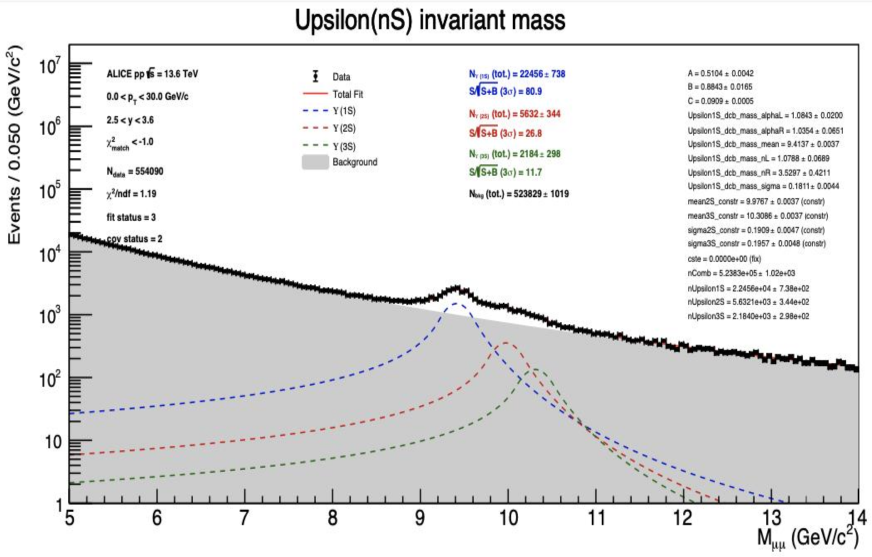
3-



4-



5-



- **Fit method :**
  1- Only background
  → 2/3- Include $\Upsilon(1S)$ and adapt signal shape
  → 4/5- Include $\Upsilon(2S)$ then $\Upsilon(3S)$ with constrains

- **Constrains :**

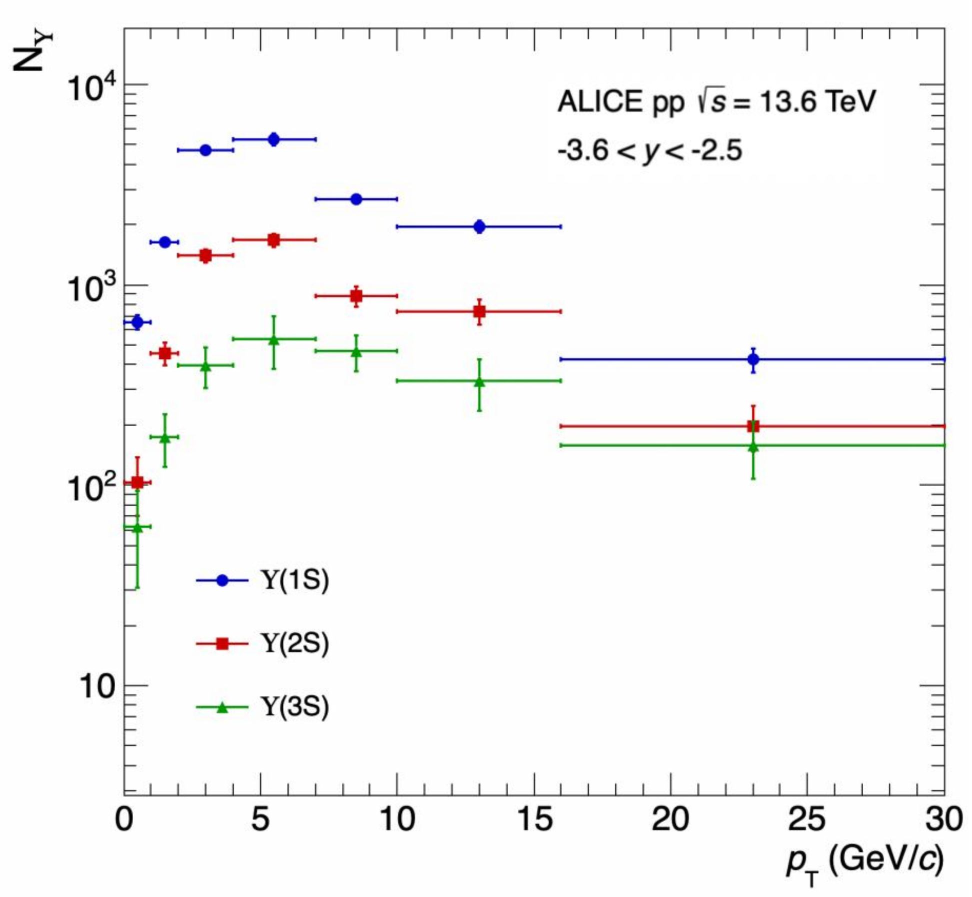
$$\sigma_{\Upsilon(nS)} = \sigma_{\Upsilon(1S)} \frac{\sigma^{MC}_{\Upsilon(nS)}}{\sigma^{MC}_{\Upsilon(1S)}}$$

$$m_{\Upsilon(nS)} = m_{\Upsilon(1S)} + m_{\Upsilon(nS),PDG} - m_{\Upsilon(1S),PDG}$$

Monte-Carlo for the tail shapes of the signals, need for realistic simulation

Analysis — Upsilon production

- Υ(nS) raw yields :



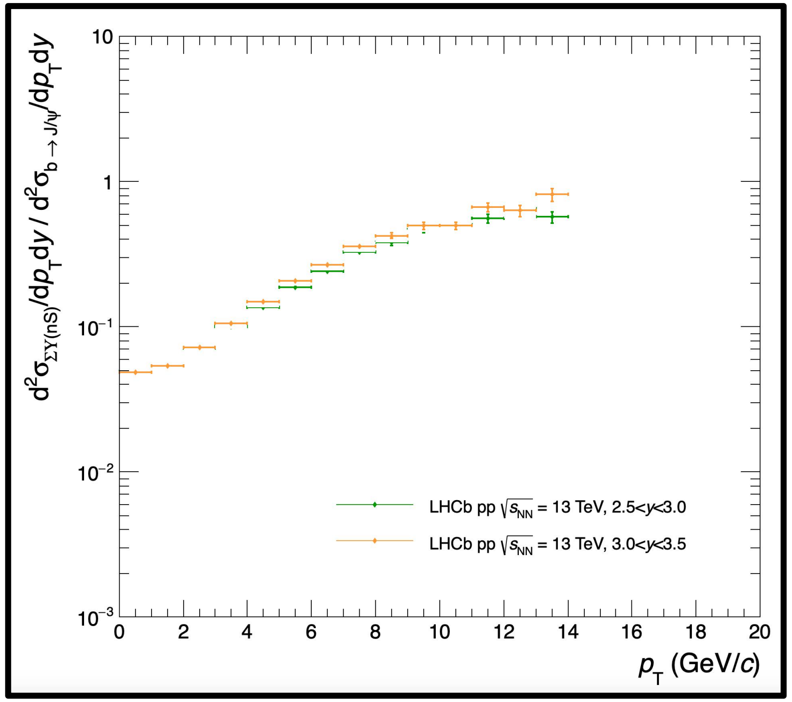
➢ **hierarchy :** $\Upsilon(1S) > \Upsilon(2S) > \Upsilon(3S)$

➢ **next step :** raw yields correction

Analysis — Hidden over Open beauty production

Goal : $\frac{d\sigma_{\Upsilon(nS)}}{dp_T dy} / \frac{d\sigma_{np-J/\psi}}{dp_T dy} \propto \sum_{n=1}^{3} N_{\Upsilon(nS)} \; / \; N_{np-J/\psi}$

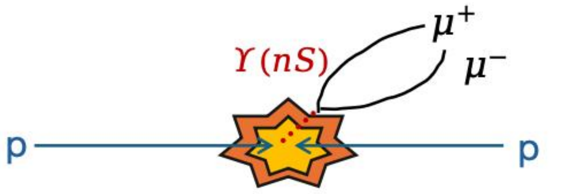
** Branching ratios and Acceptance-Effiency correction hidden in ∝*



Hidden Beauty :

$$\sum_{n=1}^{3} N_{\Upsilon(nS)}$$

Standalone : MCH + MID

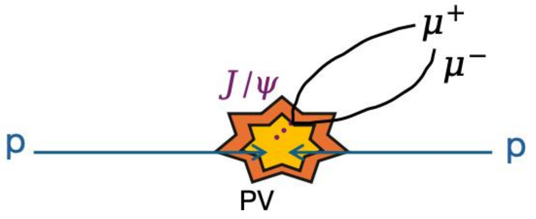


Open Beauty :

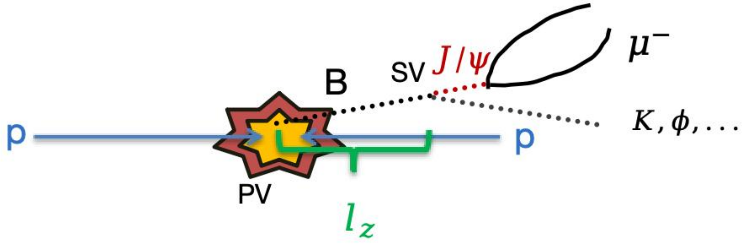
$$N_{np-J/\psi} = f_B N_{incl-J/\psi}$$

$$f_B = \frac{N_{np-J/\psi}}{N_{np-J/\psi} + N_{p-J/\psi}}$$

Standalone : MCH + MID



Global : MFT + MCH + MID

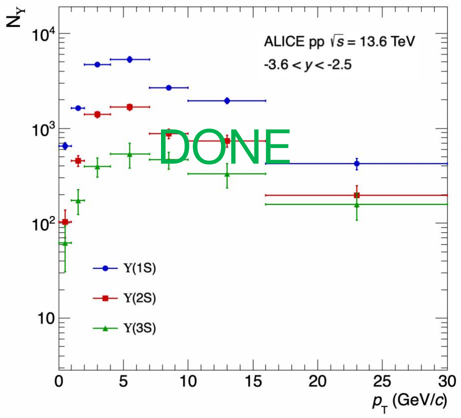


Goal : $\frac{d\sigma_{\Upsilon(nS)}}{dp_T dy} / \frac{d\sigma_{np-J/\psi}}{dp_T dy} \propto \sum_{n=1}^{3} N_{\Upsilon(nS)} \; / \; N_{np-J/\psi}$

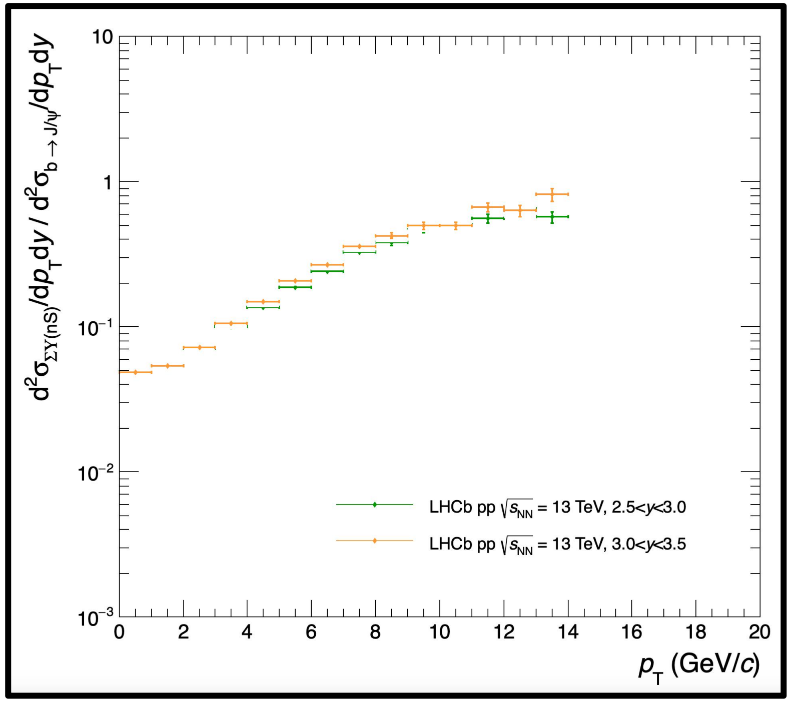
** Branching ratios and Acceptance-Effiency correction hidden in ∝*

Hidden Beauty :

$$\sum_{n=1}^{3} N_{\Upsilon(nS)}$$



DONE



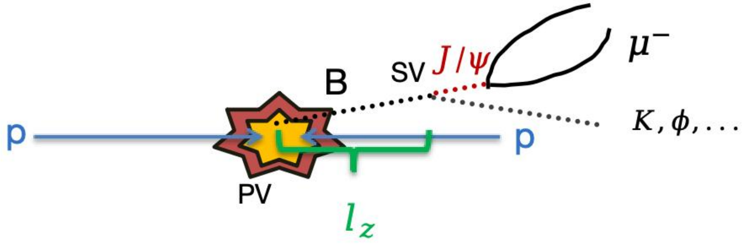
Open Beauty :

$$N_{np-J/\psi} = f_B N_{incl-J/\psi}$$

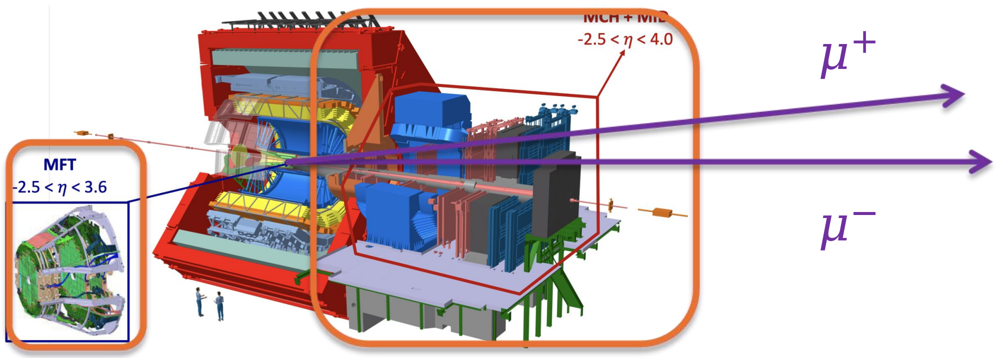
$$f_B = \frac{N_{np-J/\psi}}{N_{np-J/\psi} + N_{p-J/\psi}}$$

DONE (similar procedure)

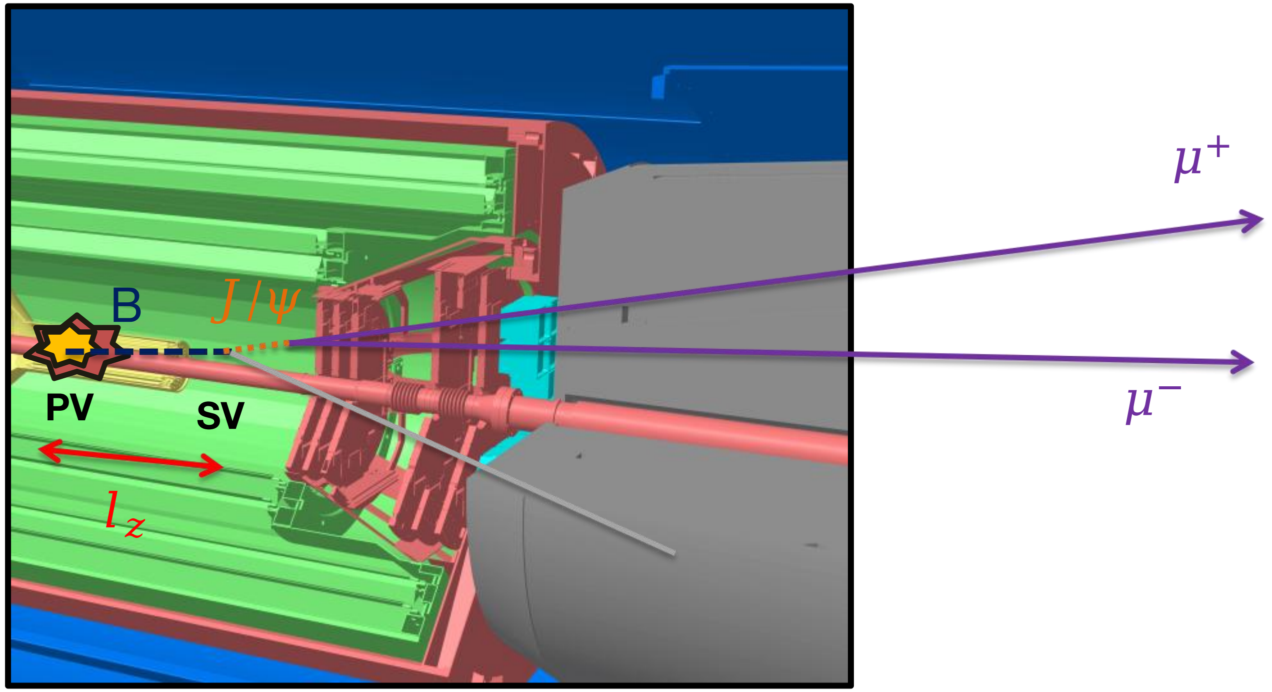
Global : MFT + MCH + MID



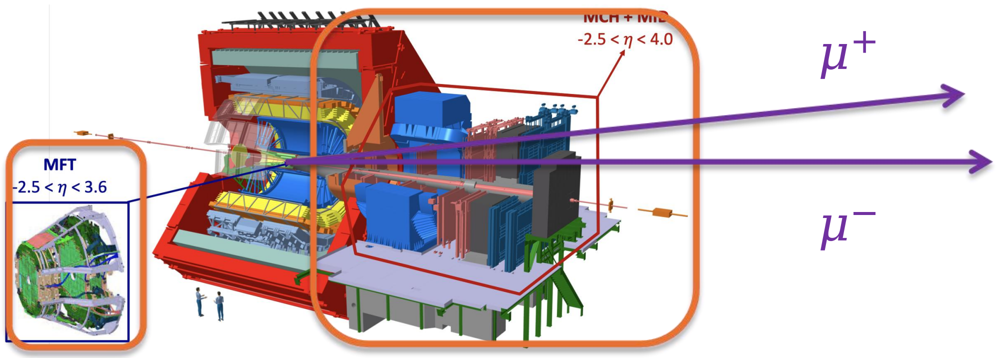
Analysis — Non-prompt/prompt J/Ψ separation



Detectors used: MFT + MCH + MID = Global

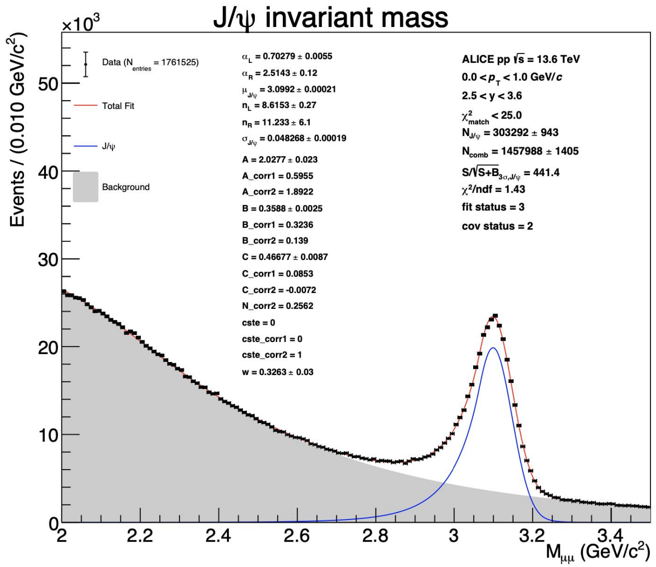


- **Prompt/Non-prompt separation method with MFT** :
  Based on the pseudo-proper decay lenght
  $$l_z = c\tau_z = c\,\frac{(z_{PV}-z_{SV})M_{J/\psi}}{p_z}$$
  → boost in z-axis : $l_z > 3\ mm$ (2.5 < |y|)

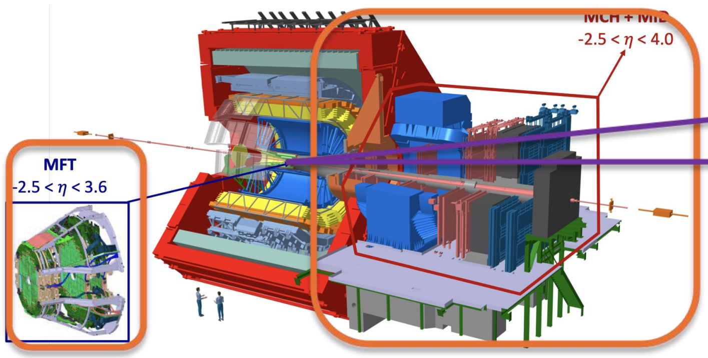


Detectors used: MFT + MCH + MID = Global

- **MFT :**
  - ➢ Allow prompt/non-prompt separation : $\mathrm{M}_{\mu\mu} \rightarrow (\mathrm{M}_{\mu\mu}, l_z)$
  - ➢ l_z alone mix background with signal



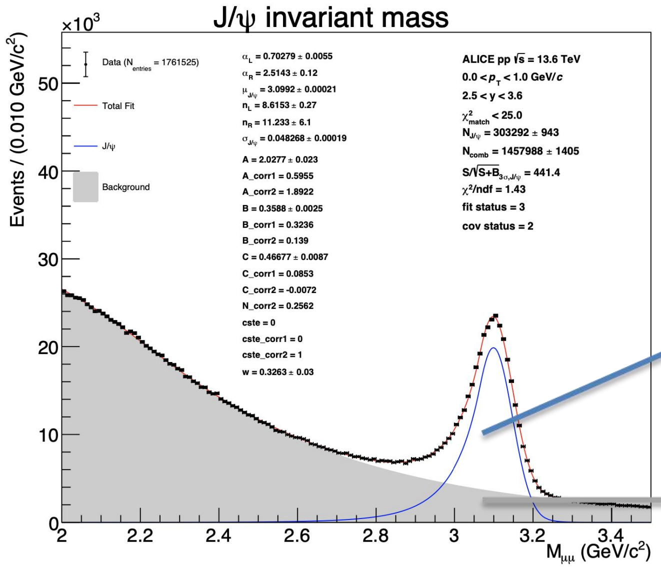
Analysis — Non-prompt J/Ψ production

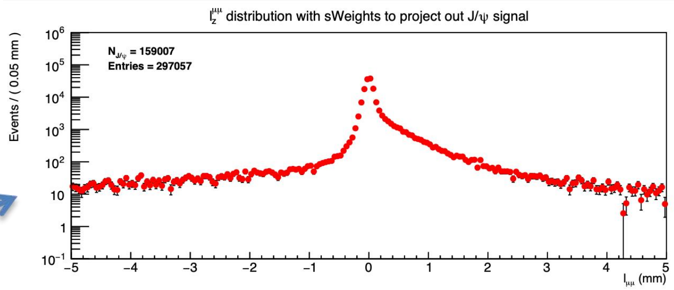


Detectors used: MFT + MCH + MID = Global

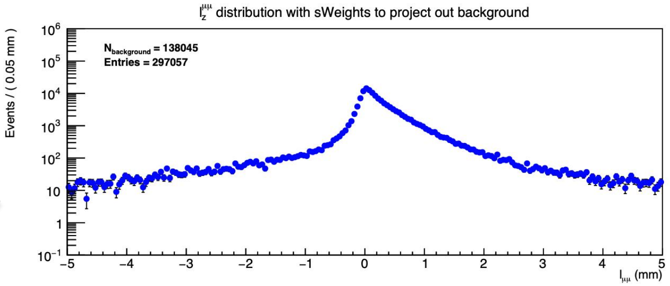
- **MFT :**
  - Allow prompt/non-prompt separation : $M_{\mu\mu} \rightarrow (M_{\mu\mu}, l_z)$
  - l_z alone mix background with signal
  - **SPlot technique :**

“Suppose f(x,y)=g(x)h(y) with 2 species (e.g. N_{sig} & N_{bkg}), sPlot assigns per-event weights derived from a fit in x, such that the weighted sum of events gives direct statistical access to h(y) for each species independently”





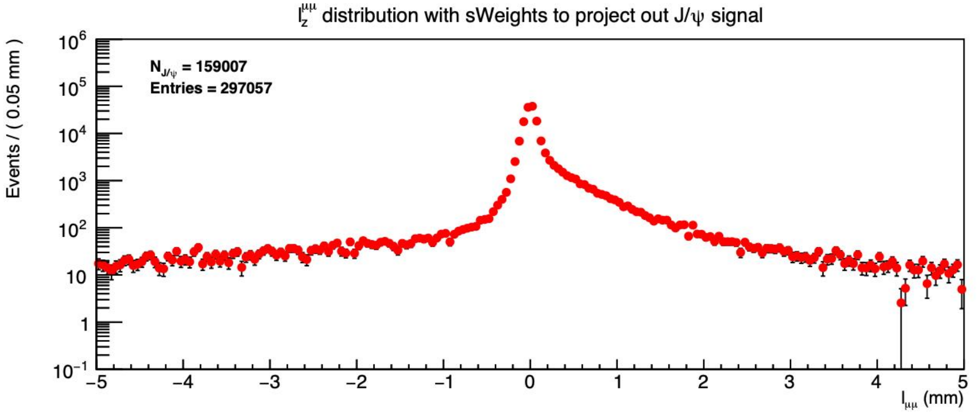
- Isolation of J/ψ_{np} and J/ψ_p

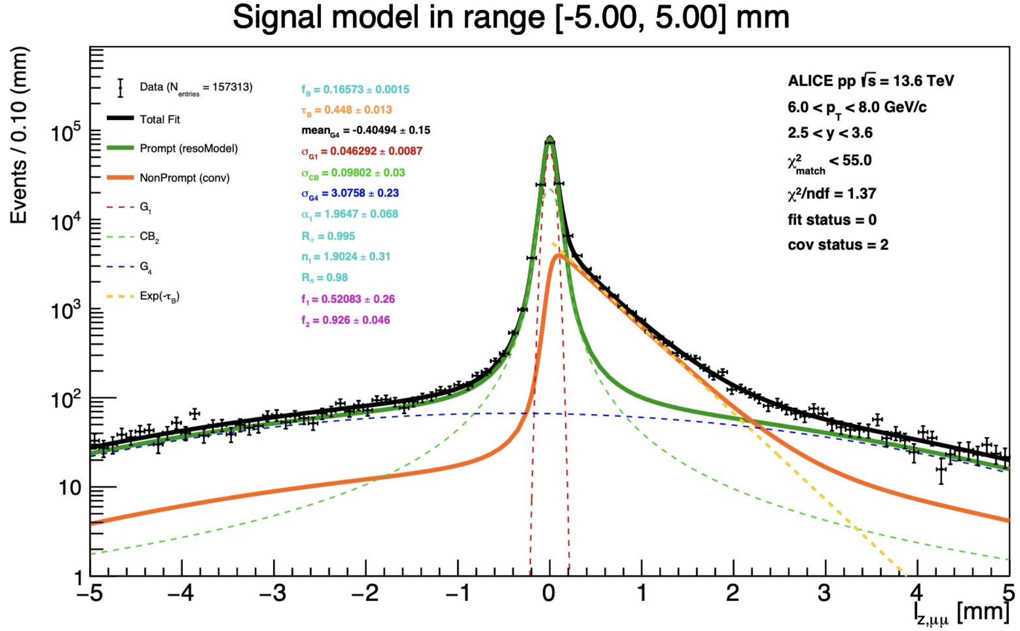


- Isolation of background

Analysis — Non-prompt J/Ψ production

- **Signal l_z :**





prompt : $\propto \delta(0)$
non-prompt : $\propto e^{-\lambda_B}$

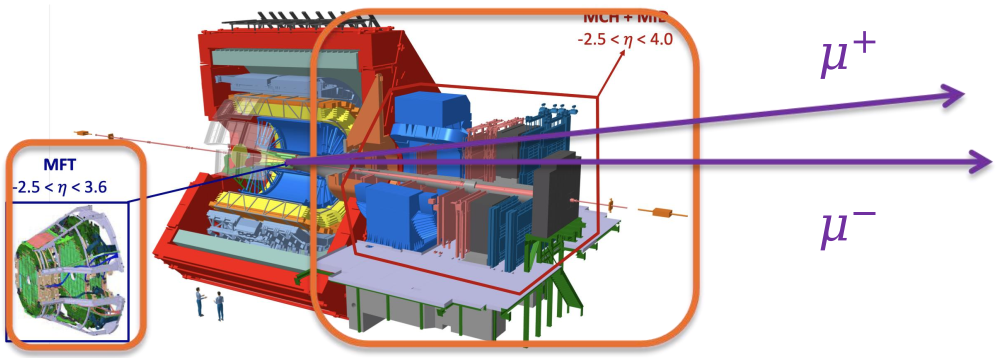
- Signal l_z : $(1 - f_b) R(\vec{\boldsymbol{\theta}}) \otimes \delta(0) \; + \; f_b R(\vec{\boldsymbol{\theta}}) \otimes e^{-\lambda_B}$
- Detectors impact prompt/non-prompt measurement :

Resolution effects : $R(\vec{\boldsymbol{\theta}}) = \; w_1 \mathbb{G}_1 + w_2 CB2 \; + w_3 \mathbb{G}_4$

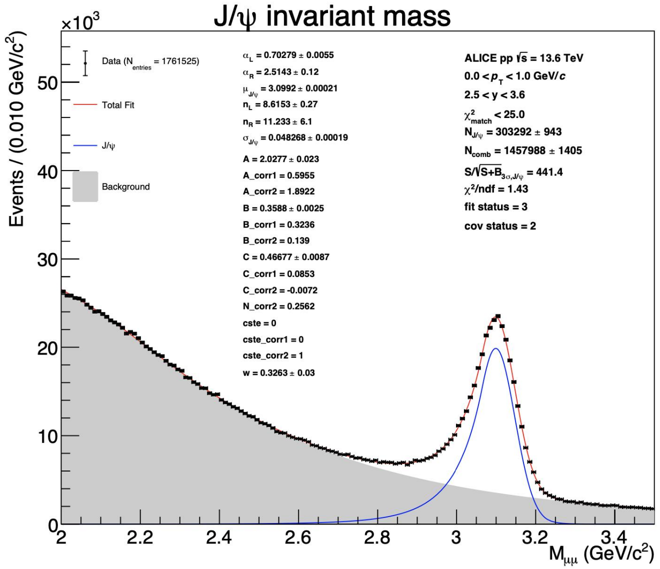
reconstruction errors : $\mathbb{G}_1 + CB2$

wrong PV : $\mathbb{G}_4$

Analysis — Non-prompt J/Ψ production



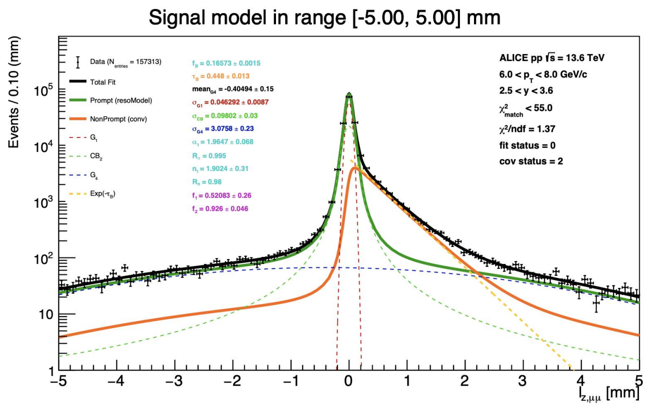
Detectors used: MFT + MCH + MID = Global

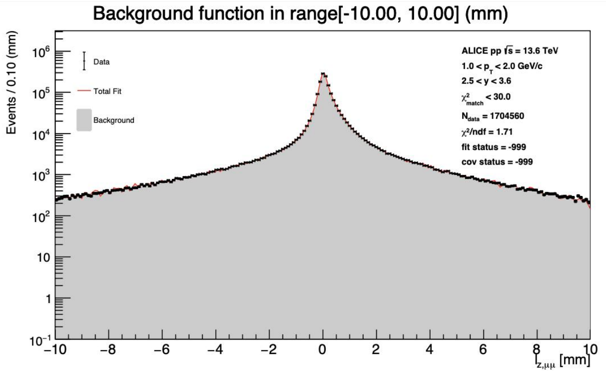


- $(\mathrm{M}_{\mu\mu}, l_z)$ 2D fit :

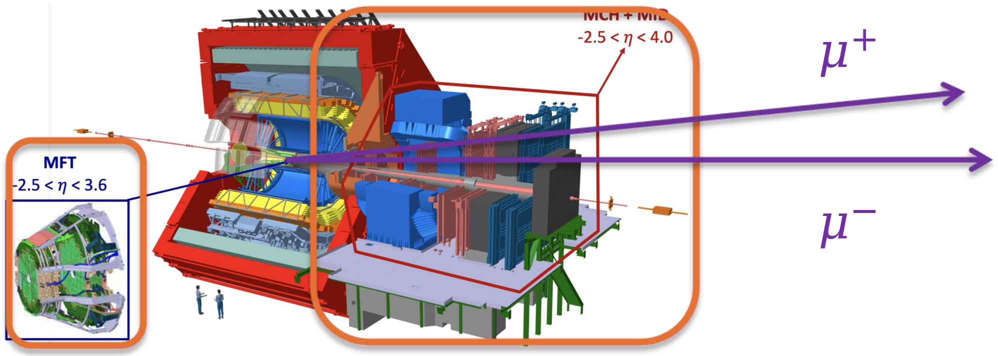
$$\mathrm{F}(\mathrm{l}_{z,\mu\mu}, \mathrm{m}_{\mu\mu}) = \mathrm{N}_{\mathrm{sig}}\mathrm{F}_{\mathrm{sig}}(\mathrm{l}_{z,\mu\mu})\ \mathrm{M}_{\mathrm{sig}}(\mathrm{m}_{\mu\mu}) + \mathrm{N}_{\mathrm{bkg}}\mathrm{F}_{\mathrm{bkg}}(\mathrm{l}_{z,\mu\mu})\ \mathrm{M}_{\mathrm{bkg}}(\mathrm{m}_{\mu\mu})$$

- Free parameters (default) : f_b, $\mathrm{N}_{\mathrm{sig}}$, $\mathrm{N}_{\mathrm{bkg}}$

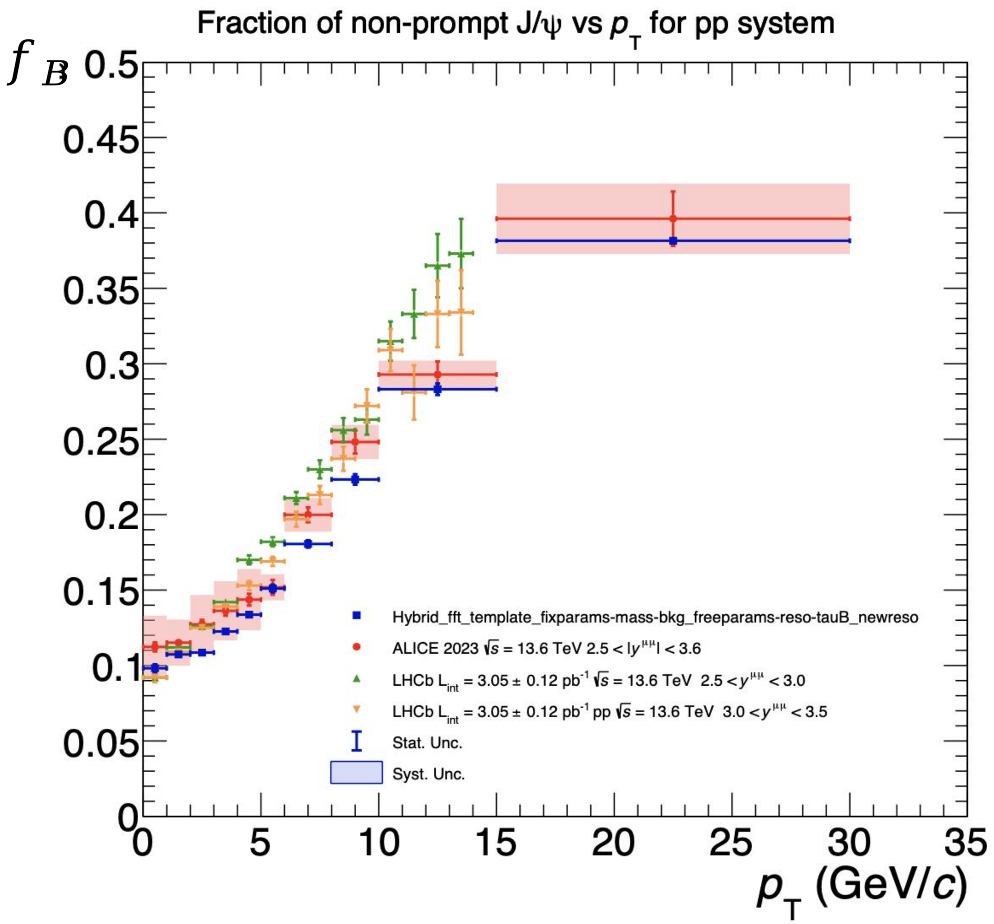




Analysis — Non-prompt J/Ψ production



Detectors used: MFT + MCH + MID = Global



- $(M_{\mu\mu}, l_z)$ 2D fit :

$$F(l_{z,\mu\mu}, m_{\mu\mu}) = N_{sig} F_{sig}(l_{z,\mu\mu})\, M_{sig}(m_{\mu\mu}) + N_{bkg} F_{bkg}(l_{z,\mu\mu})\, M_{bkg}(m_{\mu\mu})$$

- Free parameters (default) : f_b, N_{sig}, N_{bkg}

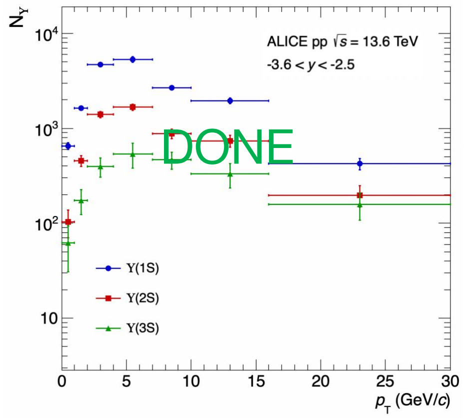
Analysis — Hidden over Open beauty production

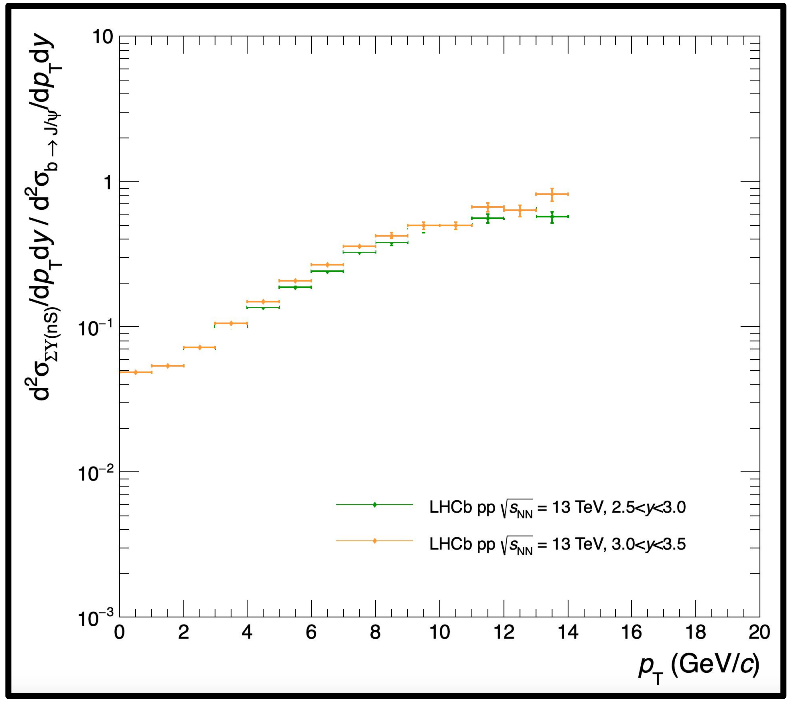
Goal : $\frac{d\sigma_{\Upsilon(nS)}}{dp_T dy} / \frac{d\sigma_{np-J/\psi}}{dp_T dy} \propto \sum_{n=1}^{3} N_{\Upsilon(nS)} \; / \; N_{np-J/\psi}$

** Branching ratios and Acceptance-Effiency correction hidden in ∝*

Hidden Beauty :

$$\sum_{n=1}^{3} N_{\Upsilon(nS)}$$





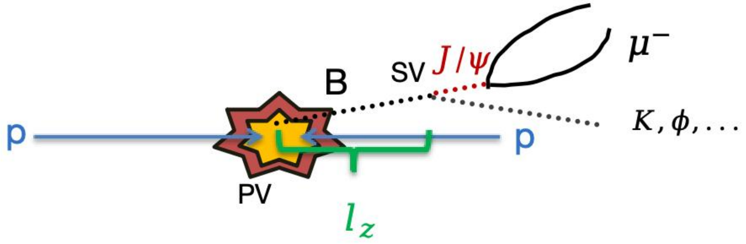
Open Beauty :

$$N_{np-J/\psi} = f_B N_{incl-J/\psi}$$

$$f_B = \frac{N_{np-J/\psi}}{N_{np-J/\psi} + N_{p-J/\psi}}$$

DONE

Global : MFT + MCH + MID



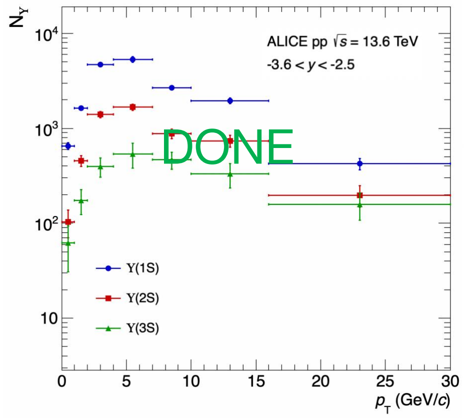
Analysis — Hidden over Open beauty production

Goal : $\frac{d\sigma_{\Upsilon(nS)}}{dp_T dy} / \frac{d\sigma_{np-J/\psi}}{dp_T dy} \propto \sum_{n=1}^{3} N_{\Upsilon(nS)} \; / \; N_{np-J/\psi}$

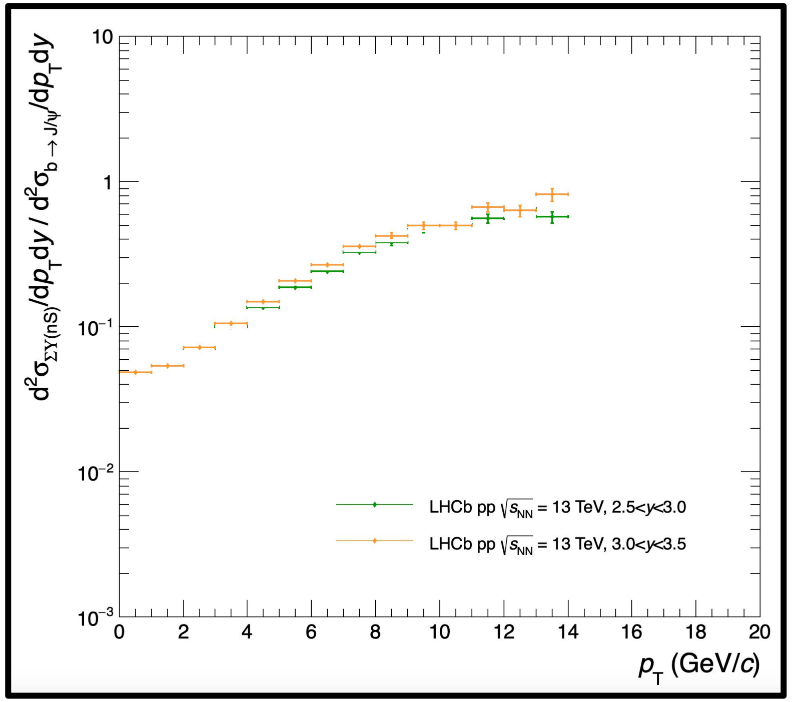
** Branching ratios and Acceptance-Effiency correction hidden in ∝*

Hidden Beauty :

$$\sum_{n=1}^{3} N_{\Upsilon(nS)}$$



DONE



Open Beauty :

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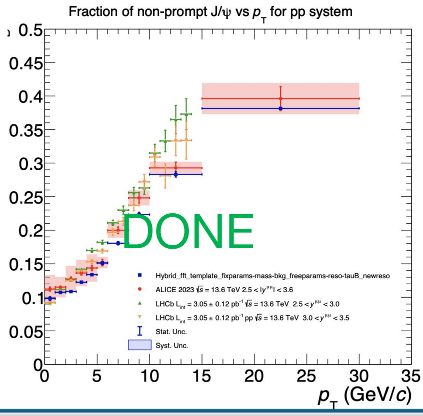
$$f_B = \frac{N_{np-J/\psi}}{N_{np-J/\psi} + N_{p-J/\psi}}$$

DONE



DONE

Conclusion & outlook

- **Acceptance-Effiencency :** Correction accounting for the probability that a particle produced in the collision is actually reconstructed in the detector. Obtained from Monte-Carlo simulations.
- **Systematics :** How does the extracted parameters response to variation in : models, cuts, ...
- **Use of MFT to extract Upsilon :**

  - Remove background contribution from Heavy Flavour → increase significance

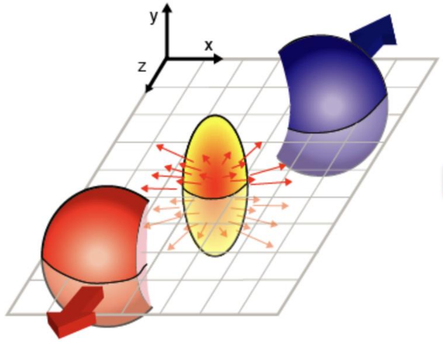
  - ... but, sensitive to MCH-MFT matching effiency & purety

Thank you for your attention!

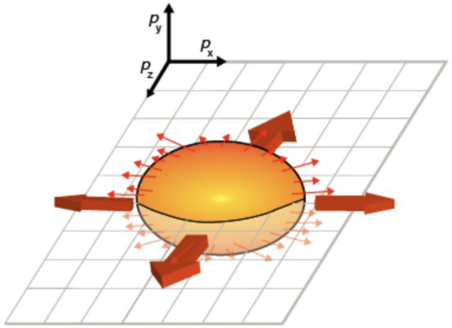
BACKUP

Quark Gluon Plasma - A perfect fluid

Initial State | **Final State**



[alice.cern]

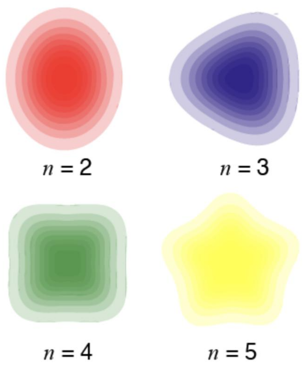


[alice.cern]

- Anisotropy of particle momentum distribution

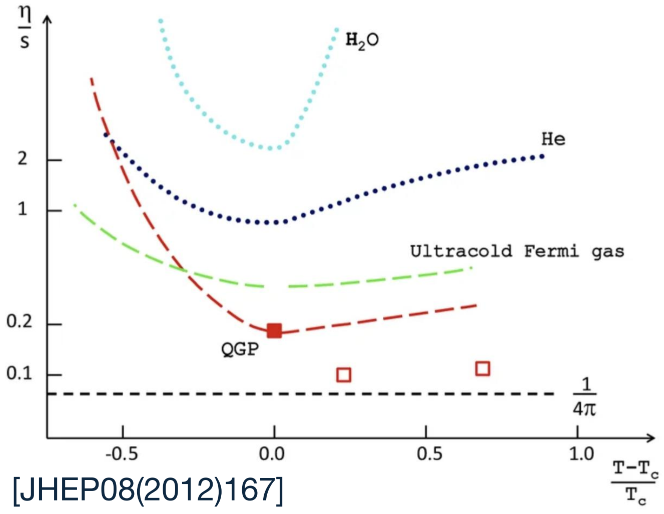
$$\frac{dN}{d\varphi} = \frac{1}{2\pi}\left(1 + \sum_{n=1}^{\infty} 2v_n \cos[n(\varphi - \psi_n)]\right)$$

v_2 : elliptic flow (collective phenoma)



[alice.cern]

- (shear) viscosity



[JHEP08(2012)167]

$\frac{\eta}{s} \approx \langle p \rangle \lambda$, λ : mean free path

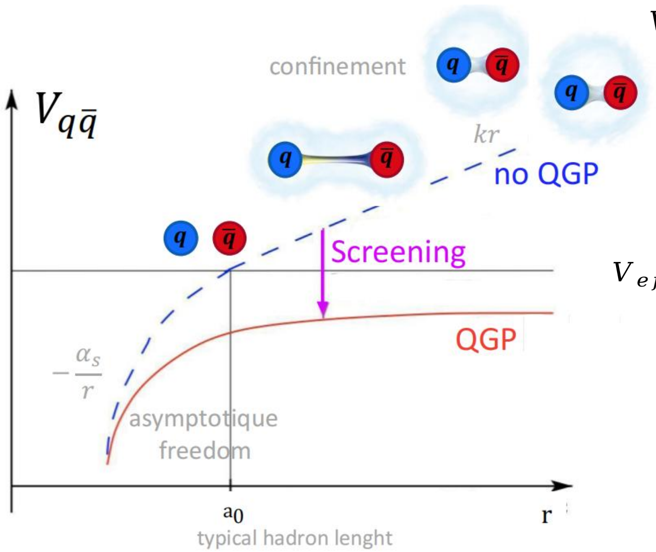
$\frac{\eta_{QGP}}{s} \approx 0.08 - 0.2$ $\longleftrightarrow$ perfect fluid (macro property)

$\longleftrightarrow$ strongly coupled fluid (micro property)

Quarkonia in the hot medium

- **Static approach :**

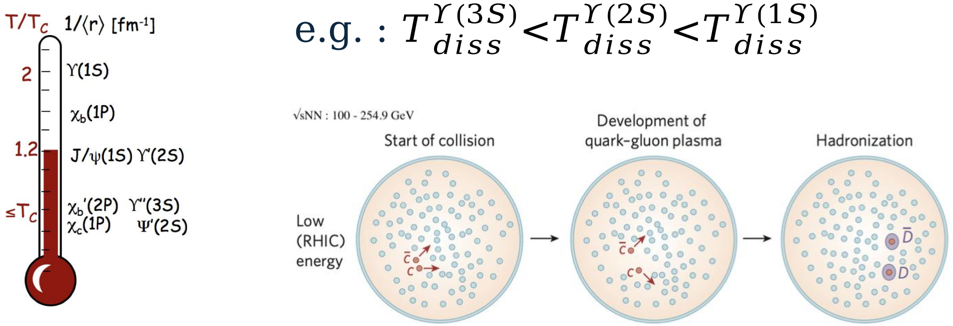
$$V(r,T) = Kr - \frac{4}{3}\frac{\alpha_s}{r} + \text{spin-spin}$$



$$V_{eff}(r,T) \longrightarrow -\frac{4}{3}\frac{\alpha_s}{r}e^{-rm_D}$$

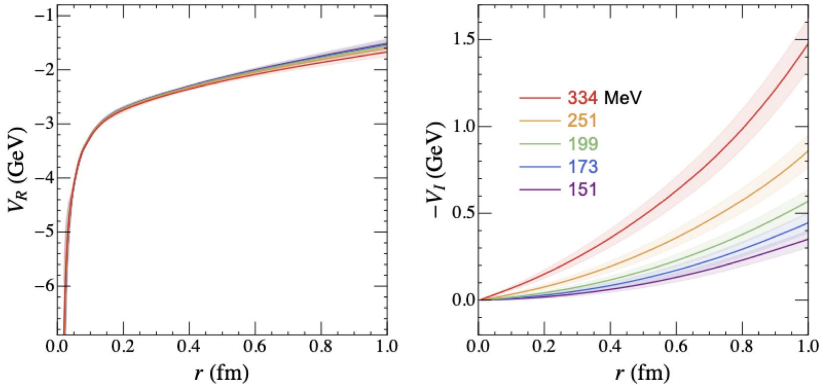
- **Sequencial Suppression :**

e.g. : $T_{diss}^{\Upsilon(3S)} < T_{diss}^{\Upsilon(2S)} < T_{diss}^{\Upsilon(1S)}$



- **Dynamic approach :**

$$V(r,T) = \text{ReV(r,T)} + \text{iImV(r,T)}$$



S. Shi, K. Zhou, JZ, S. Mukherjee, and P. Zhuang. PRD 105 (2022) 1, 1.

➢ no/a small color screening effect and a large imaginary part

- **Feature :** widths of the bound state peaks at finite T

$$\Gamma_n = 2\langle ImV(r,T)\rangle_n$$

e.g. : $\Gamma_1^{\Upsilon}(T) < \Gamma_2^{\Upsilon}(T) < \Gamma_3^{\Upsilon}(T)$

R. Katz, S. Delorme, P.B. Gossiaux [arXiv:2205.05154v2]

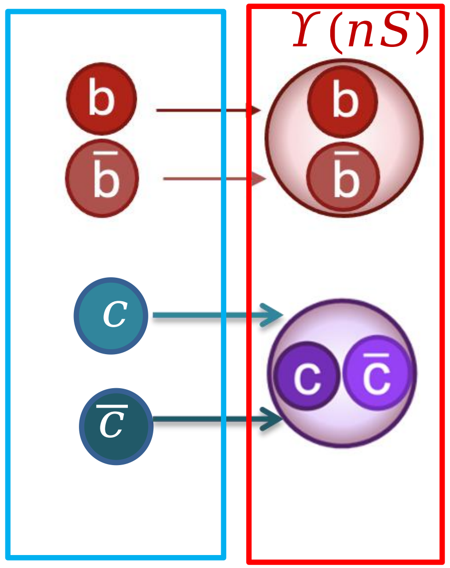
Quarkonia production : CNM effects

- **CNM effects on quarkonia production :**

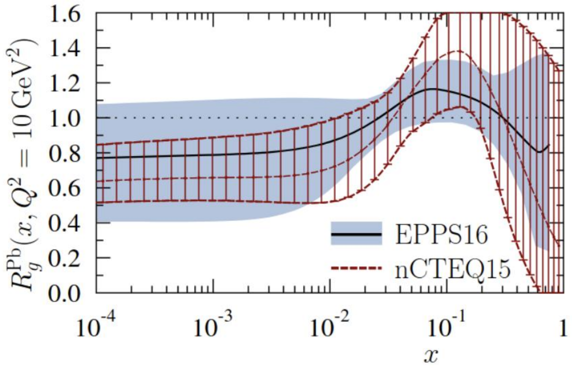
Initial state : shadowing due to modification of the nPDFs
(can reduce the production of quarkonia without QGP) [Eur. Phys. J. C (2017) 77,163]

Initial - Final state : Coherent energy loss [JHEP10(2014)073]

Final state : Interaction with comoving particle [JHEP10(2018)094]

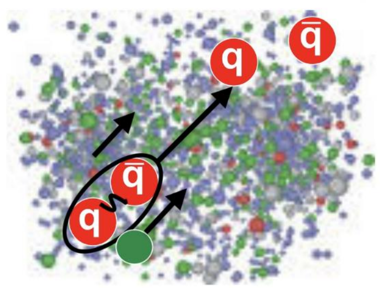


nuclear PDF modification



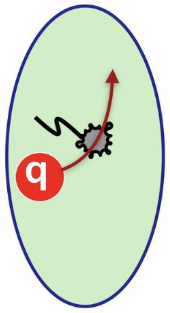
[Eur. Phys. J. C (2017) 77,163]

Comover interaction



[JHEP10(2018)094]

Coherent energy loss



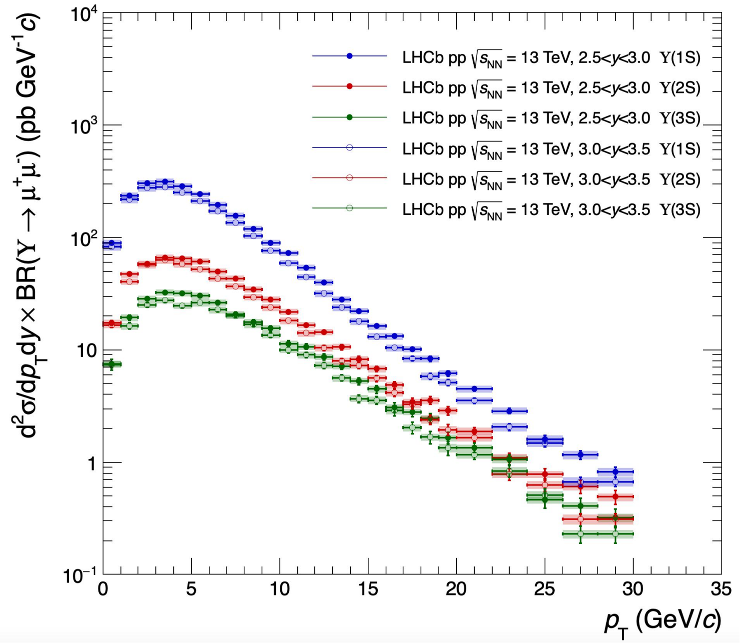
[JHEP10(2014)073]

→ picture from M. Coquet [QuarkoniaAsTools2025]

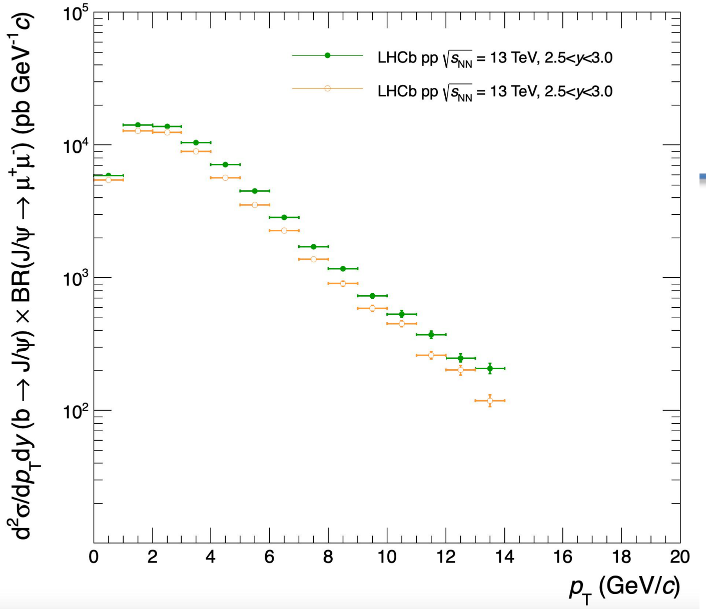
Thesis goal

- Goal: Hidden / Open beauty ratio → $\Upsilon(nS)$ over non-prompt J/ψ
- Benchmarked against **LHCb** forward J/ψ measurements.

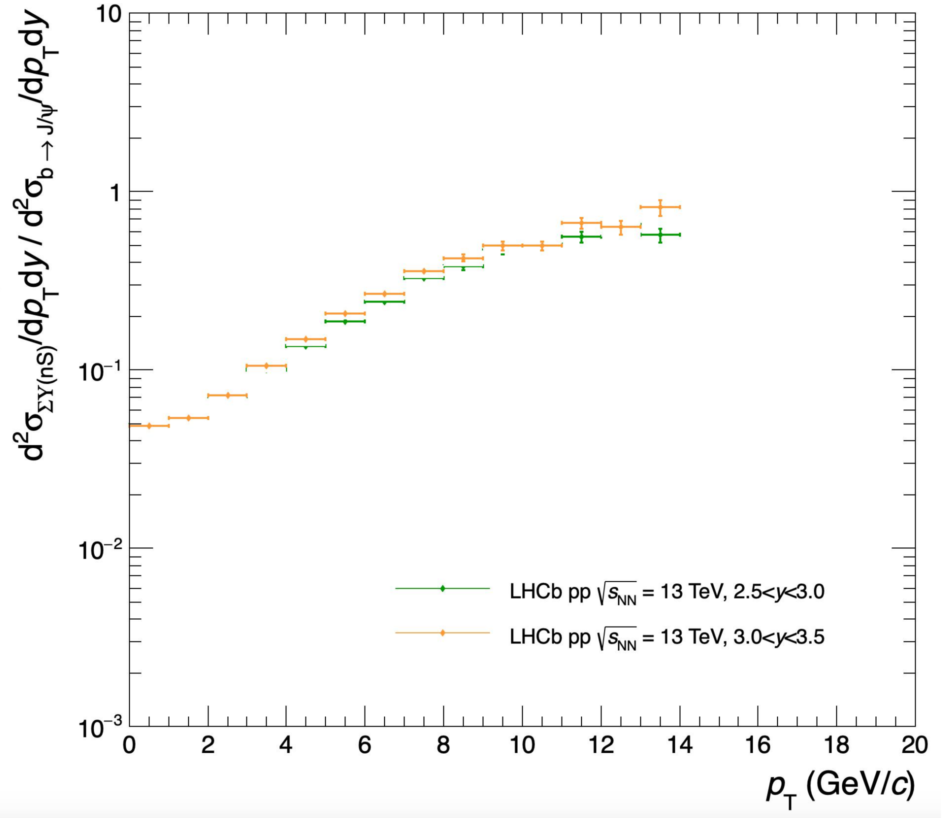
Hidden beauty production



Open beauty production

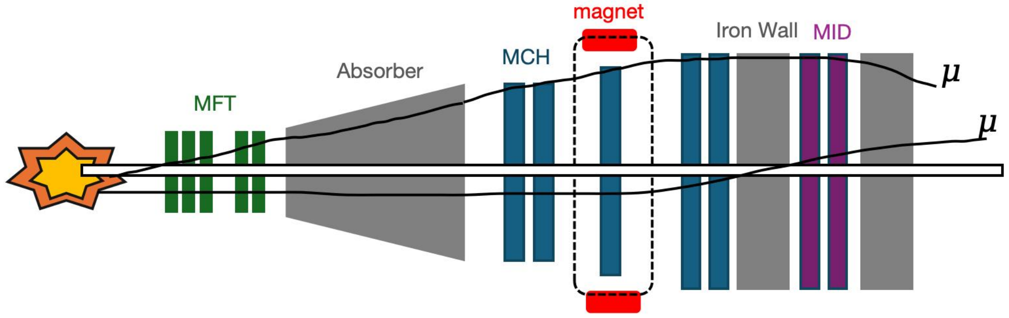


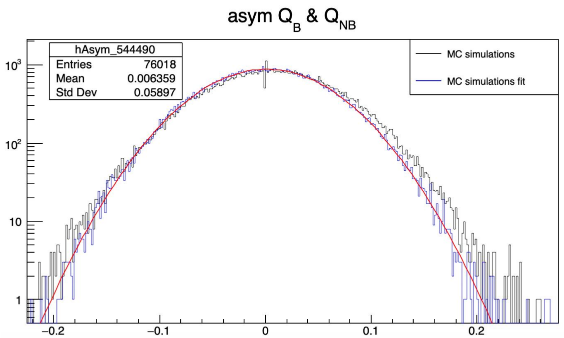
Hidden / Open beauty ratio



→ pp as baseline for Pb-Pb measurement

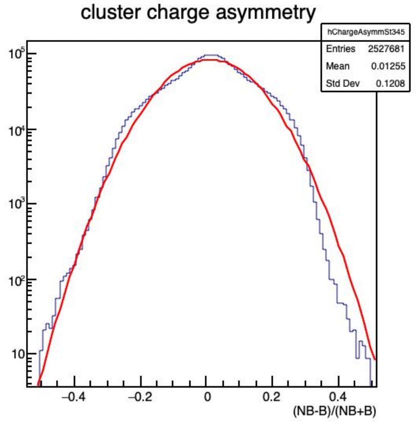
Muon Spectrometer - Monte-Carlo simulations





$$\frac{Q_{tot}^{NB} - Q_{tot}^{B}}{Q_{tot}^{B} + Q_{tot}^{NB}}$$

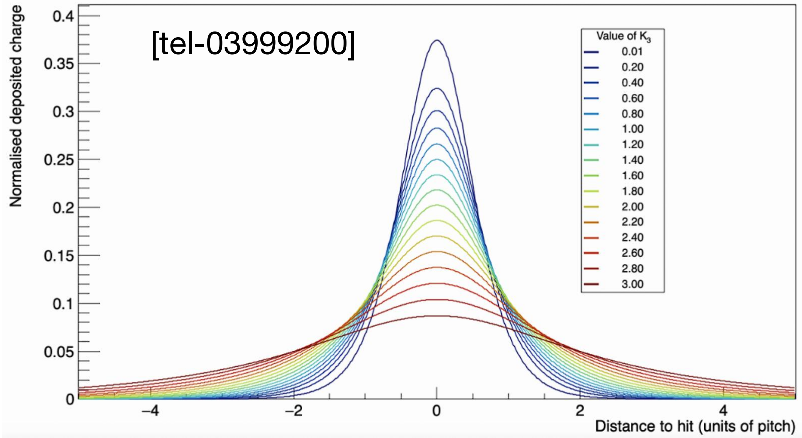
Run 3



Asymmetry & Noise in MC simulations (for all chambers) :

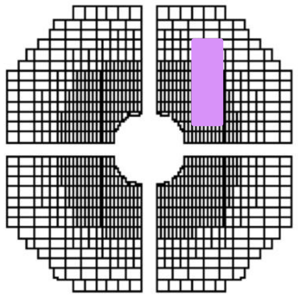
- $\mu^{\pm}$ leave a Q_{tot} on both cathode
- **Asymmetry :**
  $Q_{tot}^{B} = Q_{tot}e^{Y}$, $Q_{tot}^{NB} = Q_{tot}e^{-Y}$ with $Y \rightarrow \mathcal{N}(0\,,\ 0.11/2\,)$
- **Noise :**
  $$Q_{pad}^{B} = f_{pad}Q_{tot}^{B} + X \ \text{ with } X \rightarrow \mathcal{N}\left(0\,,\ 0.5 * \sqrt{round\left(\left(\frac{ADC}{13}\right)^{\frac{2}{3}} + 14\right)}\right)$$
- **Mathieson-Gatti witdh (2D) :**
  width parametrization $(K_{3x}, K_{3y}) = (0.3,\ 0.3)$

Mathieson-Gatti distribution

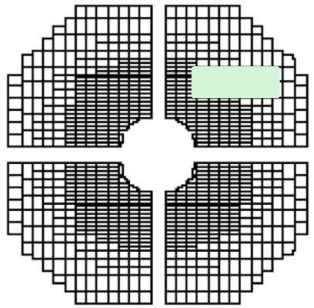


Muon Spectrometer - Strategy

Non-Bending (NB)



Bending (B)

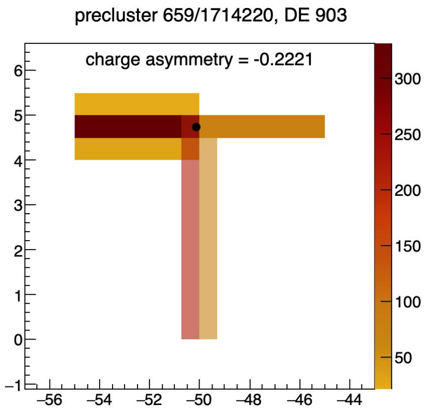


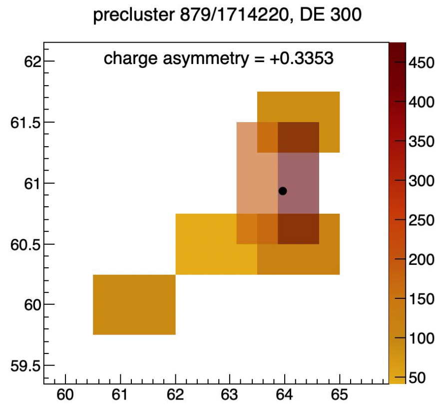
- **Tuning detector response & noise in MC simulations from data :**
  - ➢ Charge resolution (i.e noise)
  - ➢ Bending and Non-Bending charge asymmetry

Toy MC : 1. more flexible for adjusting the noise and asymmetry
2. use real cluster (position, charge) as input

I - Compare MC and toy-MC (closure test)
II - Compare Run 3 and toy-MC

- **Run 3 preclusters :**





minimization $\chi^2 : \sum_{i \in B,\,NB} \frac{[ADC_i - \lambda_i]^2}{[\sqrt{ADC_i}]^2} = \sum_{i \in B,\,NB} \frac{[residual_i]^2}{[\sigma_i]^2}$

Conjecture :

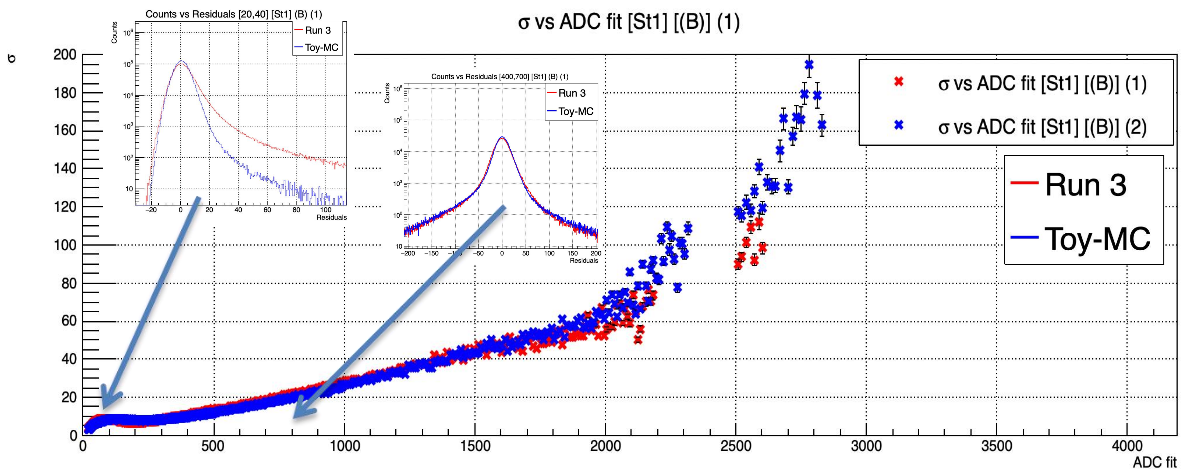
$$\sigma(Q)^{biaised}_{toyMC} \sim \sigma(Q)^{biaised}_{MC-DATA} \Leftrightarrow \sigma(Q)^{true}_{toyMC} \sim \sigma(Q)^{true}_{MC-DATA}$$

with $\sigma(Q)$ extracted from the residual(Q) distribution

Muon Spectrometer - Outlook

➢ First results (fall within 10-20%):

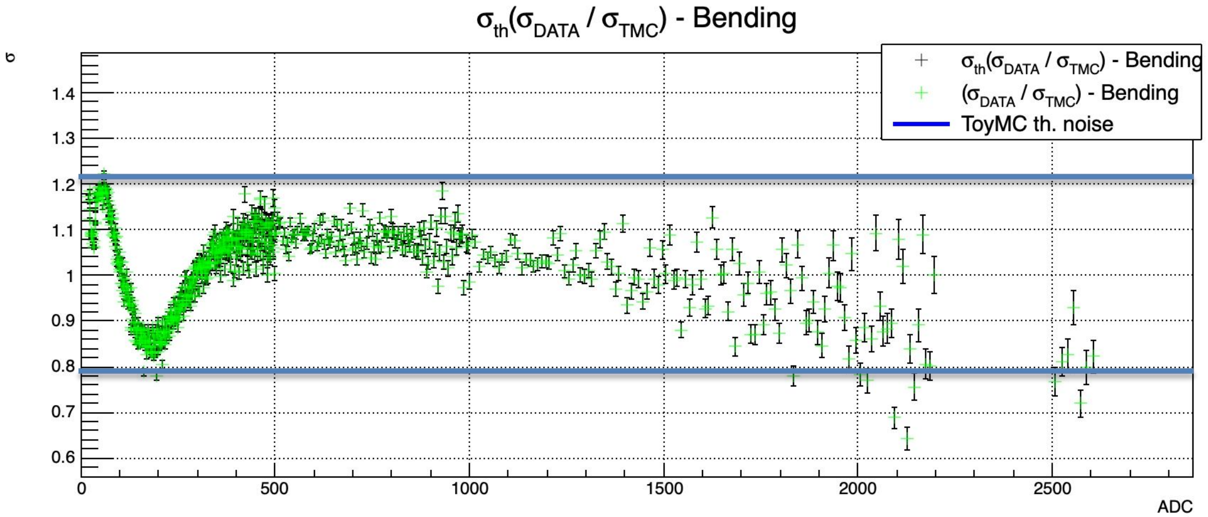
- St. 1 (B) : $1.3ADC^{1/2} - 0.085ADC^{2/2} + 0.004ADC^{3/2}$
- St. 1 (NB) : $1.3ADC^{1/2} - 0.095ADC^{2/2} + 0.005ADC^{3/2}$
- St. 2 (B) : $0.79ADC^{1/2} + 0.0058ADC^{2/2} + 0.0067ADC^{3/2}$
- St. 2 (NB) : $0.82ADC^{1/2} + 0.012ADC^{2/2} + 0.0071ADC^{3/2}$
- St. 345 (B) : $0.77ADC^{1/2} - 0.034ADC^{2/2} + 0.004ADC^{3/2}$
- St. 345 (NB) : $0.93ADC^{1/2} - 0.068ADC^{2/2} + 0.006ADC^{3/2}$



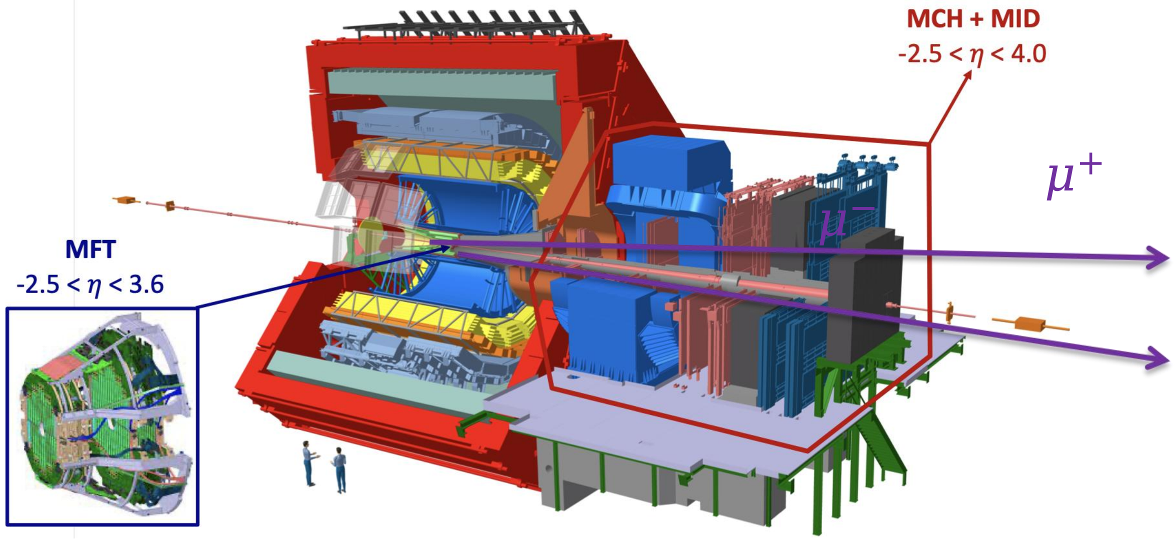
➢ Open studies :

→ K_3
→ fraction of the total charge seen by the pads (f_{pad})

10-20%

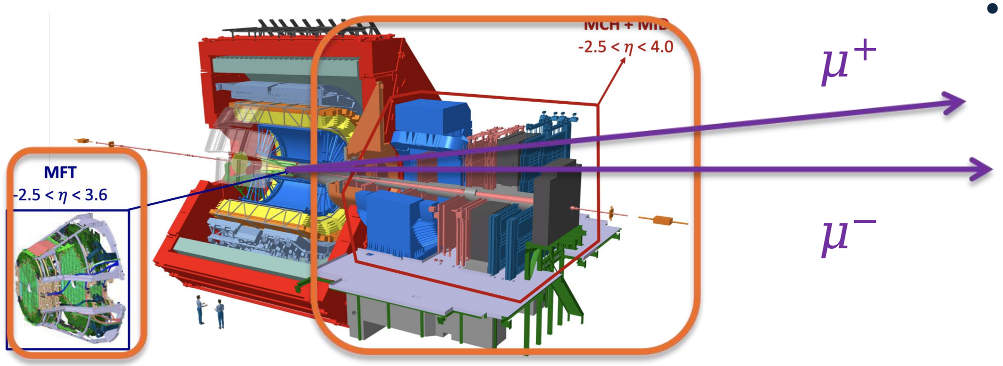


Analysis — Data selection



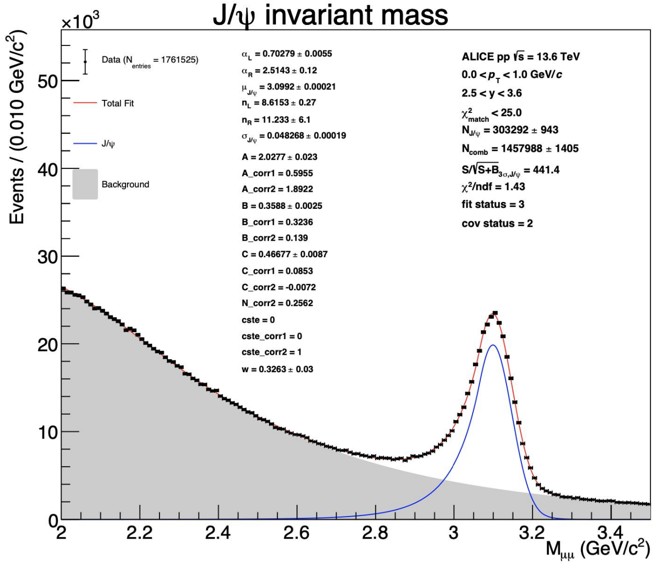
- **Dataset :**
  - 2024 pp at $\sqrt{s}$ = 13.6 TeV
- **Events selection :**
  - $z_{vtx} \in \ ]-10\ cm,\ +10\ cm\ [$ (within central barrel)
  - tracks associated (in time) with a vertex
- **Muon selection :**
  - $-3.6 < \eta_{\mu} < -2.5$ (acceptance)
  - $p_{T,\mu} > 0.7\ GeV/c$
- **DiMuon selection :**
  - $2.5 < y_{\mu\mu} < 3.6$
- **Global only :**
  - selection on matching cut between MCH - MFT : χ^2_{MFTMCH}

Analysis — Non-prompt J/Ψ production



Detectors used: MFT + MCH + MID = Global

- **Invariant mass fit** $M_{\mu\mu} = \sqrt{2p_- p_+(1 - cos(\theta_{-+}))}$:

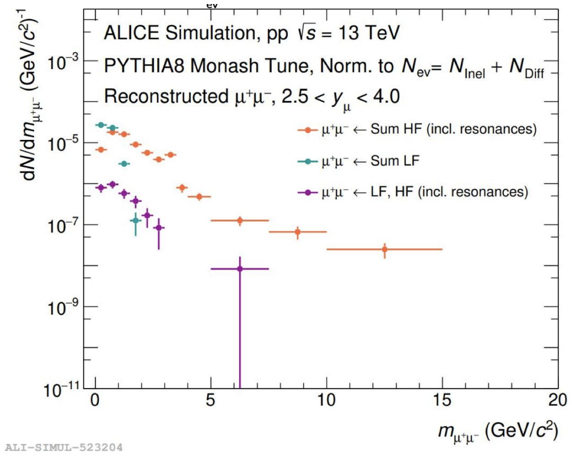


- **Signal :** *Double-Crystal ball, ...*

$$J/\psi = f_B J/\psi_{np} + (1 - f_B) J/\psi_p$$

f_B cannot be determined with only $M_{\mu\mu}$

- **Background :** *Variable Width Gaussian, ...*



$\pi^\pm$
$K^\pm$
...

- **Double-Crystal Ball :**

$$f(x;\alpha,n,\bar{x},\sigma) = N \cdot \begin{cases} \exp(-\frac{(x-\bar{x})^2}{2\sigma^2}), & \text{for } \frac{x-\bar{x}}{\sigma} > -\alpha \\ A \cdot (B - \frac{x-\bar{x}}{\sigma})^{-n}, & \text{for } \frac{x-\bar{x}}{\sigma} \leqslant -\alpha \end{cases},$$

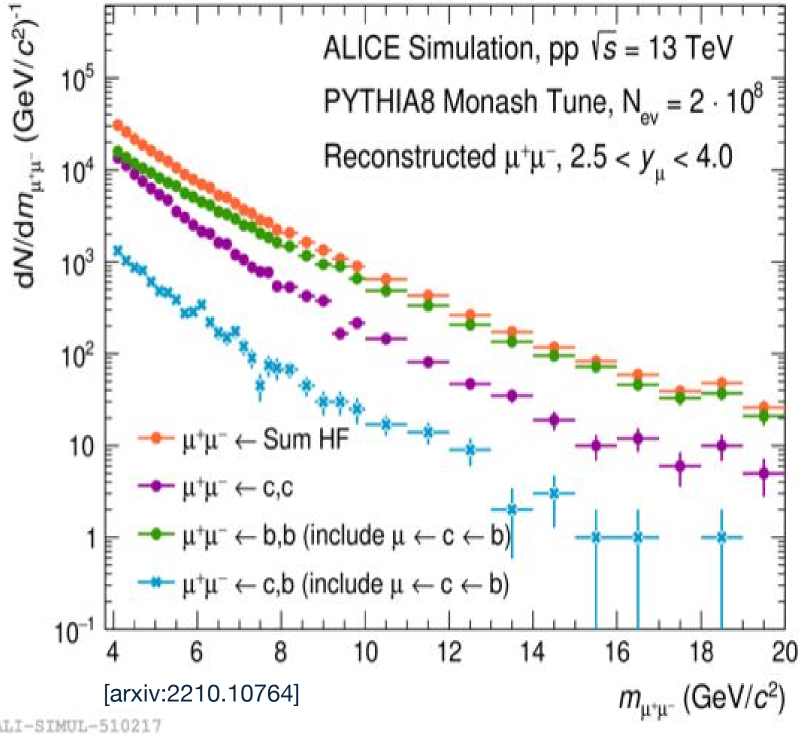
- **Variable Width Gaussian :**

$$f(m) = \exp\left(-\frac{(m-A)^2}{2\sigma(m)^2}\right) + \text{cste}, \quad \sigma(m) = B + C\frac{m-A}{A}$$

[arxiv:2210.10764]

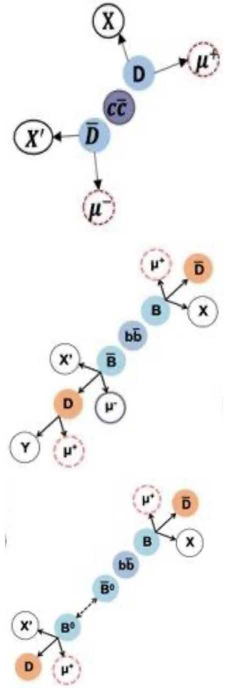
Analysis — Upsilon production

- one objective of **Global** selection → increase signal region of $\Upsilon(nS)$

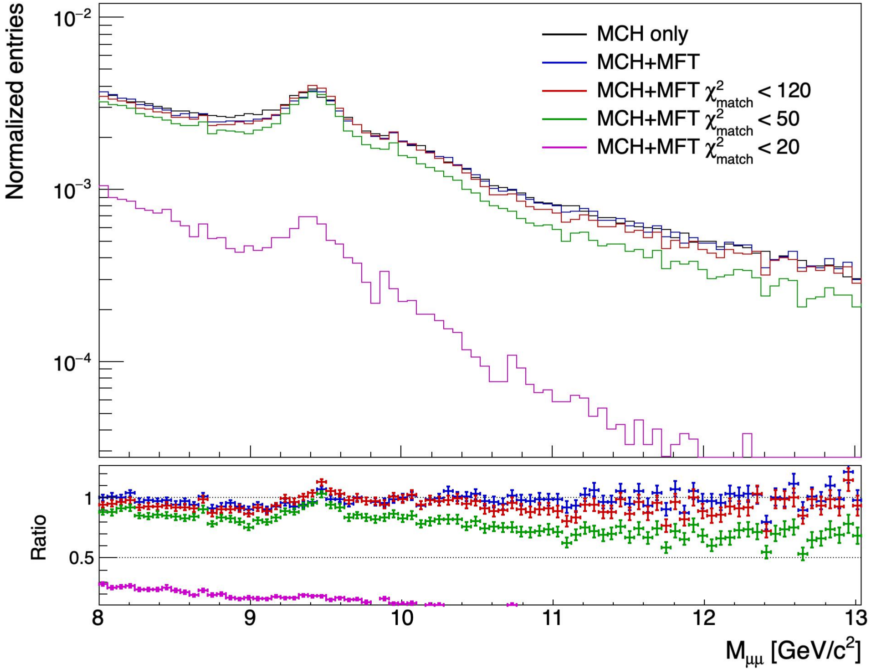


[arxiv:2210.10764]

ALI-SIMUL-510217

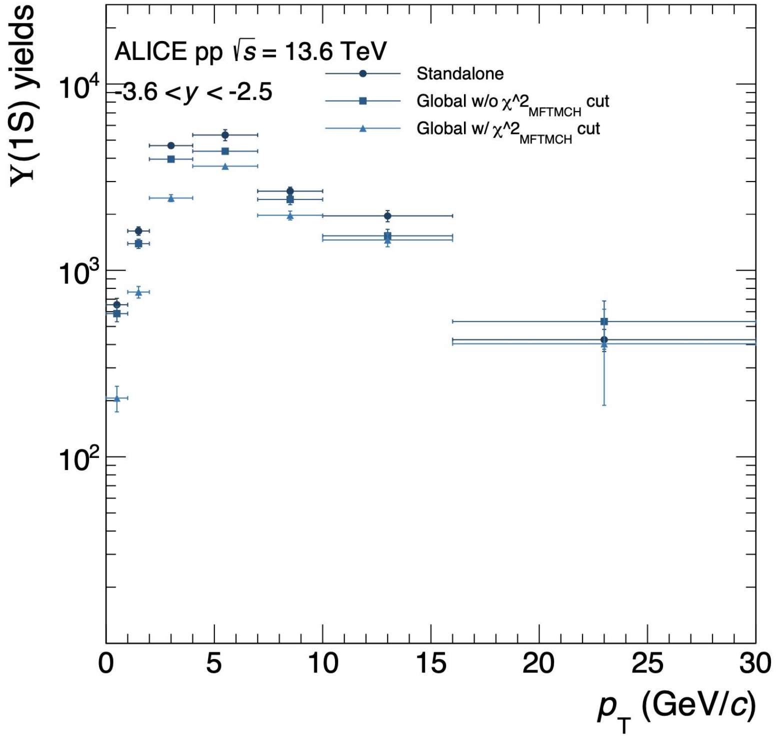


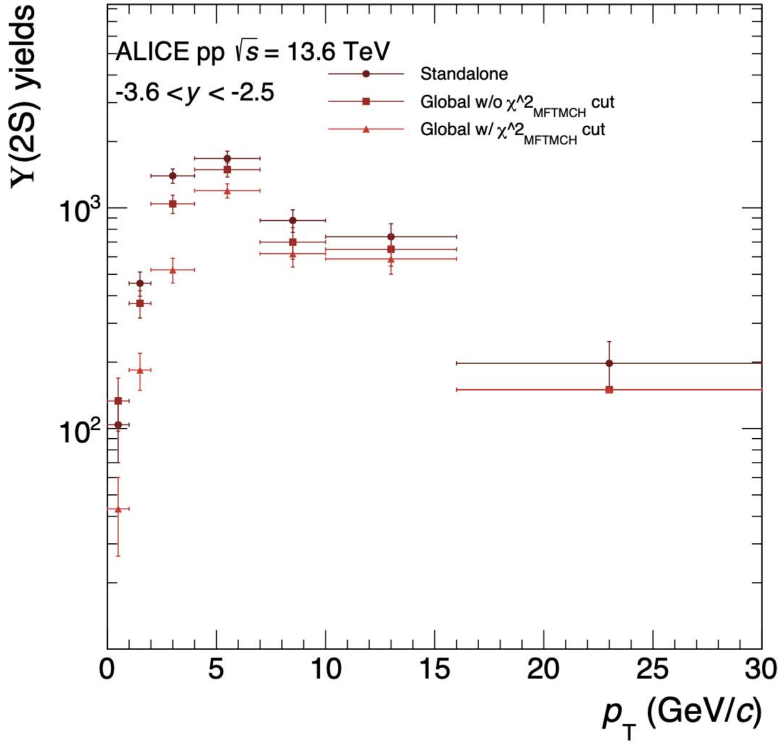
$\Upsilon(nS)$ invariant mass
integrated over p_T and -3.6 < y < -2.5

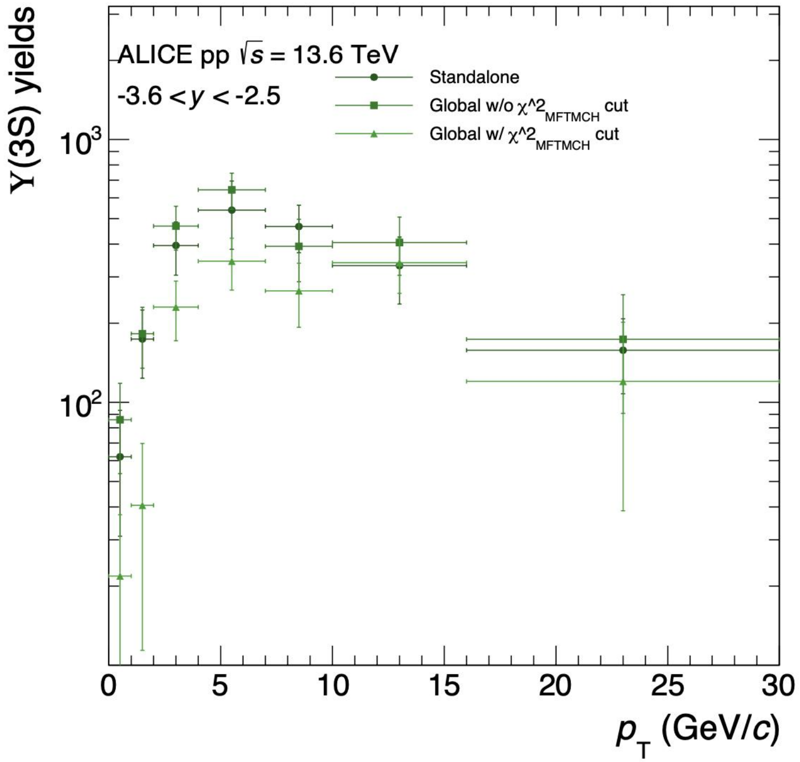


Analysis — Upsilon production

- **Υ(nS) yields (without detectors Acceptance-Efficiency correction) :**



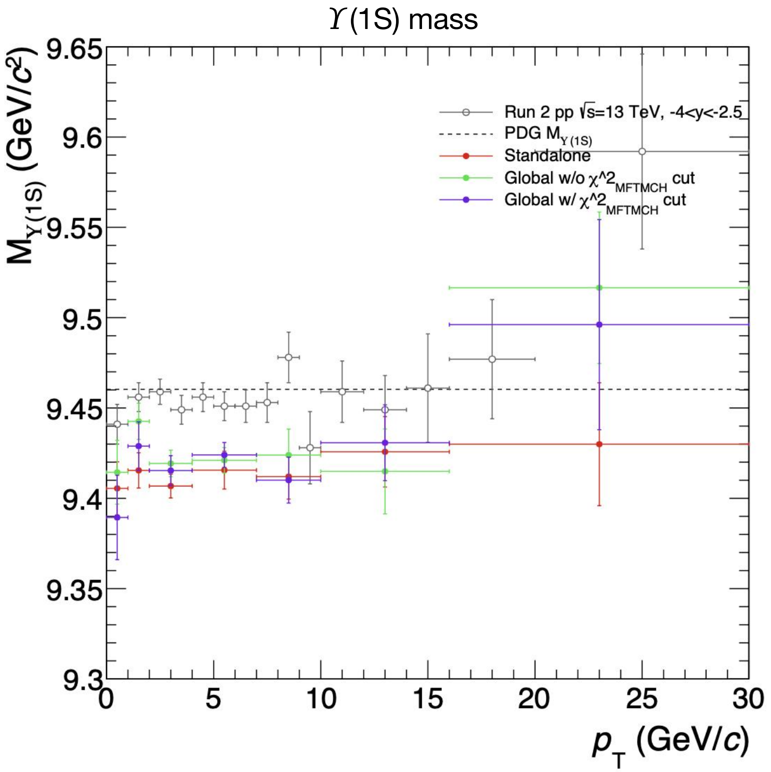


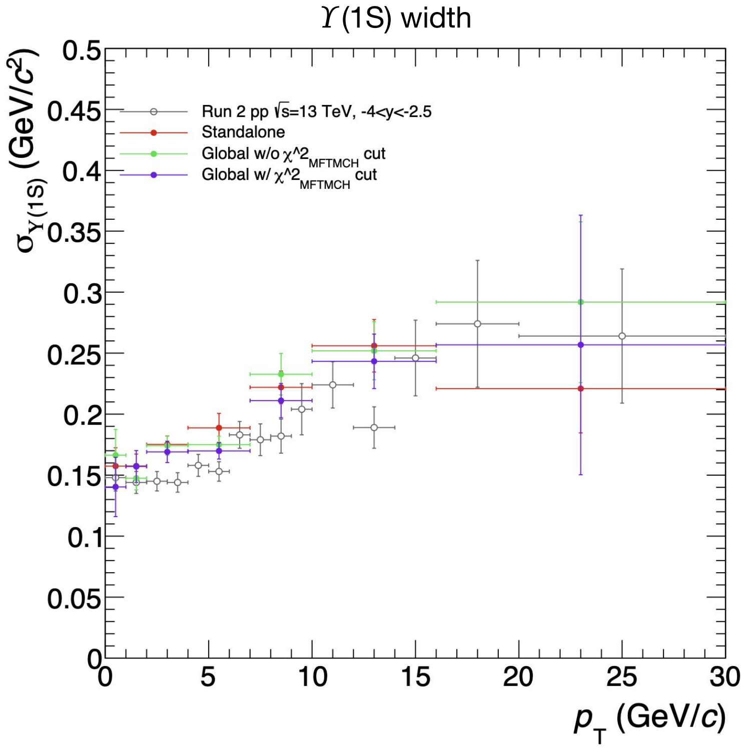


- Adding MFT reduced upsilon resonances yields (except for Υ(3S))
- Using MFT χ^2_{MFTMCH} cuts, which enhence J/ψ significance, reduce the yield even more and doesn't improve significance → increase of σ_{stat}

Analysis — Upsilon production

- **Υ(1S) mass and width resolutions :**





- ➢ But we gain in mass and width resolutions ...
- ➢ Others discriminating variables in perspective : l_z, distance of closest approach in the interaction plane