Enigmass
The enigma of mass

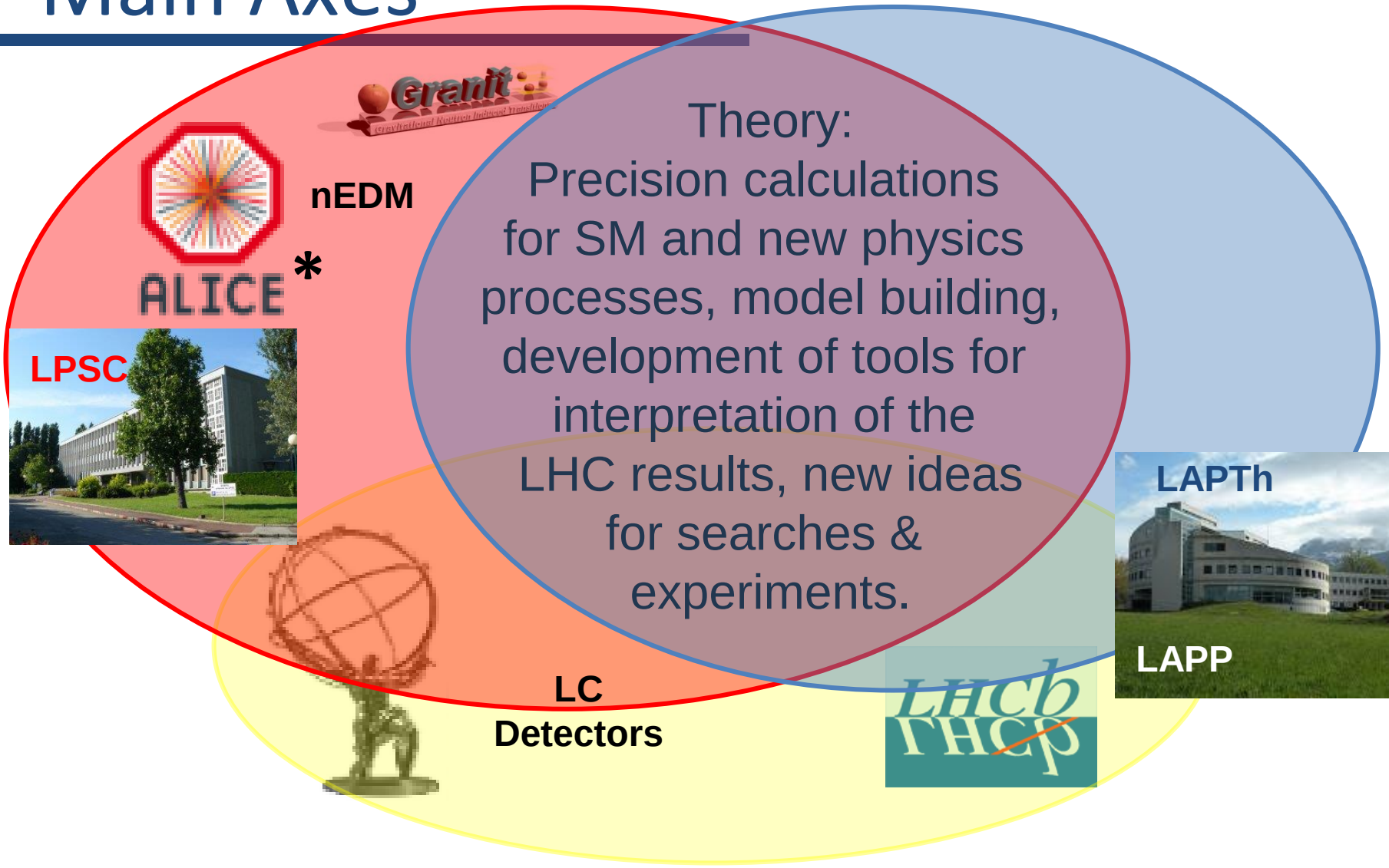
Report from Collider & Particle Physics Work-Package

Tetiana Berger-Hryn'ova

ENIGMASS Meeting
20/07/2017

LPSC
A
LAPTh
P

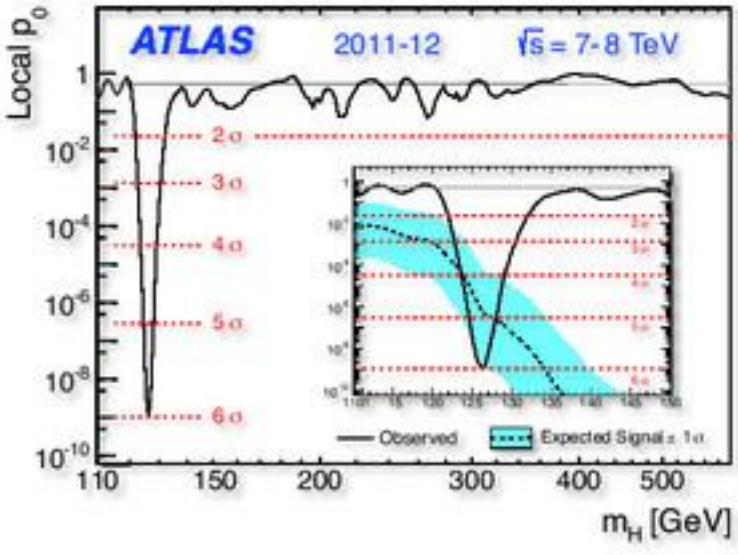
Main Axes

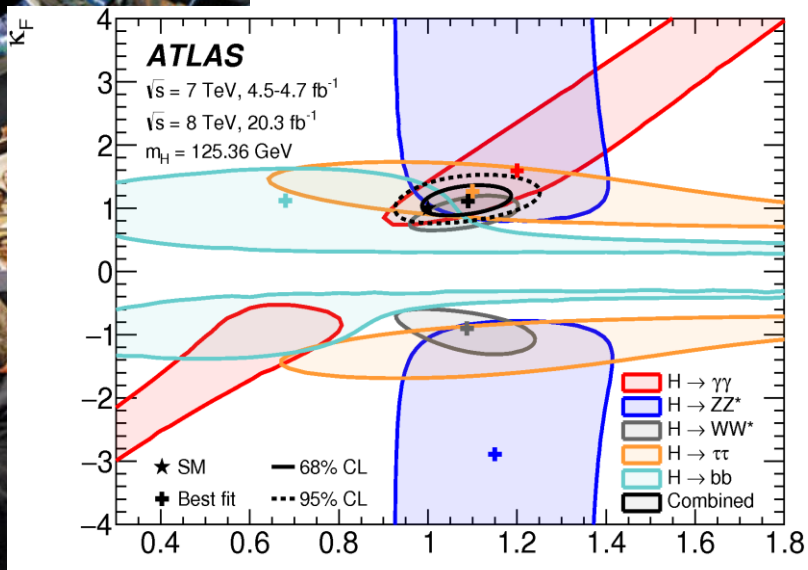


*New for the ENIGMASS renewal

Achievements 2012-2017

Higgs Discovery: Nobel Prize (Physics) 2012



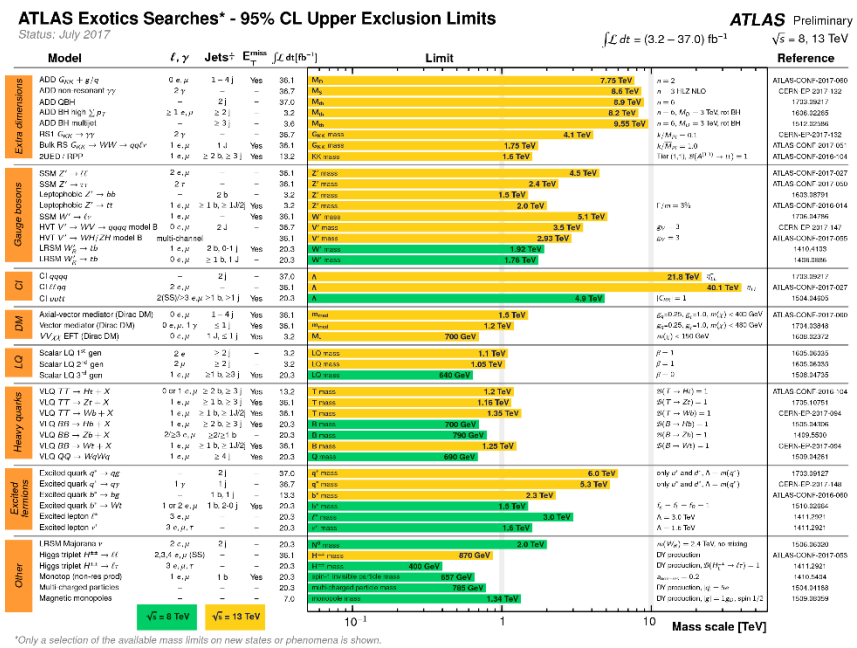


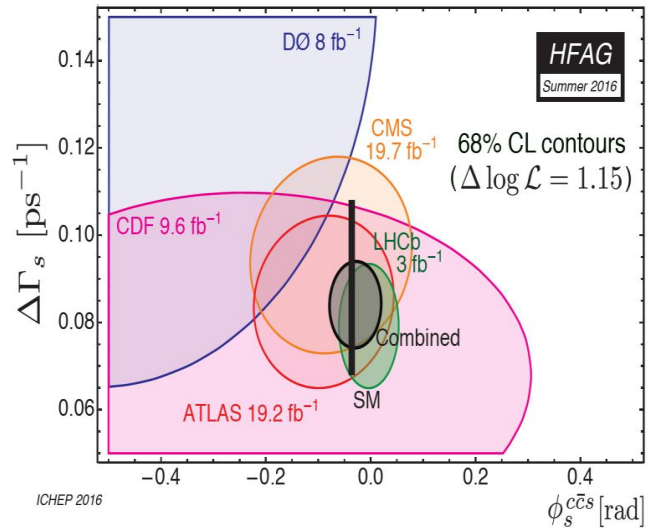
Eur. Phys. J. C76 (2016) 6

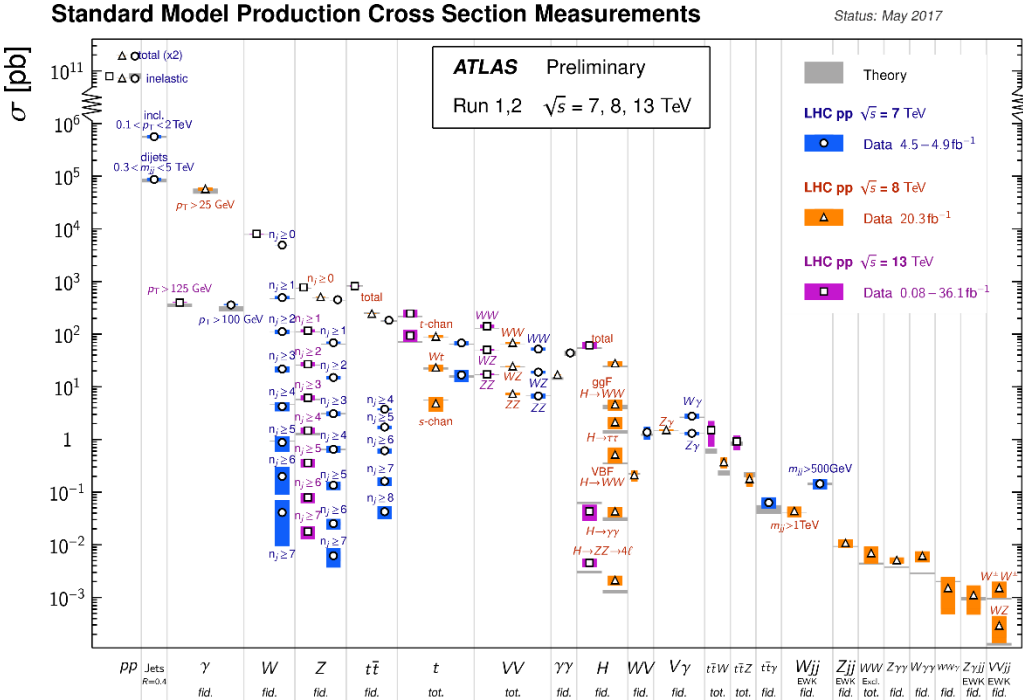
No New Physics @ LHC yet

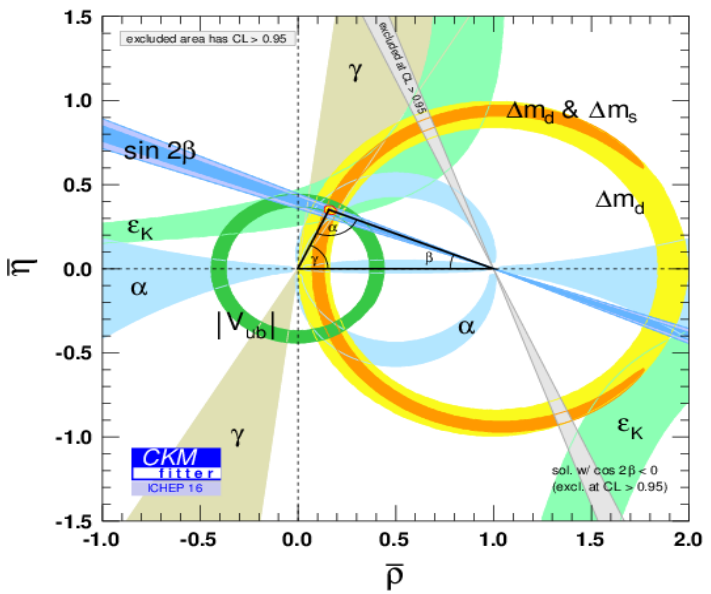
Our searches:
γγ, γ+MET,
ll, tb, tt, etc...

Measurements:
WZ & γγ,
top polarization,
Higgs properties
CKM angles
(β, γ, ϕ_s); B→K*γ
etc..

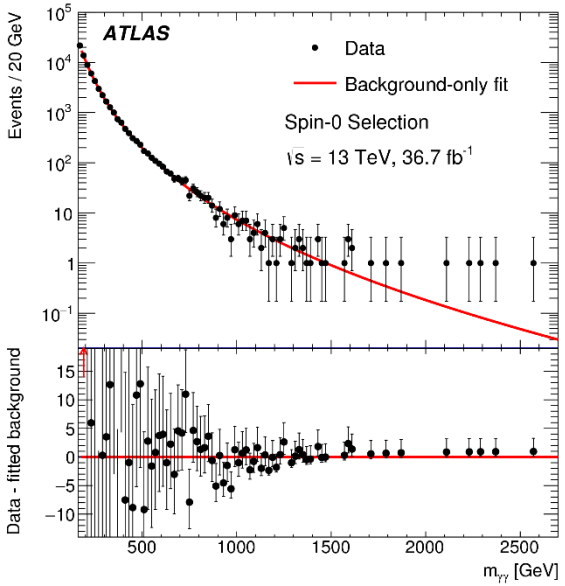








ENIGMASS Highlights Experiment

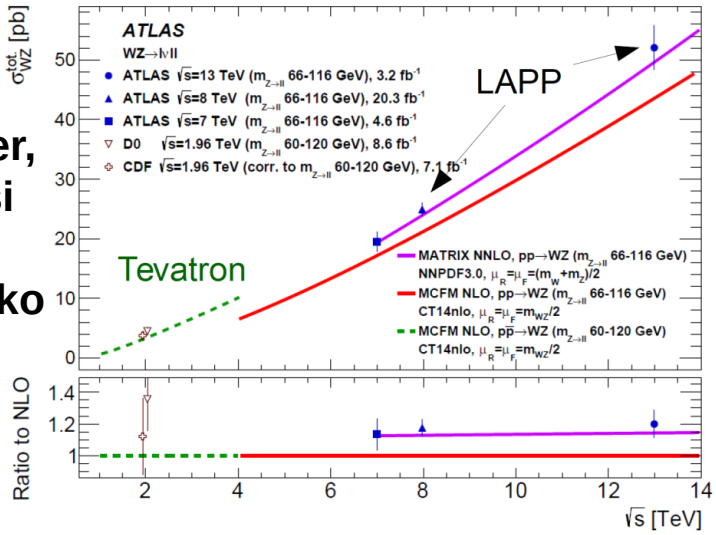


γγ: SM, Higgs & BSM

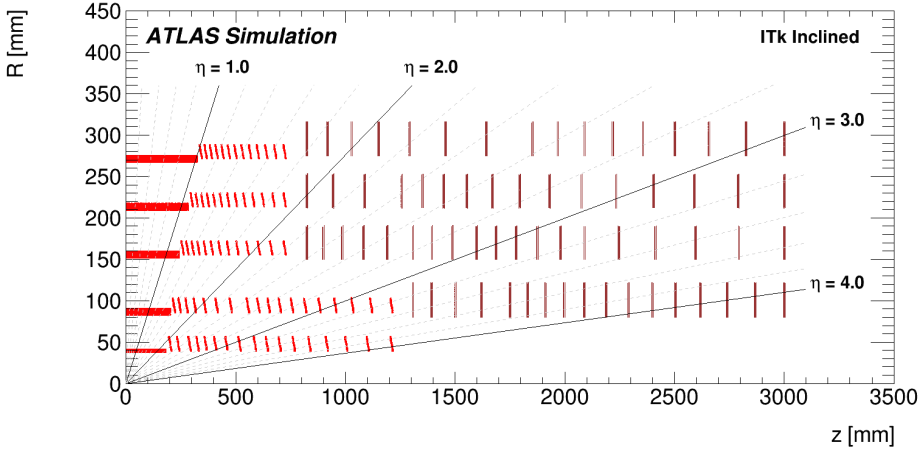
PhD:
Z. Barnovska
K. Grevtsov,
PD:O. Kivernyk

SM WZ

PhD:
A. Burger,
O. Dartsi
PD:
E. Yatsenko

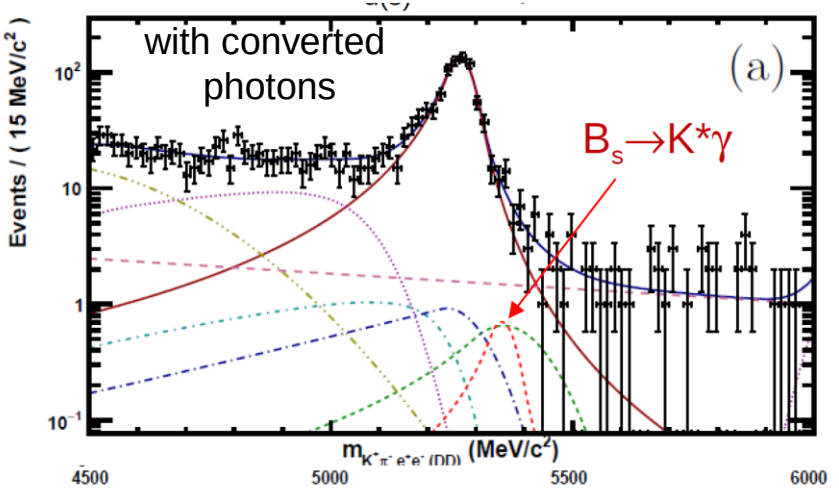


ATLAS Tracking Upgrade: Inclinded



PD: A. Bethani, B. Smart, N. Readioff, A. Rummler + hardware

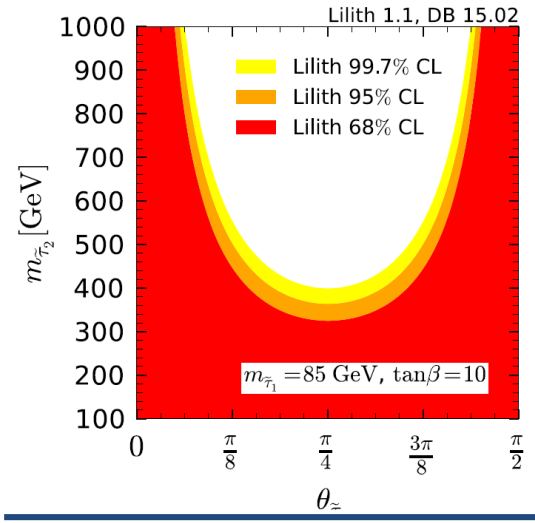
Radiative $B_{d,s}$ decays



PhD: L. Beaucourt

ENIGMASS Highlights Theory

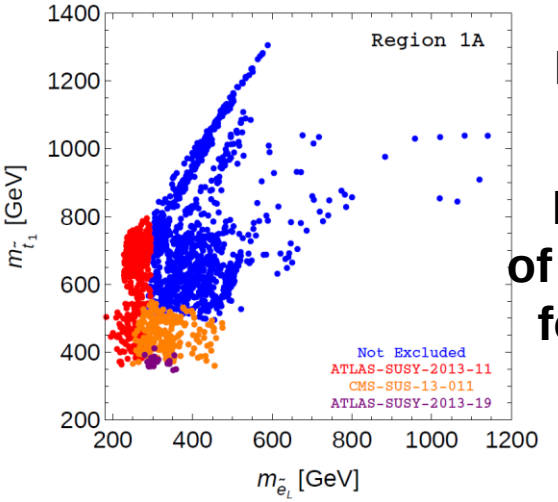
Constrain NP from measurements



New Tool: Lilith

PhD: J. Bernon

Recasting Tools

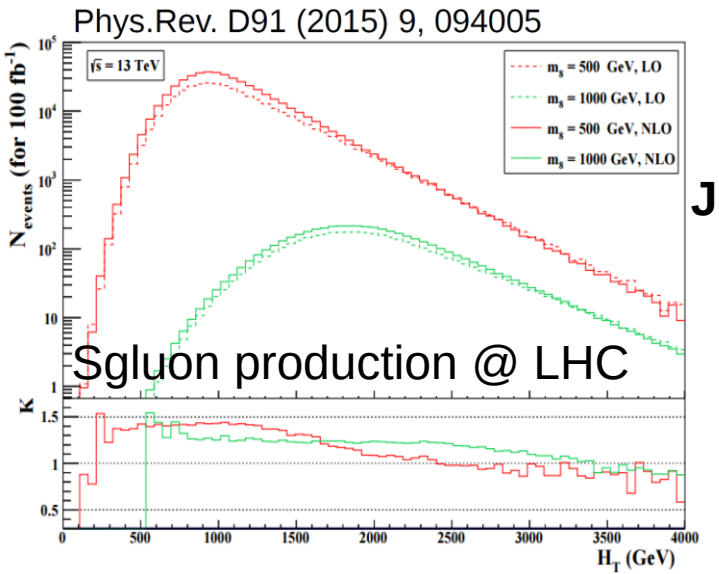


Tools: SmodelS MadAnalysis5

Forums: Interpretation of the LHC results for BSM studies

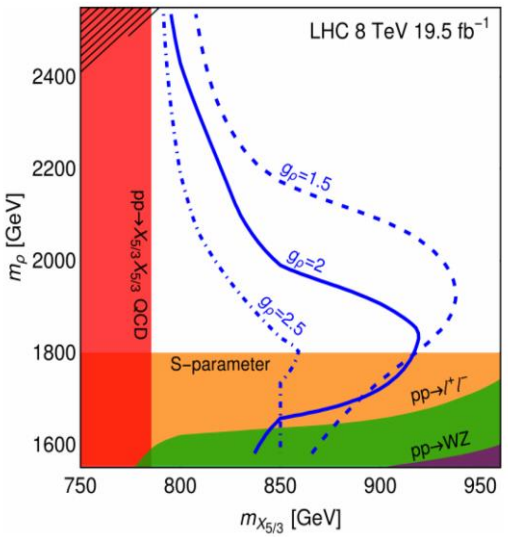
PhD: U. Laa

Higher Order Computations



PhD: J. Proudom

New models, search proposals…



PD: C. Delaunay

Theory-Experiment Example

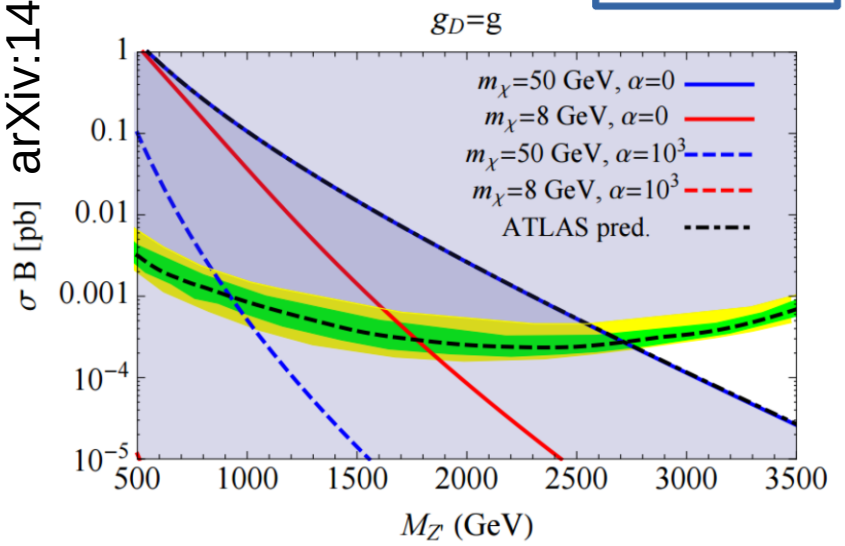
Proposal in Dark Matter Working group (Sept 2016) by **B. Zaldivar** (**PD** ENIGMASS):

Model: *Sequential Z' with extra coupling to DM*

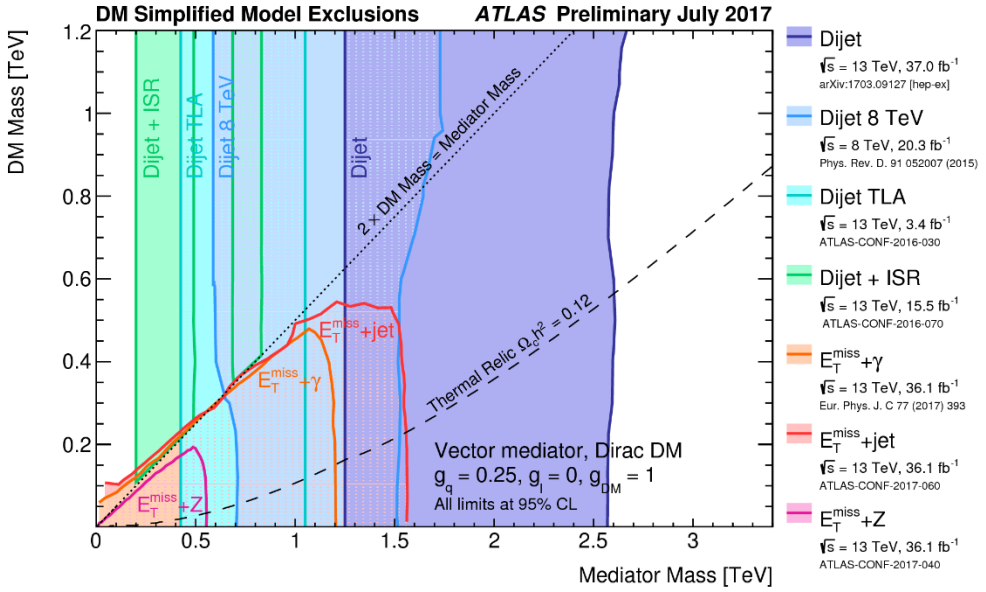
$$\Delta\mathcal{L} \supset g_D \bar{\chi}\gamma^\mu \left(V_D^\chi - A_D^\chi \gamma^5\right) \chi \; Z'_\mu + g_D \sum_f \bar{f}\gamma^\mu \left(V_D^f - A_D^f \gamma^5\right) f \; Z'_\mu .$$

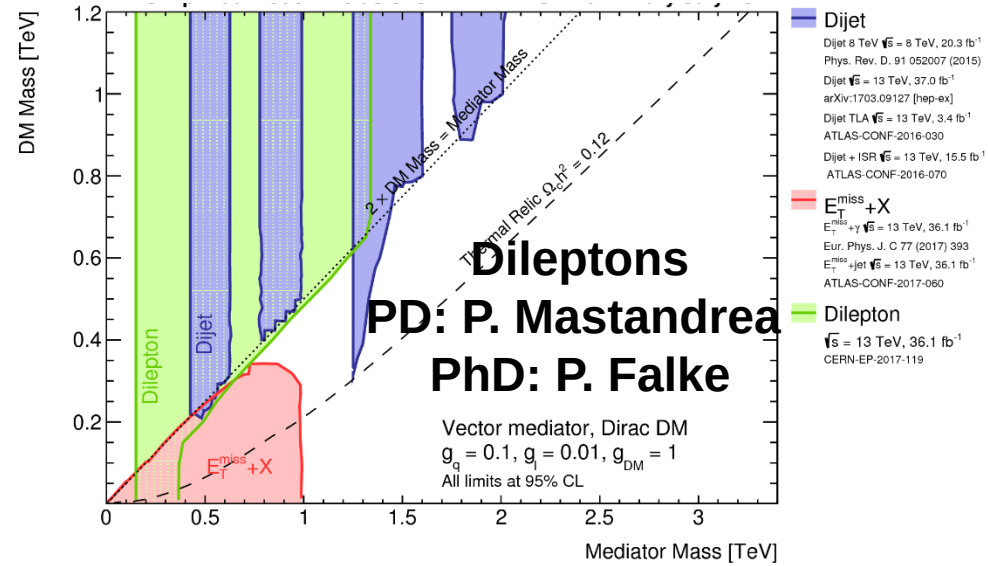
$$\alpha \equiv A_D^\chi / V_D^\chi$$

arXiv:1401.0221



based on:
- ATLAS, 1209.2535, 7TeV, ~5/fb
- LUX, 1310.8214





Also common PhDs: M. Reboud (LHCb-LAPTh) LFV in B decays; S. Berlendis (LPSC ATLAS-Theory), Searches in same-sign tt final state

Next 10 years

Search for any deviations from Standard Model predictions

Direct observation:

In-direct observation:

LHC

Our searches: $\gamma\gamma$, γ+MET, ll, tb, tt, etc.

Vector Boson Scattering, Double Higgs production, Measurements of CKM angles, Flavour anomalies, Precision QCD...

Theory

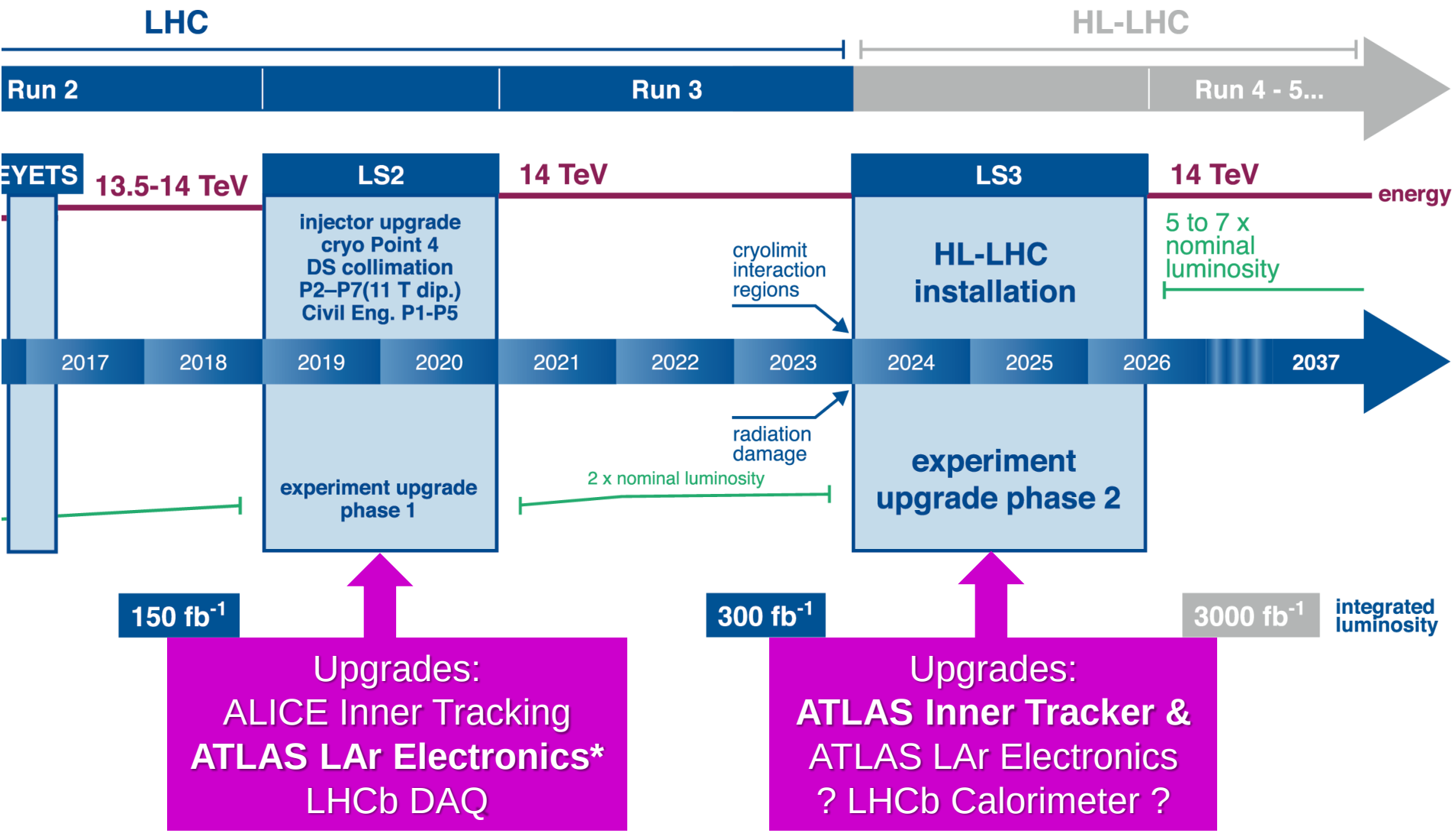
Recasting of existing searches, New models, search proposals

Higher Precision Calculations, EFT extension of SM

Non-LHC

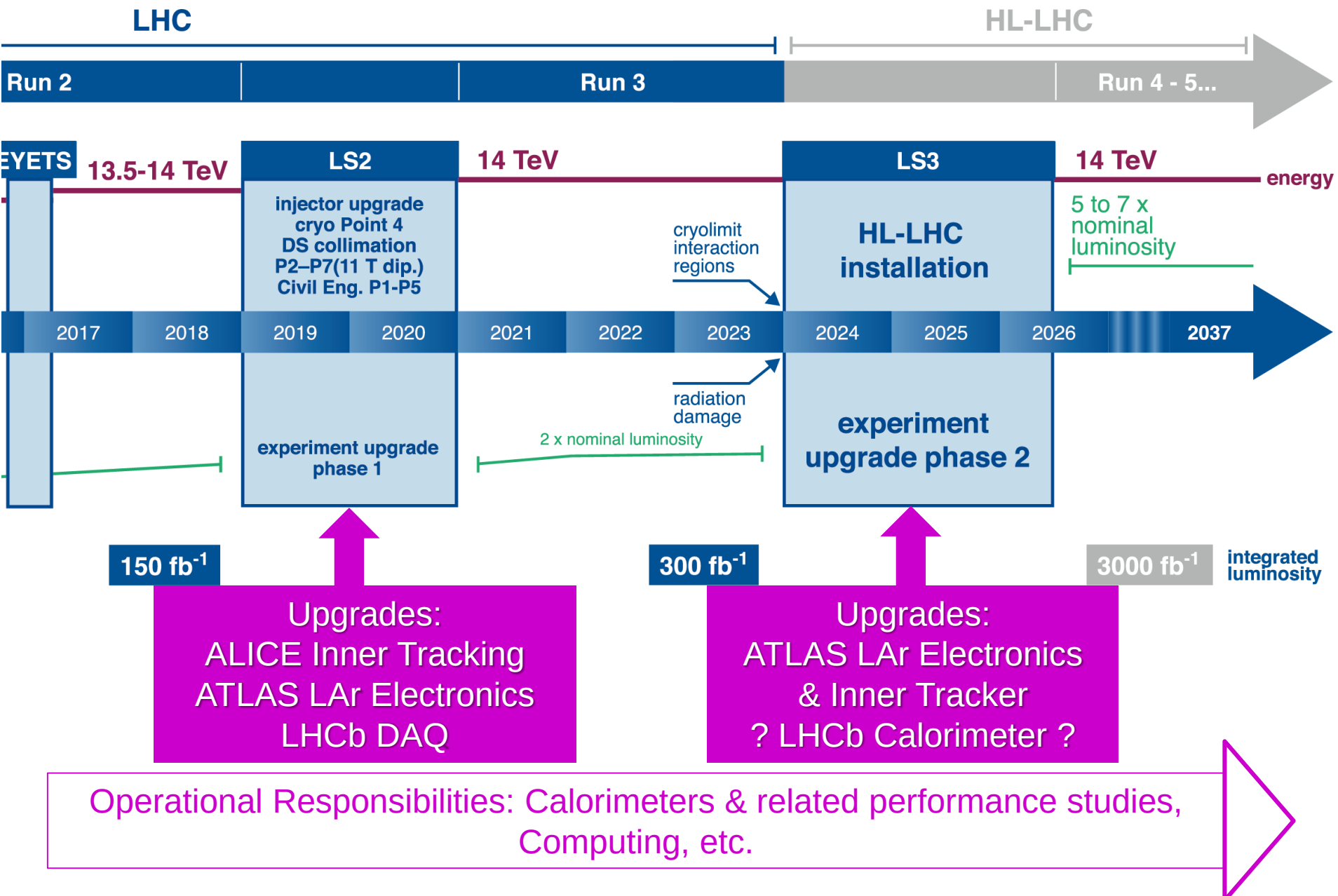
Measurement of neutron electric dipole moment, Measurement of magnetic resonant transitions between neutron quantum states in the gravity field… Future collider experiments.

LHC Timeline

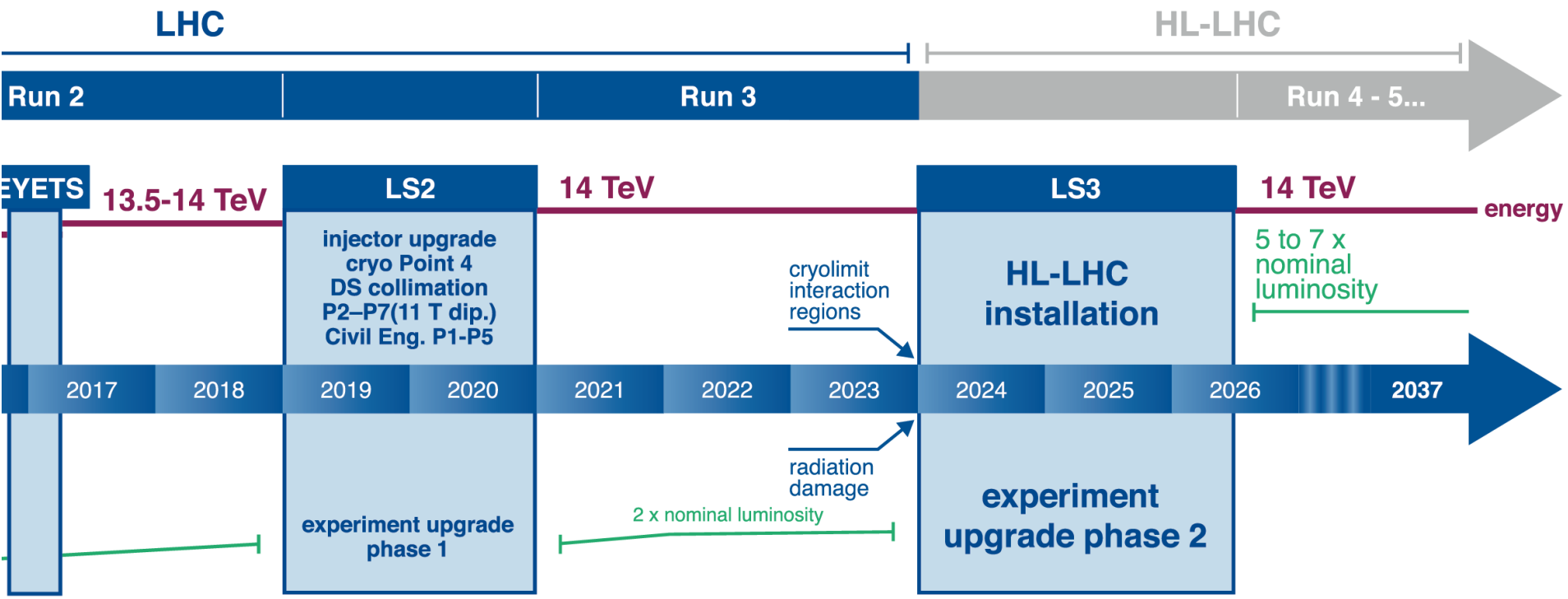


ENIGMASS funded-activity in bold
*** PhD P. Falke, PD Gabaldon-Ruiz**

LHC Timeline



LHC Timeline

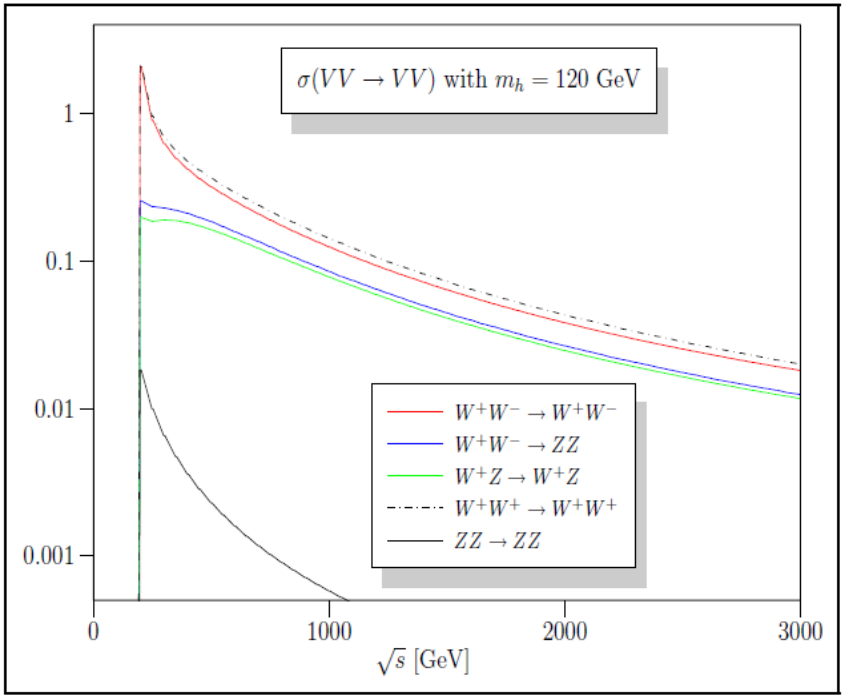


	ATLAS	LHCb	ALICE (HI)
2017	$40fb^{-1}$	$5fb^{-1}$	$1nb^{-1}$
2019	$150fb^{-1}$	$8fb^{-1}$	
2024	$300fb^{-1}$	$28fb^{-1}$	
2028	$1000fb^{-1}$	$42fb^{-1}$	$10nb^{-1}$

Probing Nature of EWSB: New@HL-LHC

VBS cross-section in longitudinal mode is sensitive to new physics. Crucial to check consistency with SM predictions.

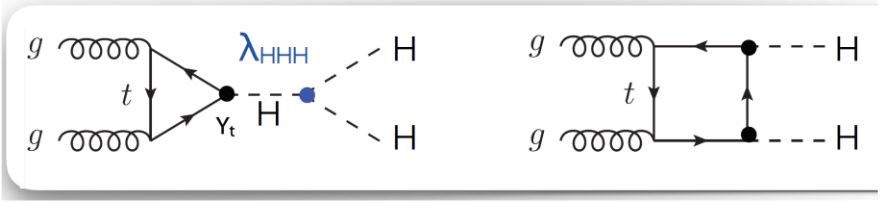
SM with a 120 GeV Higgs boson



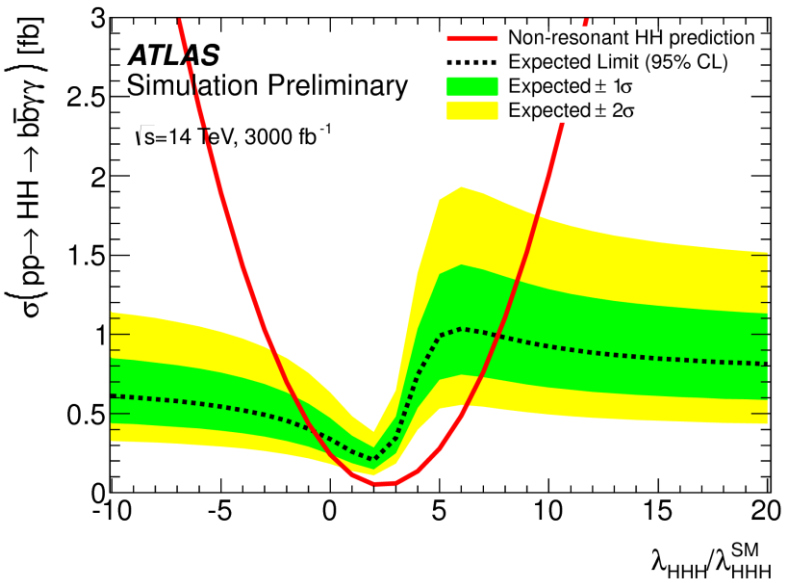
CERN-LHCC-2017-005

	$\frac{\Delta\sigma}{\sigma}$
Without forward tracking	4.5%
With forward tracking	3.9%

Double Higgs production: probes the shape of the scalar Higgs potential



Negative interference between HH production with and w/o HHH vertex.



ATL-PHYS-PUB-2017-001

In bbγγ expect 9.5 signal over 90.9 bkg events in 3 ab^{-1} (~1σ) Need to combine with other channels & CMS.

SM Effective Field Theory (EFT)

- SM scale ~ v = **246 GeV**, no BSM physics seen below **Λ ~ 1 TeV**

  $\Rightarrow$parameterize the BSM using an **EFT extension of the SM**

$$L = L_{SM}^{(d\leq 4)} + \frac{1}{\Lambda^2}\sum_i c_i^{(d=6)} O_i^{(d=6)} + \frac{1}{\Lambda^4}\sum_i c_i^{(d=8)} O_i^{(d=8)} + \ldots$$

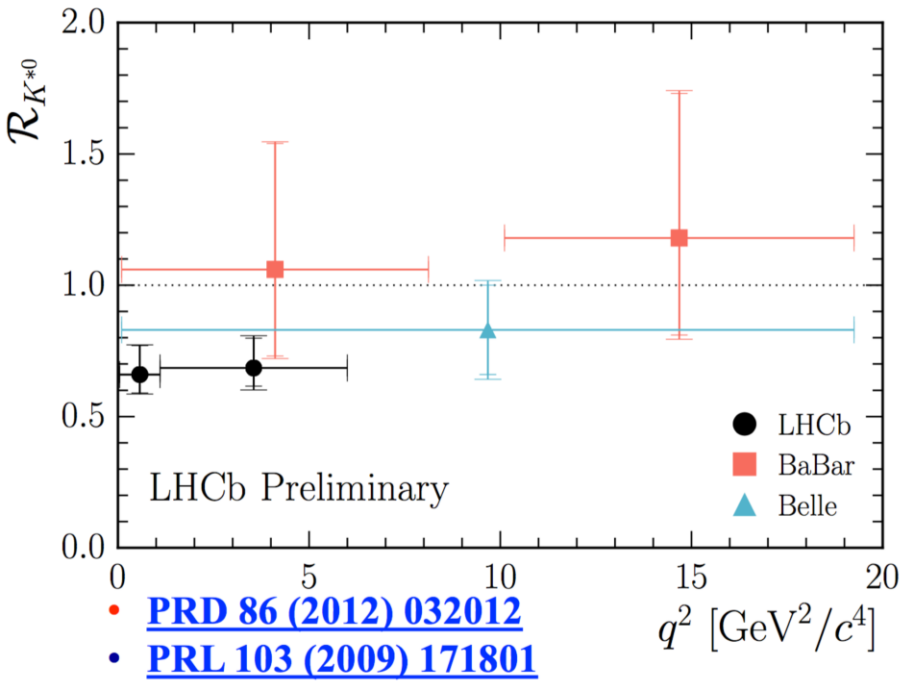
- Usually(*) leading effect from **interference of d=6 and SM ~$(v/\Lambda)^2$** and can **neglect d≥8** and $|c^{(d=6)}|^2$.

  $\Rightarrow$ **Report experimental constraints on the c_i, compare to model predictions**

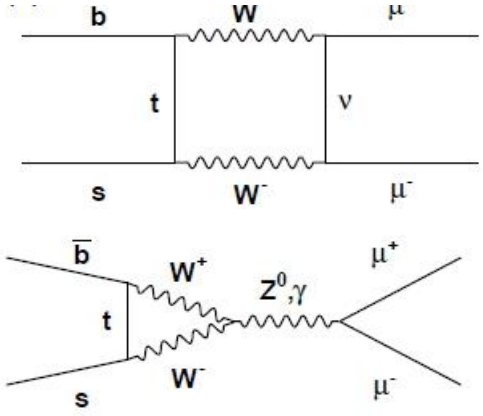
- Straightforward to extend to higher orders in SM couplings
- **Many operators**: **2499** for n_{gen}=3
  - Higgs operators
  - Other EW operators (TGCs)
  - 4-fermion operators (flavour measurements)

Measu-rements planned $\Leftrightarrow$ Theory predictions are crucial.

Flavour Anomalies ($b\to sll$ & $b\to c\tau\upsilon$)

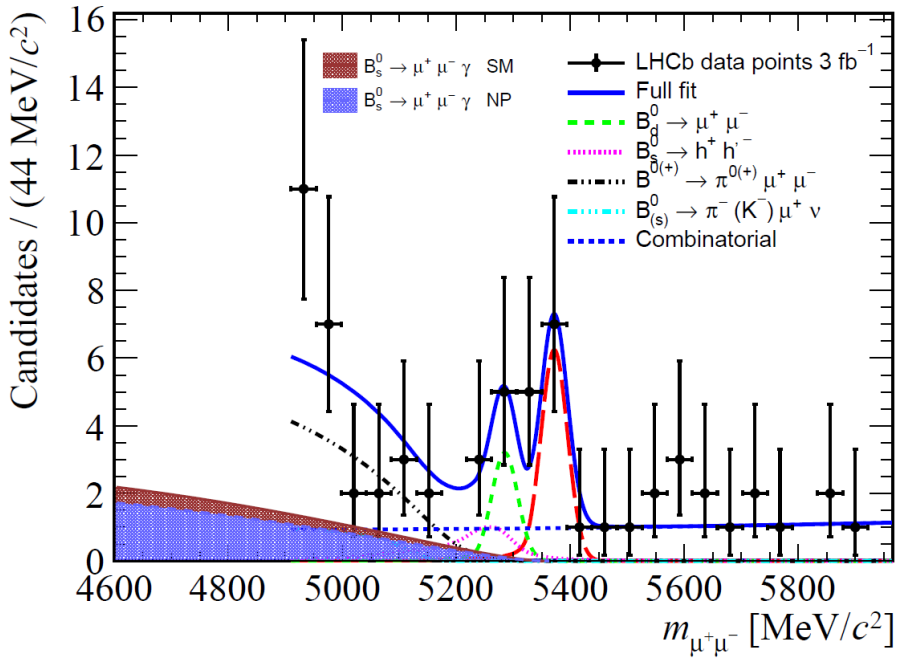


- PRD 86 (2012) 032012
- PRL 103 (2009) 171801



$BR_{obs}(B_s\to\mu\mu)/BR_{SM}(B_s\to\mu\mu)=0.76^{+0.20}_{-0.17}$
$\Rightarrow$ More precise measurement needed.

$BR(B_s\to\mu\mu\gamma)$ ~5 $BR(B_s\to\mu\mu)$, not seen yet.
Also interesting to see $B_s\to e\mu\gamma$.



arXiv:1610.00629

Sign of New Physics? Stat Fluctuations?
QCD effects not fully accounted for?

Probing QCD with Quark Gluon Plasma (QGP)

- Study of QGP in **Pb-Pb**: new constraints on strong interaction
- Study of **pp** collisions: baseline for the QGP study and for comparisons with QCD calculations;
- **p-Pb** collisions: cold nuclear effect

ALICE @ LPSC:

Inclusive jets, jet-jet and photon-hadron/jet correlations measurements

→parton fragmentation related observables

→in-medium modification of parton energy loss and energy redistribution at ~ low p_T

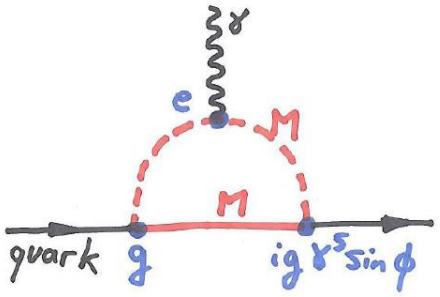
New b-tagging methods for heavy flavour identification in jets:

→ use to study quark flavor dependence of energy loss in QGP: test dead cone effect prediction

Beside LHC

nEDM: Search for BSM CP violation mechanism

- Possible contribution from new physics: multi-TeV BSM sensitivity



$$d_n \approx \frac{e g^2 \sin\varphi}{16\pi^2} \frac{\hbar c\, m_q}{M^2}$$
$$\approx \left(\frac{1\ \mathrm{TeV}}{M}\right)^2 \times \sin\varphi \times 10^{-25}\ e\ \mathrm{cm}$$

- Test of electroweak baryogenesis (requires also BSM scalar sector)
- Timeline :
  - 2018 : publication slightly improved result / RAL-Sussex result : $d_n < 3.\ 10^{-26}$ e cm
  - 2017 – 2020: design/construction n2EDM spectrometer
  - 2020-2025: Data taking with n2EDM at the PSI UCN source → $d_n \sim 10^{-27}$ e cm
- LPSC contribution (ANR and ERC grants): Hg magnetometry, B mapping, UCN switch

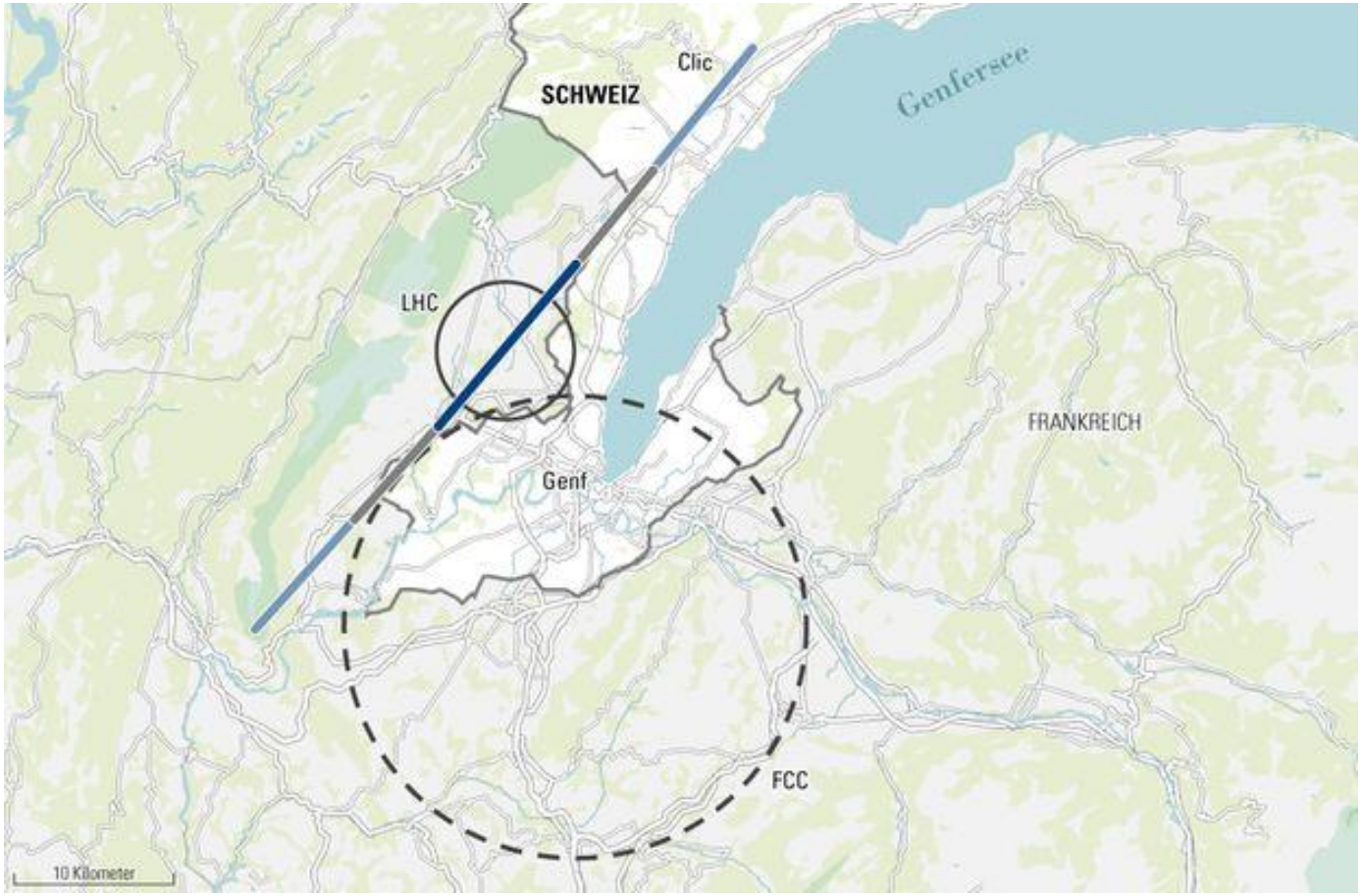
GRANIT: Testing Gravity using neutron quantum bouncer

- Unique test of weak equivalence principle
  → independent measurements of inertial and gravitational masses

$$-\frac{\hbar^2}{2m_i}\frac{d^2\psi}{dz^2} + m_g g\, z\, \psi = E\, \psi$$

- Test of modified gravity and new short range interactions: cosmological chameleon, symmetron...
- Collaboration LPSC-ILL

Beyond LHC: new colliders



Small ILC groups @ LAPP & LPSC

Following developments on FCC, CLIC and ILC.

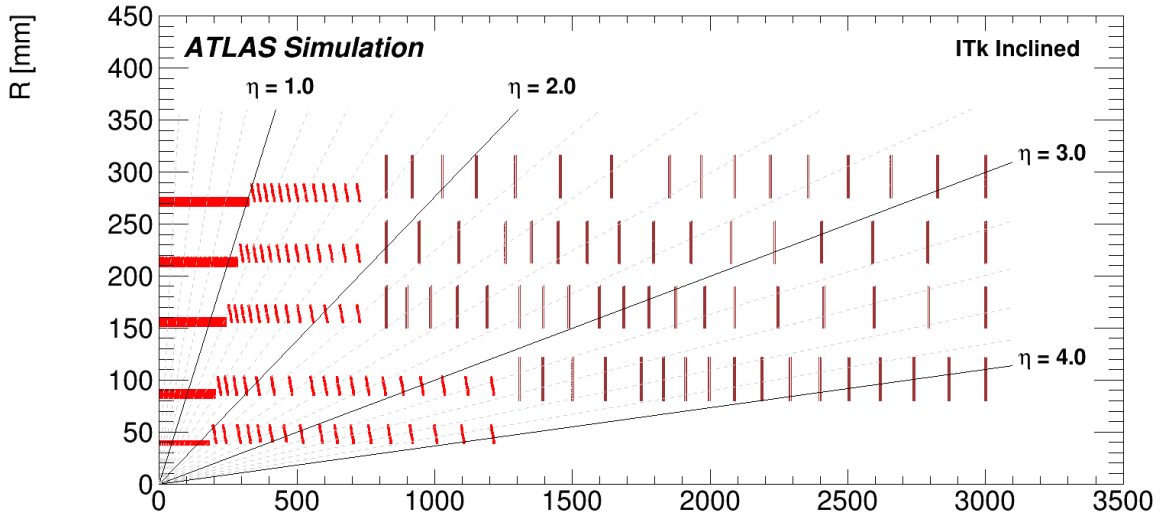
Current Research Team Composition

	ALICE LPSC	ATLAS LAPP	ATLAS LPSC	ILC LAPP	ILC LPSC	nEDM/ GRANIT	LAPTh PP	LHCb LAPP	LPSC Theory
PERM PHYS	**5**	**13**	**11**	**2[&]**	**1[&]**	**3**	**9**	**8[&]**	**4**
PD	**0**	**6(4)**	**1(1)**	**0**	**0**	**1**	**2(1)**	**1**	**2**
PhD	**4**	**7(4)**	**5[y]**	**0**	**0**	**2**	**3[x]*(1[x])**	**1***	**5[yx] (1[x])**

& Not full time
x One shared LAPTh-LPSC
* One shared LAPTh-LHCb
y One shared LPSC ATLAS- LPSC Theory
() Currently funded by ENIGMASS

Backup

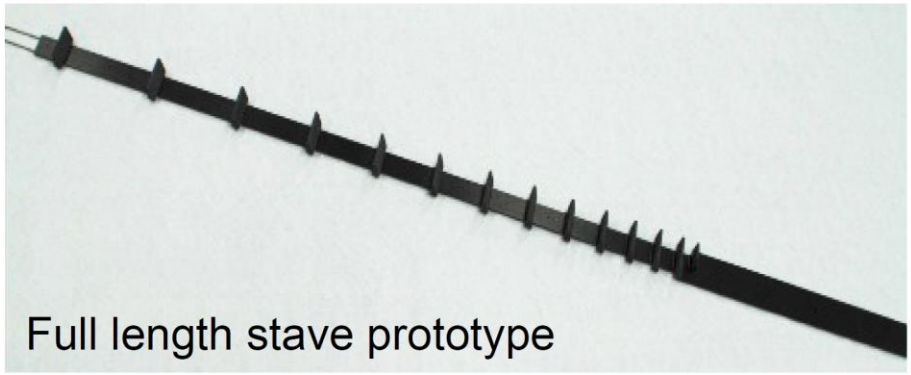
ATLAS Tracking Upgrade (2024-25)

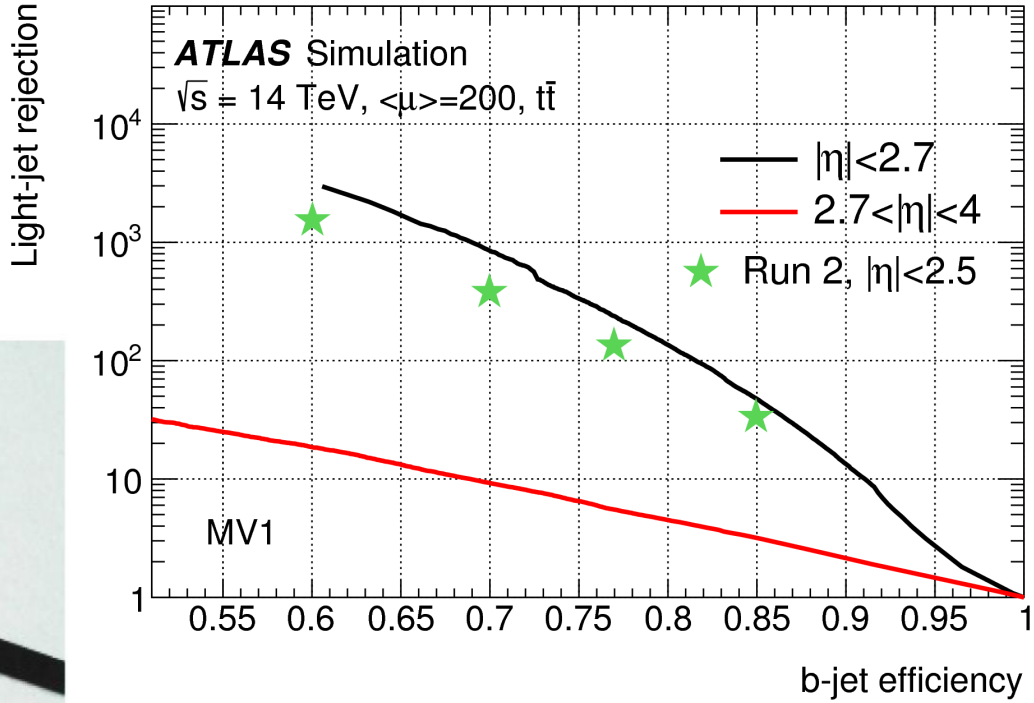


Goals: improved tracking performance in higher pile-up & radiation environment

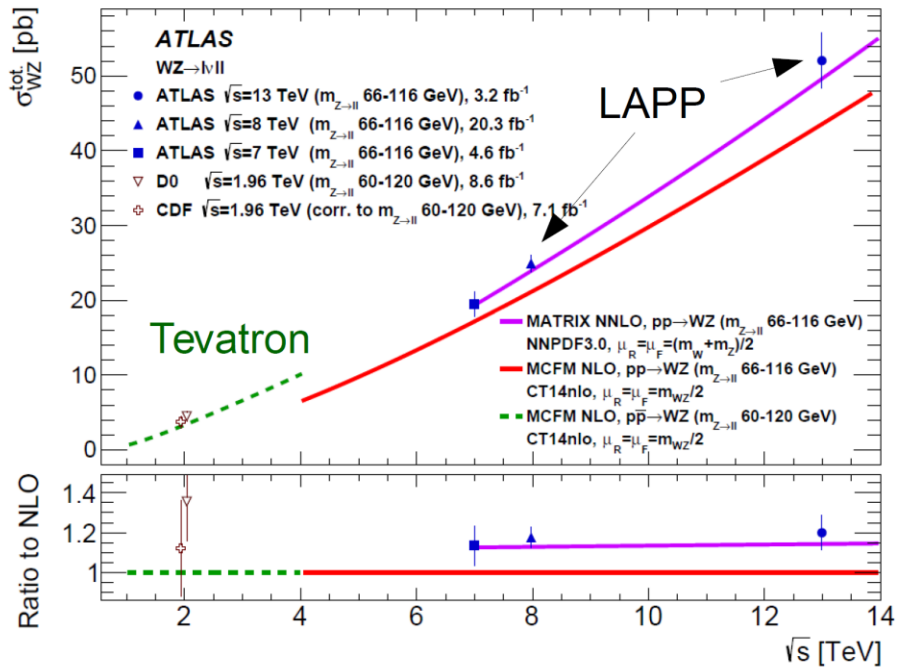
Inclined Layout
Idea initiated at LAPP: less material, less silicone

LAPP & LPSC: Layout Simulation, Thermal & Mechanical tests, Electronics (Services),.. Future construction

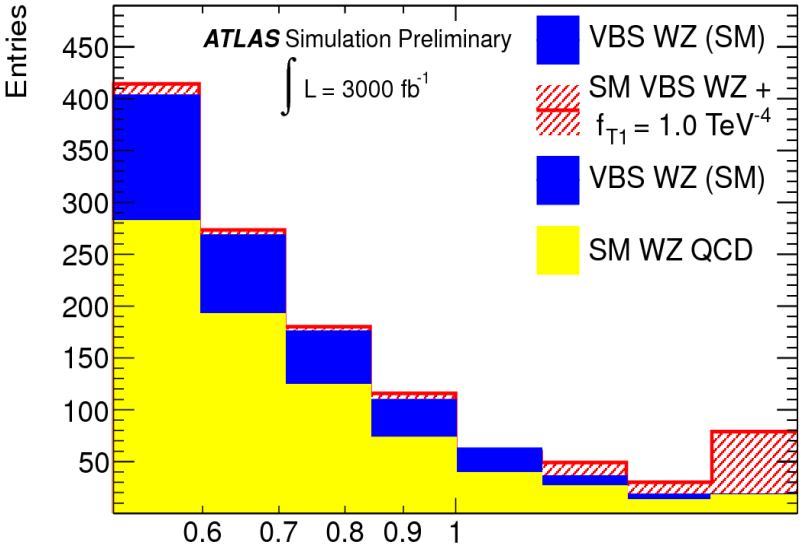




Dibosons to VBS

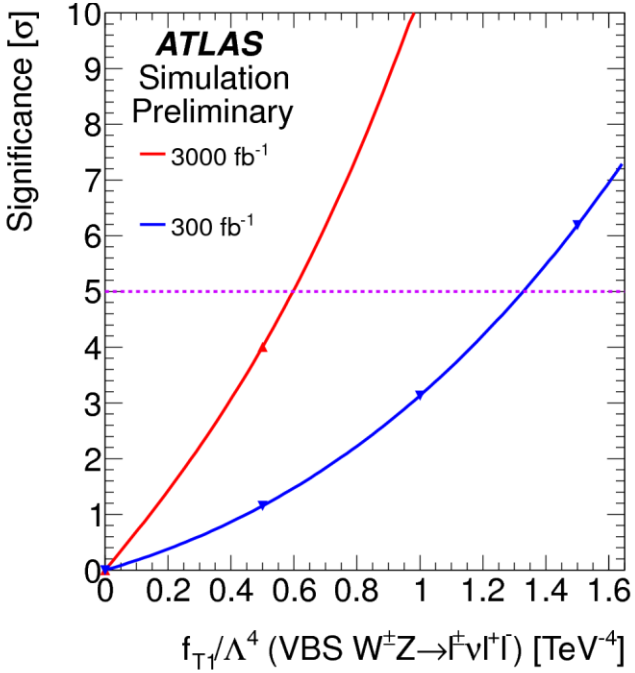


ATL-PHYS-PUB-2013-006

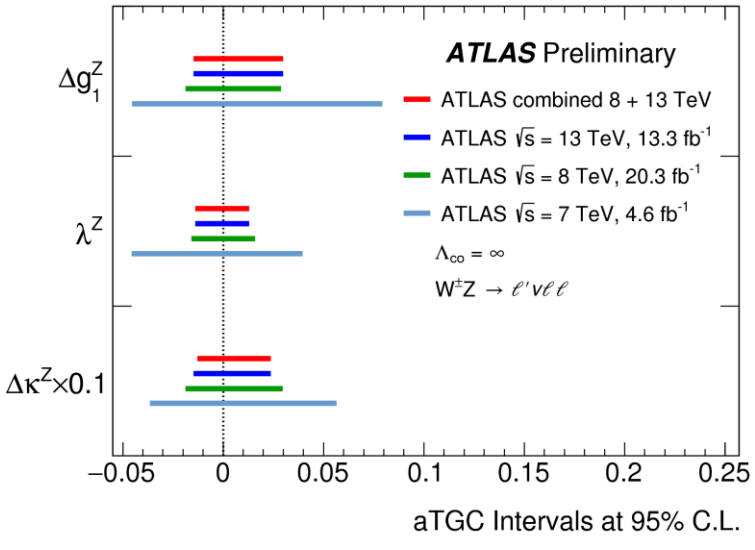


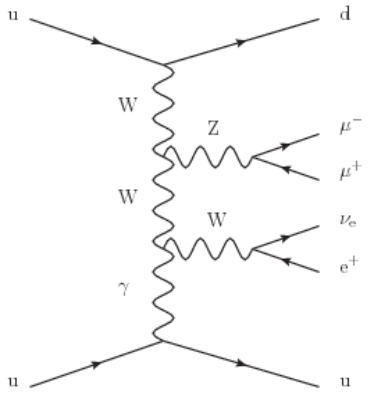
$$\mathcal{L}_{T,1} = \frac{f_{T1}}{\Lambda^4}\mathrm{Tr}[\hat{W}_{\alpha\nu}\hat{W}^{\mu\beta}] \times \mathrm{Tr}[\hat{W}_{\mu\beta}\hat{W}^{\alpha\nu}]$$

To Do



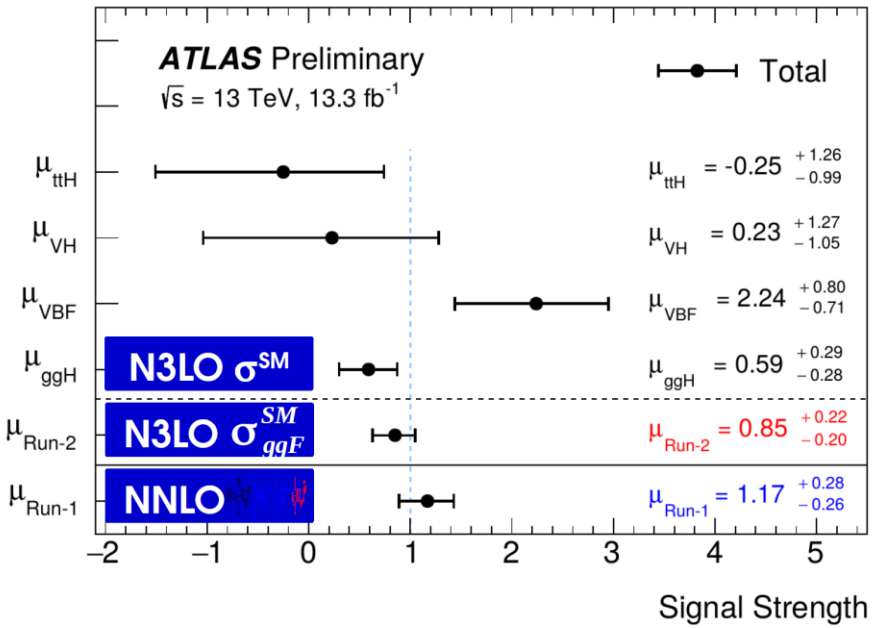
ATLAS-CONF-2016-043





H→γγ couplings

ATLAS-CONF-2016-067

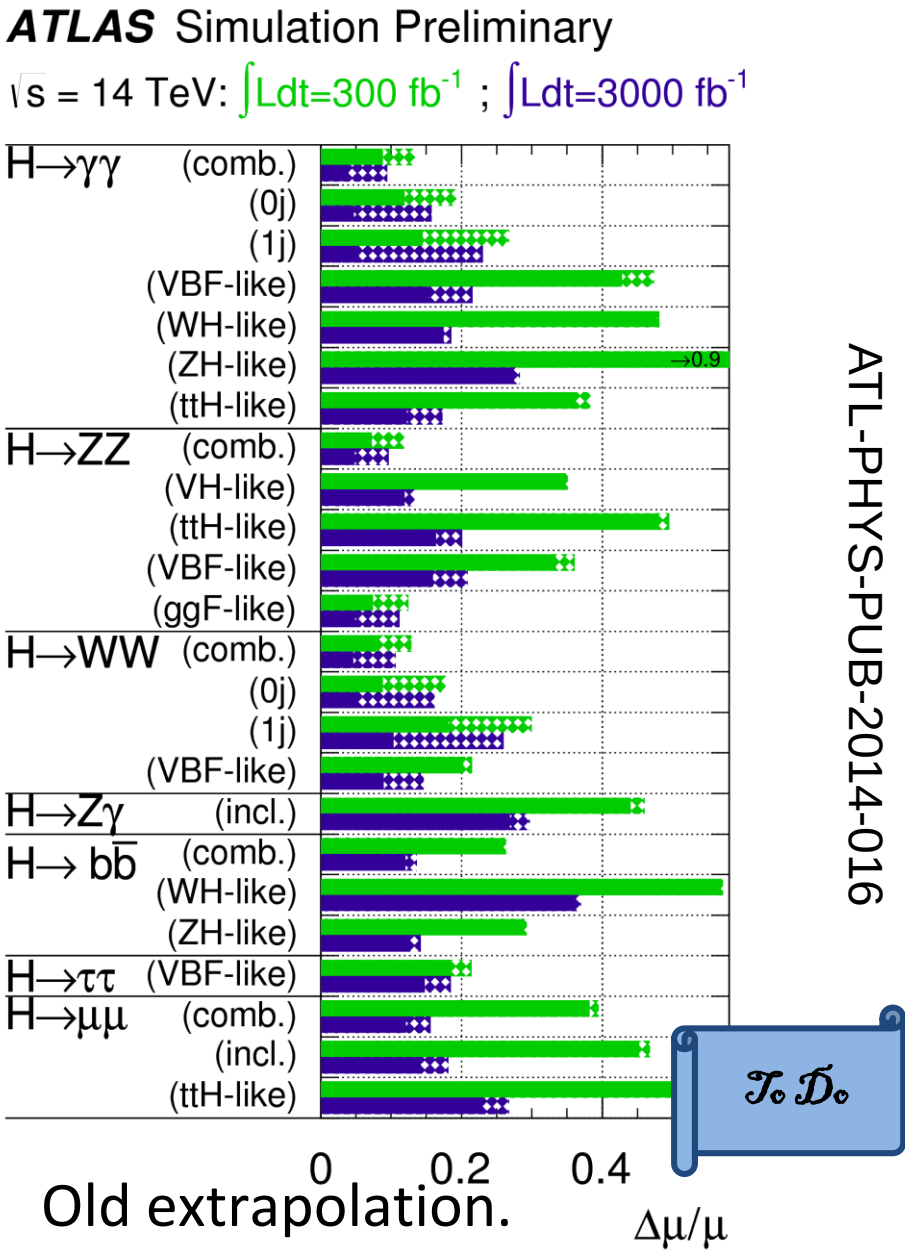


New ggF N3LO calculation

- +3% change in σ^{SM}_{ggF}
- QCD pert. uncert. 7.8% → 3.8%
- PDF+α_s uncert.: ~7% → 3.2%

Experimental precision needs to catch up with theory!

JHEP(2016)058



ATL-PHYS-PUB-2014-016

Old extrapolation.

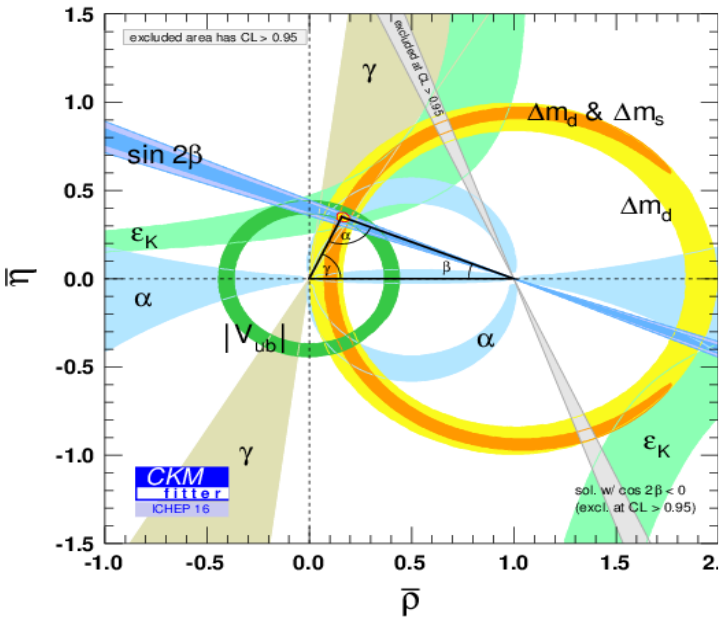
Analyses improved.

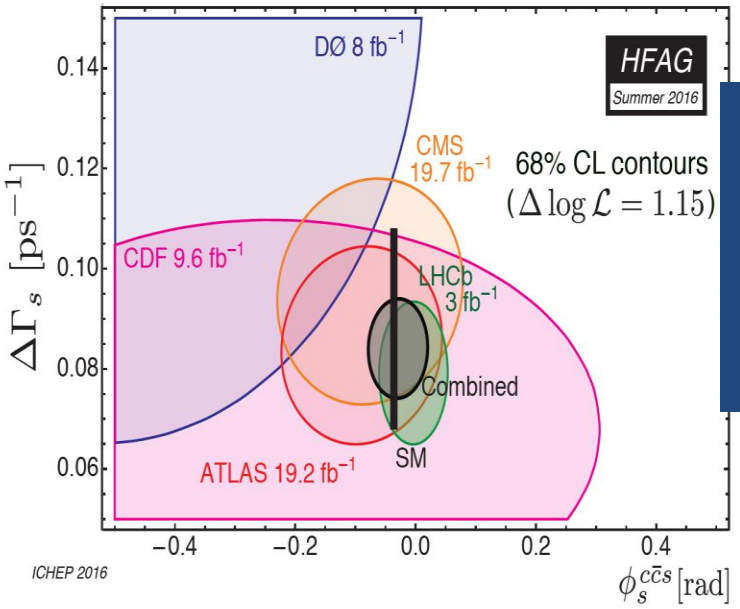
Sizable theory uncertainties!

From N. Berger @ Dissecting the LHC results 2017

CKM angles

arXiv:1612.07233





Now (CKMFitter):

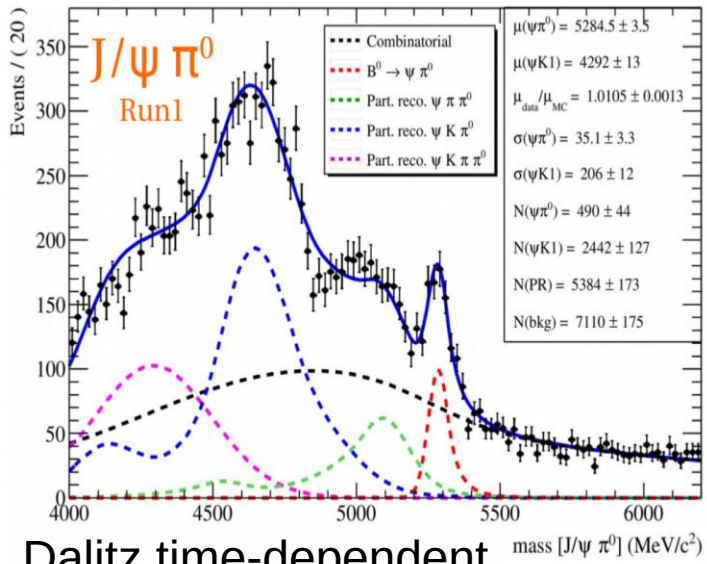
sin2β=0.691±0.017

γ =(72.2$^{+5.3}_{-5.8}$)°

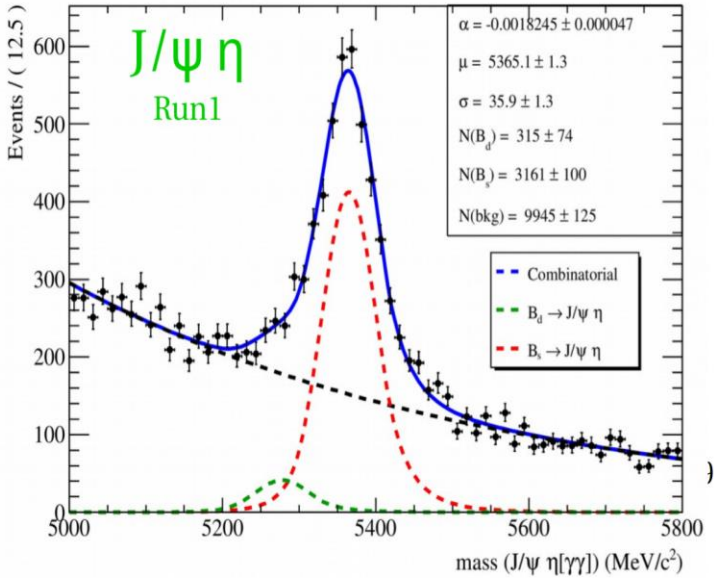
ϕ_s=-0.015±0.035rad

	LHCb Uncertainty End of Run 4
β	0.031°
γ	0.9°
ϕ_s	0.009 rad

Testing SM predictions



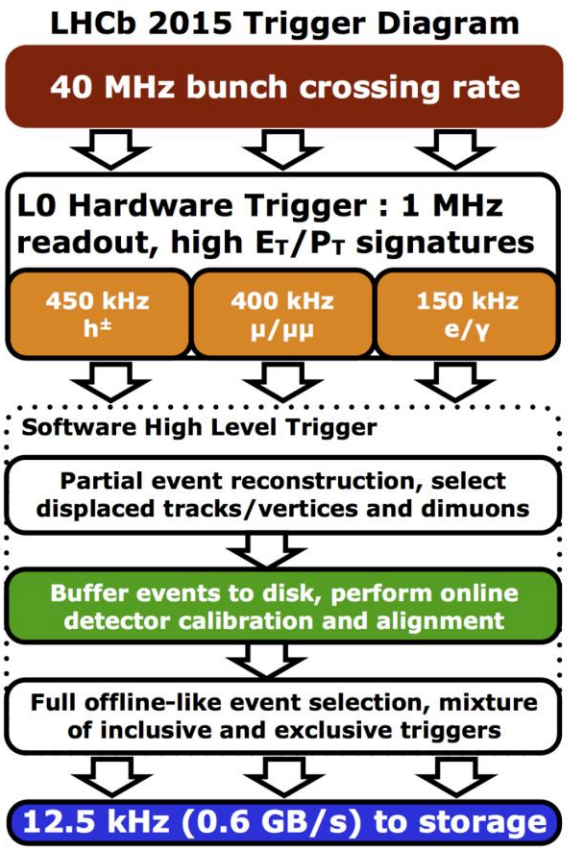
Dalitz time-dependent analysis for Run 2

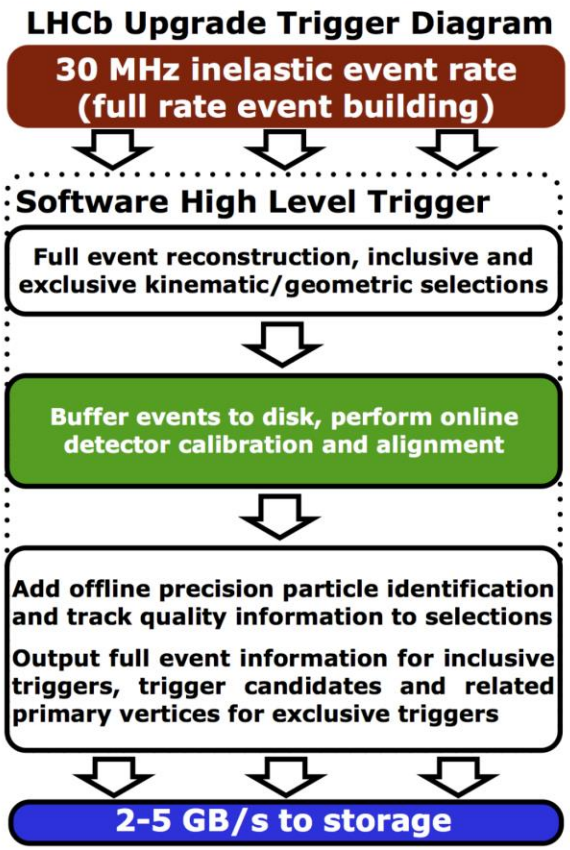


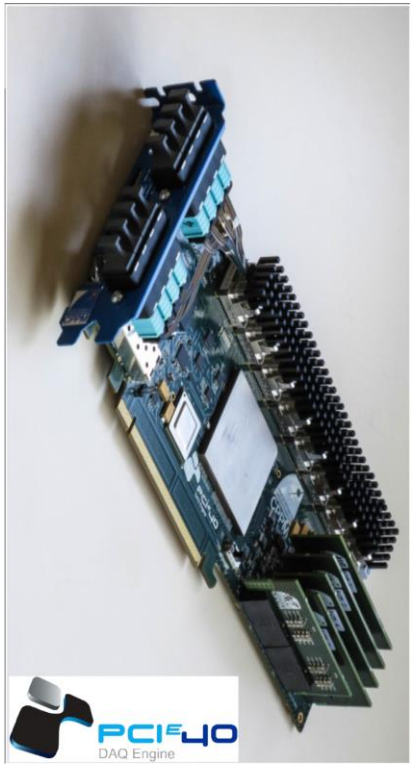
Also $B_s \to J/\psi\eta'(\rho^0\gamma,\eta\pi^+\pi^-)$

LHCb DAQ Upgrade (2019-20)

Goal: Remove Hardware Trigger





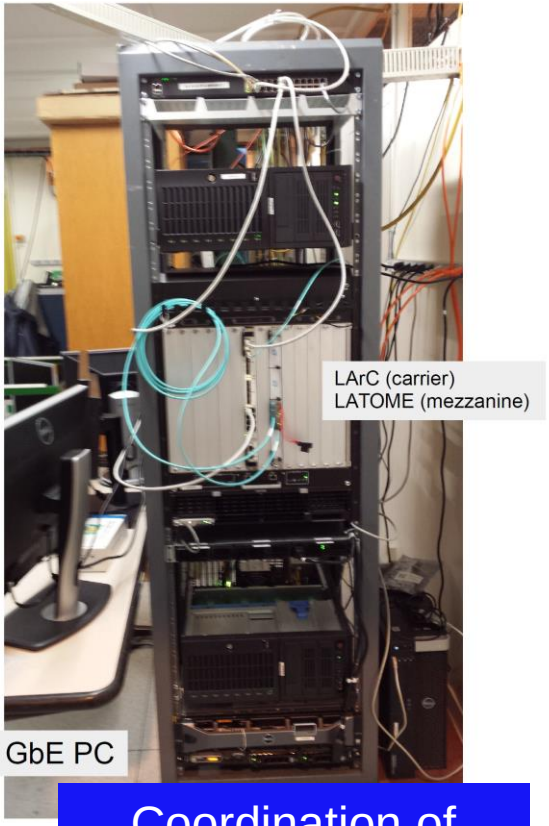


LAPP coordinates firmware development for Prototype Readout Board Used for Event Building

Potential participation in the LHCb Calorimeter upgrade 2024-2025

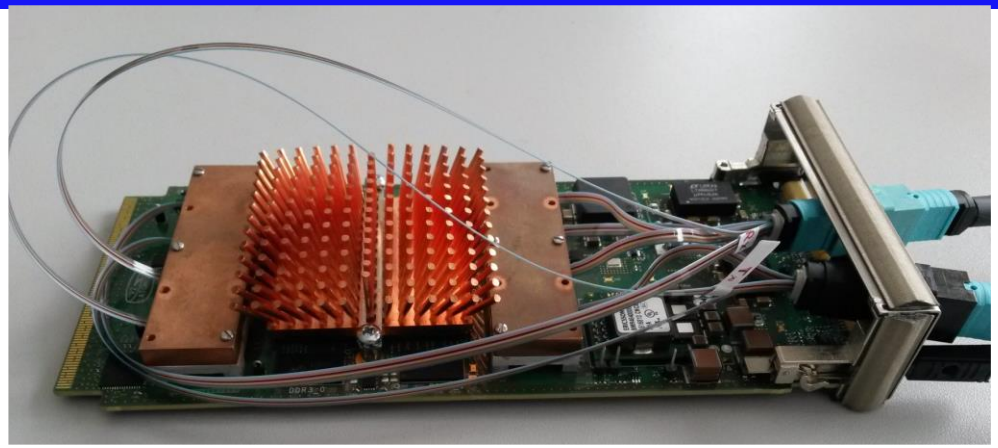
ATLAS LAr Calorimeter Upgrade (2019-20)

Goal: increase calorimeter hardware trigger granularity and to do digitisation at 40 MHz



Coordination of tests at CERN

LAPP developed a fast and dense processing unit (E_T calculation, LHC bunch crossing identification etc.)

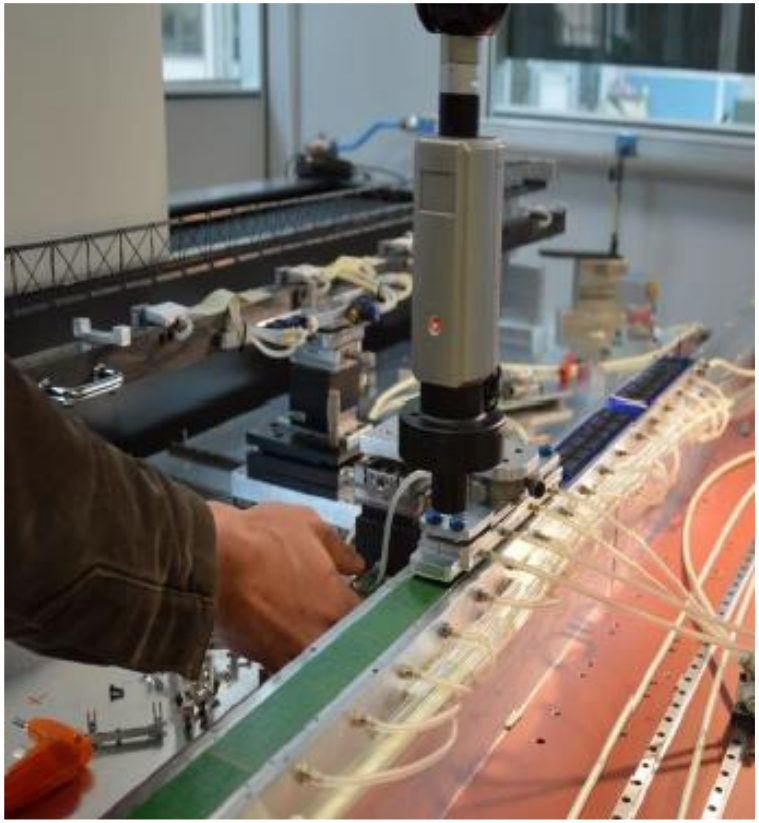


LAPP coordinates firmware development

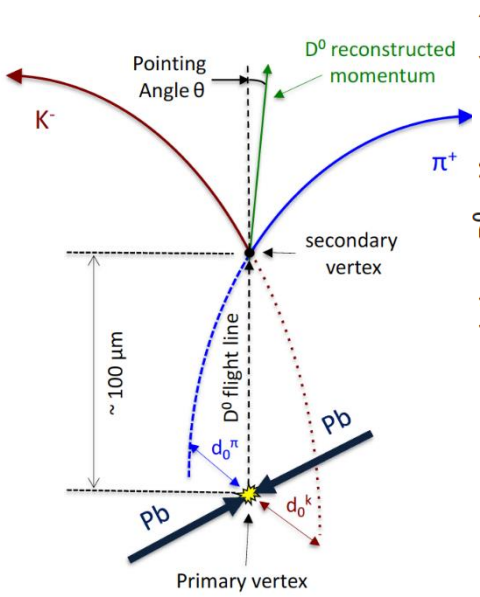
IPMC : ATCA controller card developed at LAPP

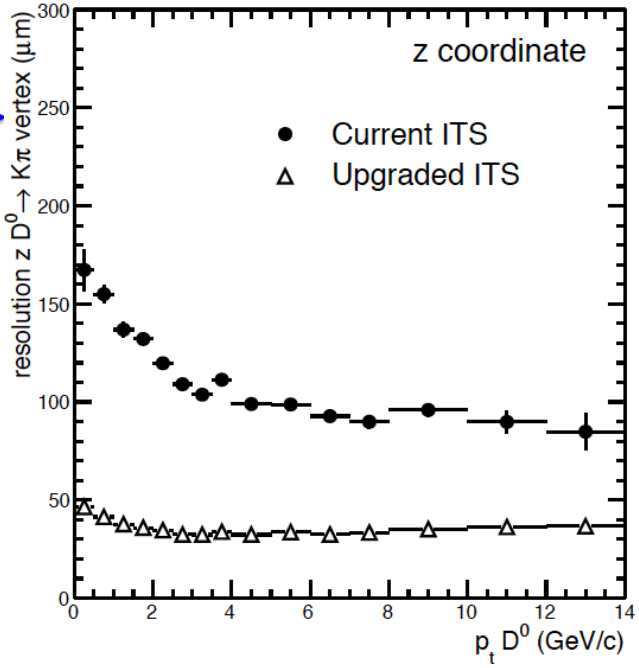
ATLAS LAr Electronics upgrade 2024-2025: back-end & calibration card

ALICE Tracking Upgrade (2019-20)



Goals: improve tracking performance

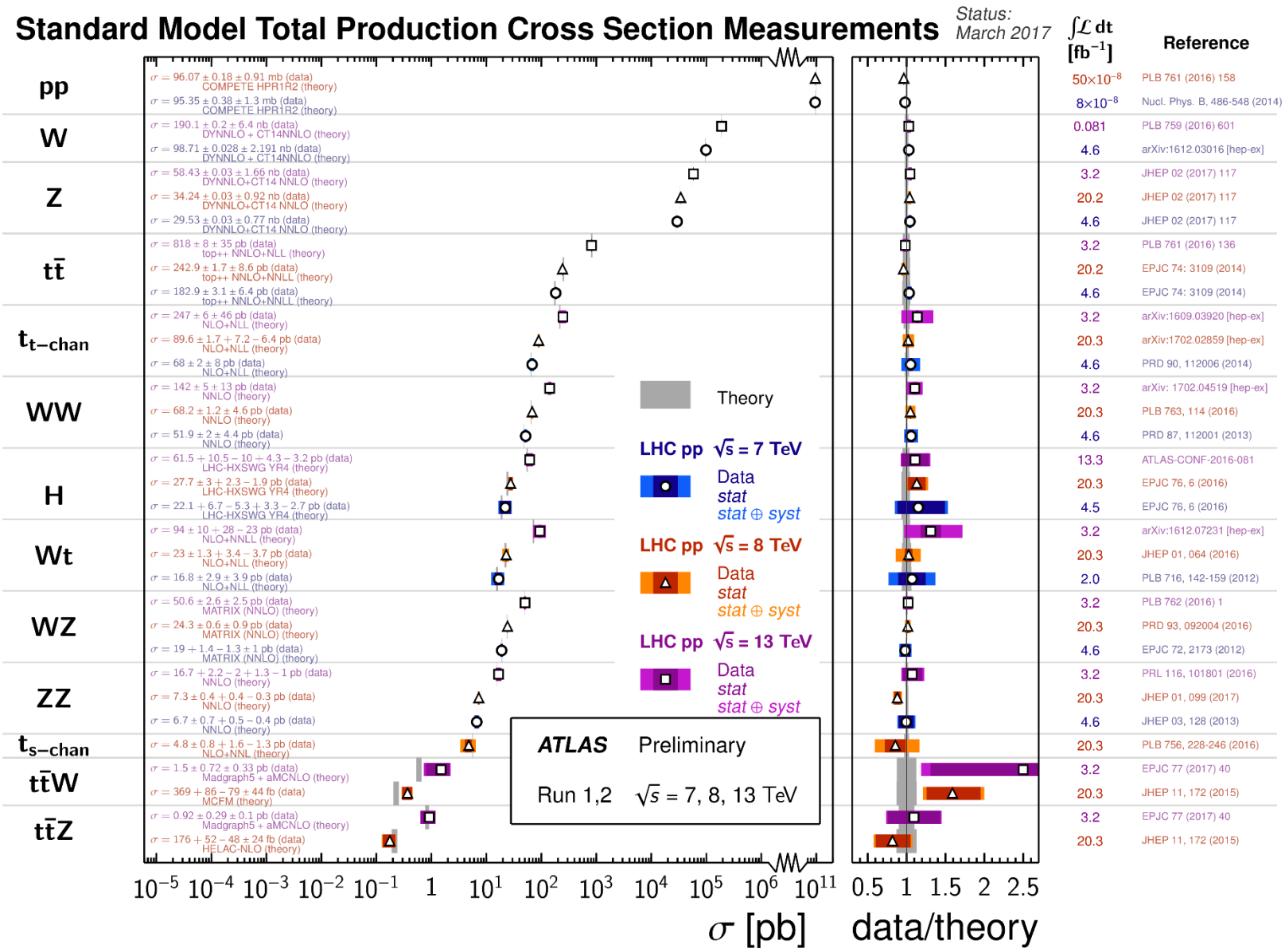




LPSC: Construction of manufacturing molds for staves.
Design and production of the Middle Barrel staves assembly tool.

Potential Synergy with ATLAS Tracking Upgrade in LPSC

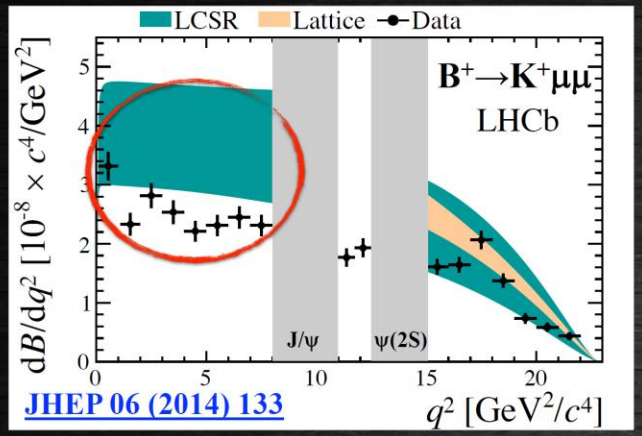
Indirect Searches = Measurements

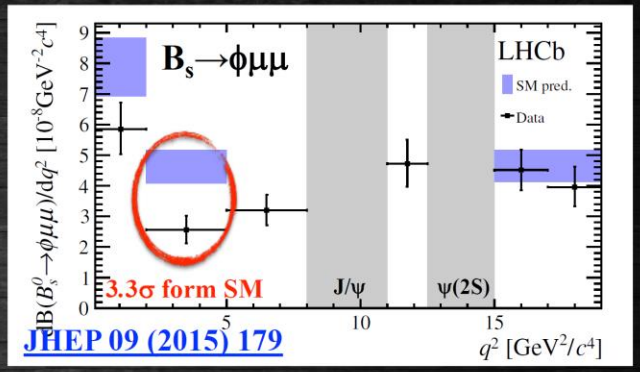


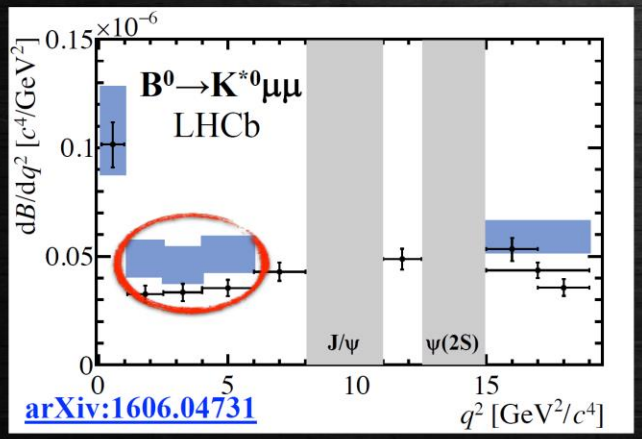
LHCb anomalies (1)

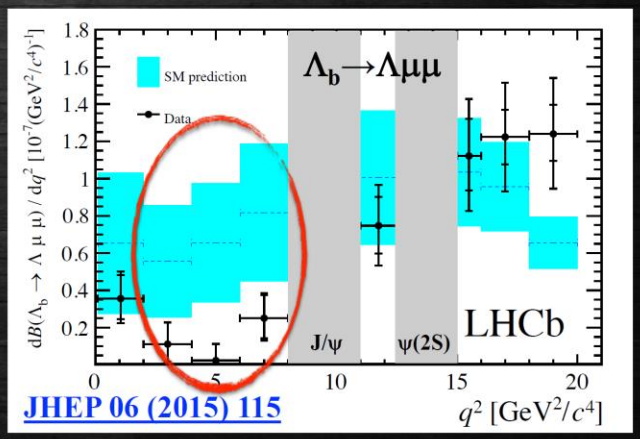
Differential Branching Fractions

› Results **consistently lower than SM predictions**

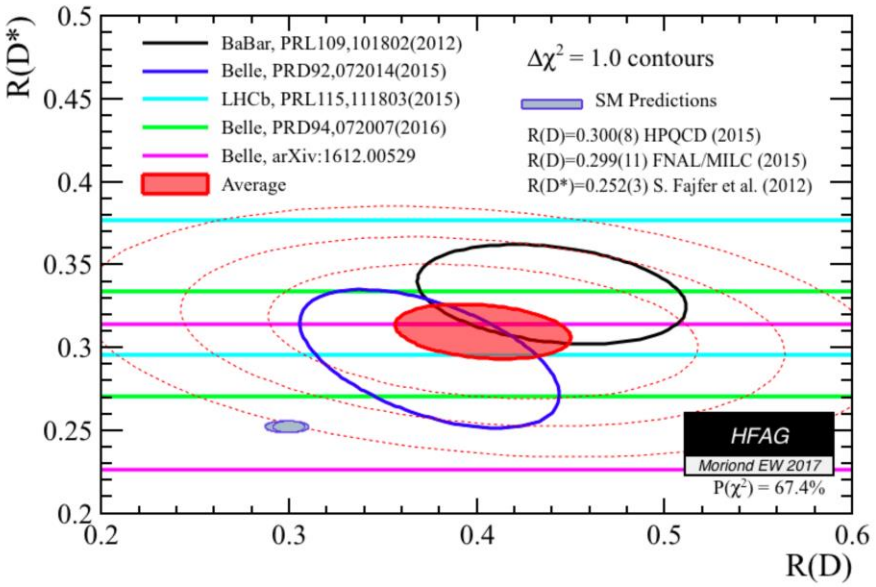


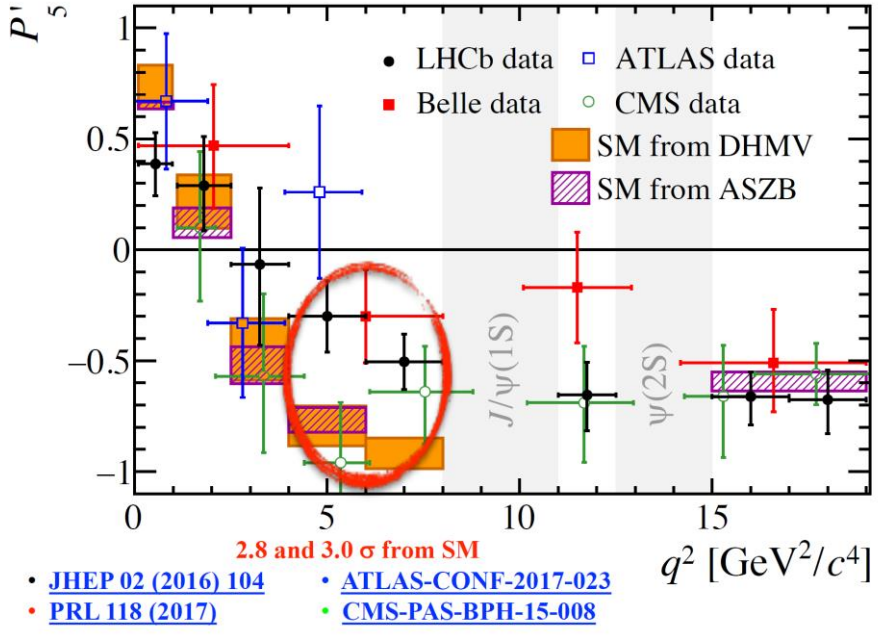




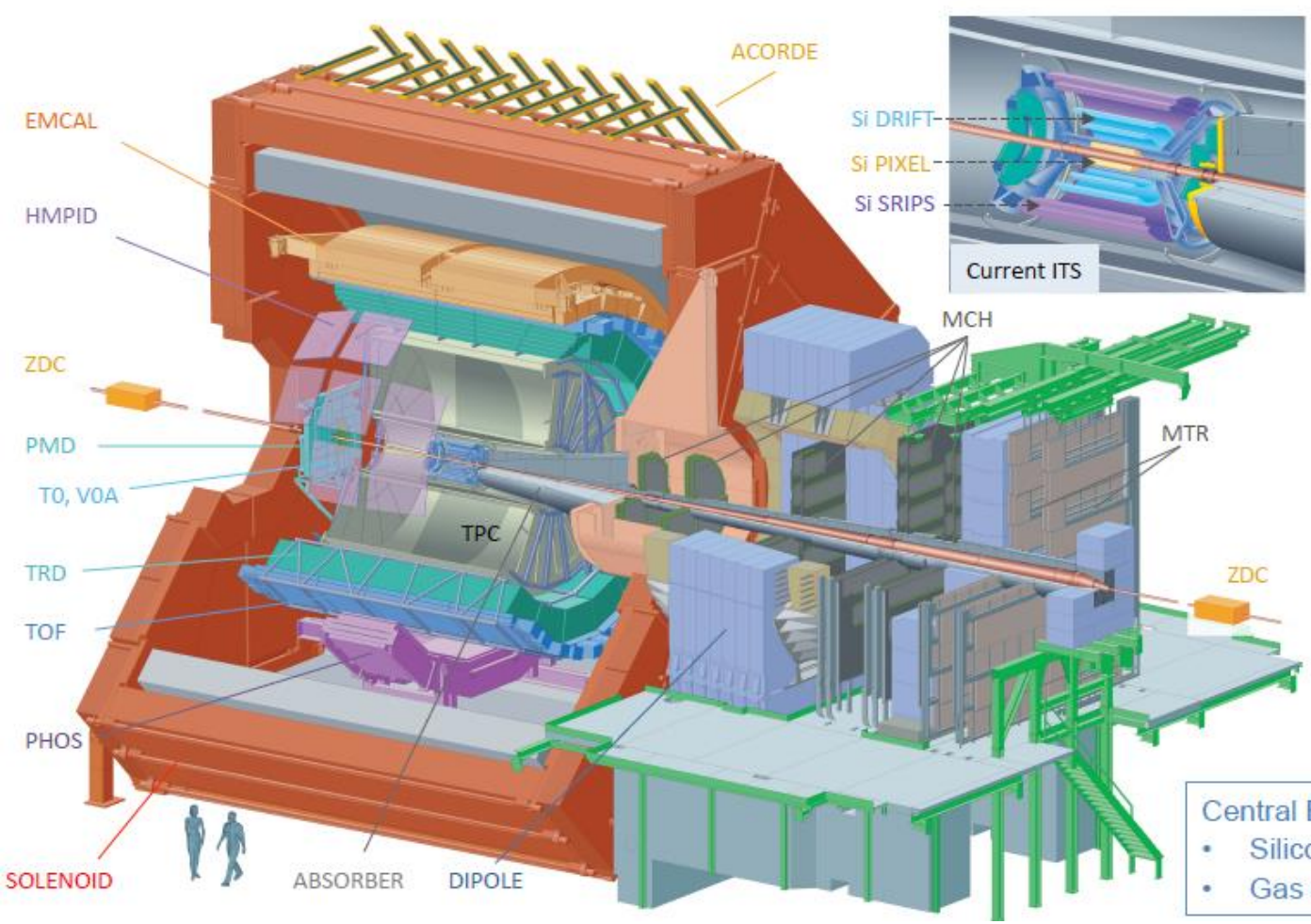


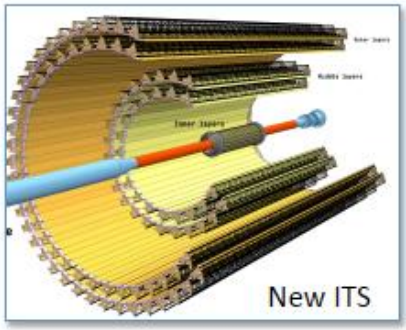
LHCb anomalies (2)





Upgrade d'ALICE run 3&4





Readout rate is currently limited by TPC and ITS (SDD)

~ 1kHz for Pb-Pb

Central Barrel Tracking
- Silicon: 39 – 430 mm
- Gas (TPC, TRD): 88 – 368 cm

- New electronics (TPC, TOF, TRD, Muon spectro…) + New DAQ & HLT (50 kHz Pb-Pb, O2 project)
  - New detectors: Internal Tracking System and MFT (Muon Forward tracking)

Quark Gluon Plasma & ALICE experiment

LPSC team:

- **5 permanents :** G. Conesa-Balbastre (CR), J. Faivre (MdC), C. Furget (PR), R. Guernane (CR), C. Silvestre (CR)
- **4 PhD:** A. Vauthier (UGA), H. Yokoyama (Tsukuba/UGA), R. Hosokawa (Tsukuba/UGA), H. Hassan (Liban/UGA)

Physics goals:

- Study of high density deconfined matter like QGP produced in Pb-Pb collision at LHC provides new constraints on strong interaction at the partonic level (95% of the nucleon mass).
- Study p-p collisions as a baseline for the QGP study and for comparisons with QCD calculations; study cold nuclear effect study in p-Pb collisions
- Favoured topics: study of parton energy loss in QGP through jets production and photon-hadron correlations

Technical involvement:

- Electromagnetic calorimeter: assembly, energy calibration, Level 1 trigger, reconstruction+analysis

Projects for run 3&4:

- ALICE upgrade during LS2: improve the tracking performance and increase the statistics by 10
- New jet observables, study of in-medium energy loss for heavy flavours and precise measurements of the parton energy loss through jet-jet and photon-hadron/jet correlations