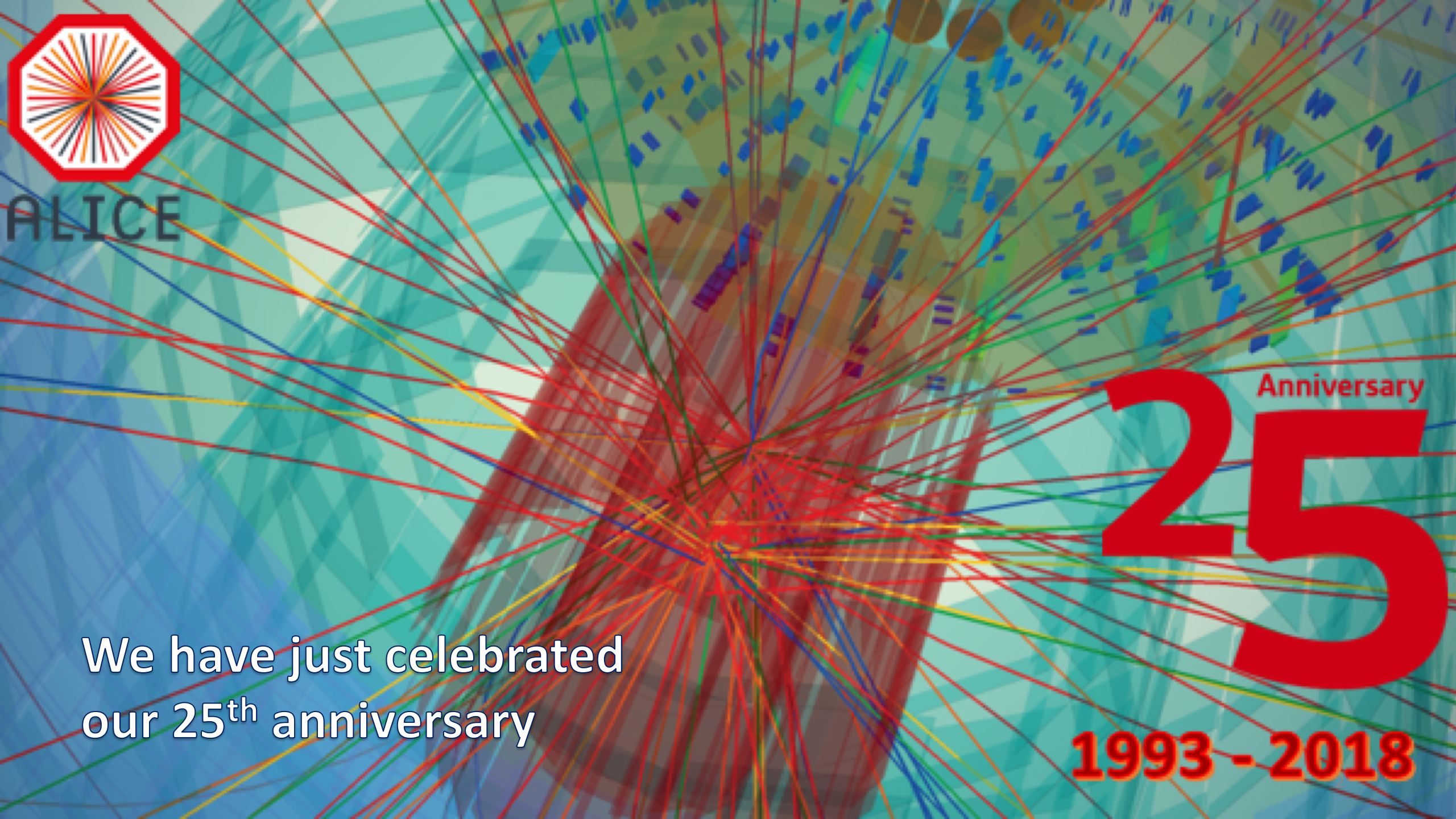
ALICE Upgrades for Run3 and Physics Projections

Wladyslaw H. Trzaska on behalf of the ALICE Collaboration

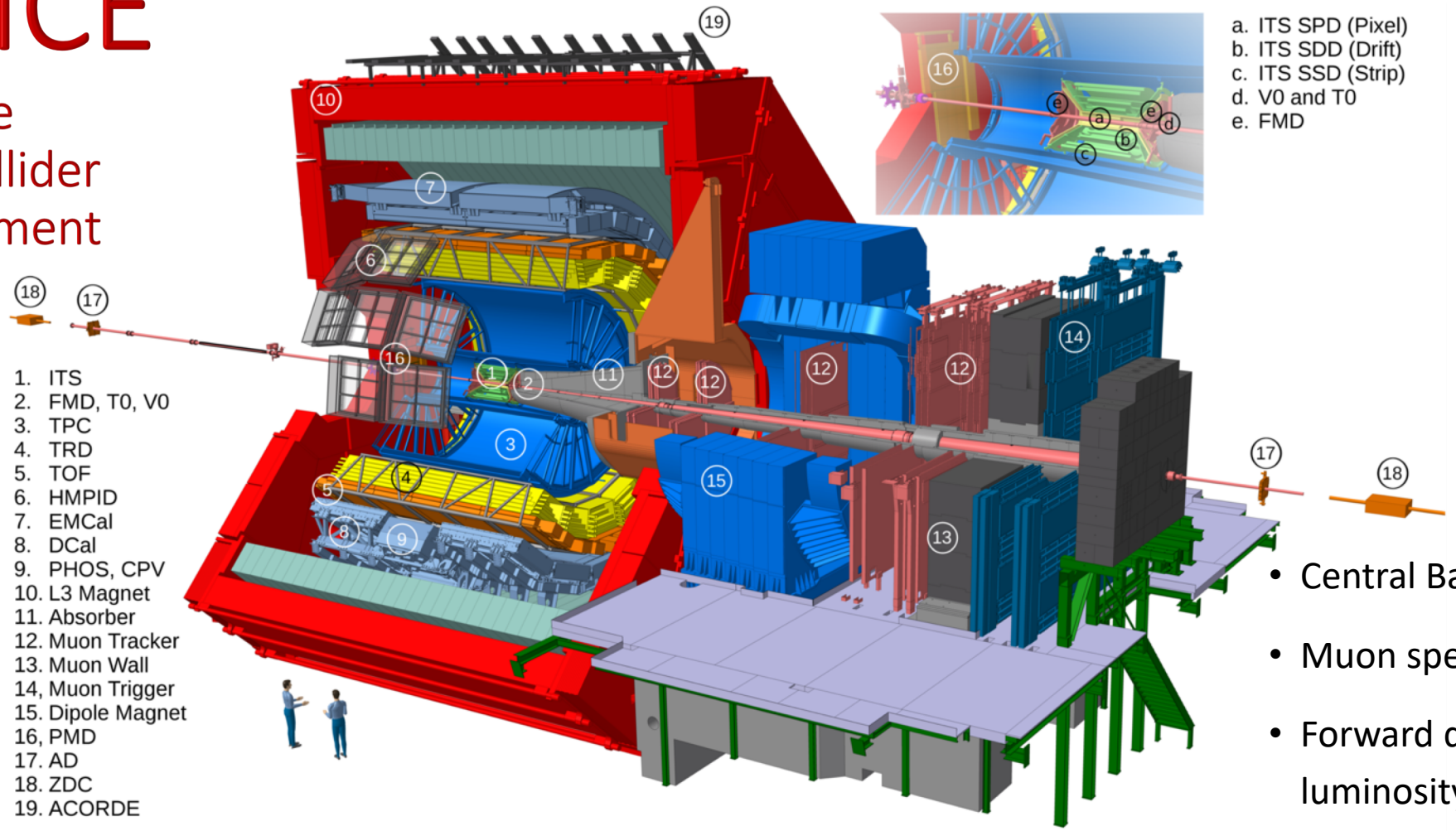
UNIVERSITY OF JYVÄSKYLÄ



We have just celebrated
our 25th anniversary

ALICE

A Large Ion Collider Experiment



Run 1 (2009 – 2013)
Pb-Pb @ $\sqrt{s_{NN}}$ = 2.76 TeV
p-Pb @ $\sqrt{s_{NN}}$ = 5.02 TeV
pp @ $\sqrt{s}$ = 0.9, 2.76, 7, 8 TeV

Run 2 (2015 – 2018)
Pb-Pb @ $\sqrt{s_{NN}}$ = 5.02 TeV Xe-Xe @ $\sqrt{s_{NN}}$ = 5.44 TeV
p-Pb @ $\sqrt{s_{NN}}$ = 5.02, 8.16 TeV
pp @ $\sqrt{s}$ = 5, 13 TeV

- Central Barrel: $-0.9 < \eta < 0.9$
- Muon spectrometer: $-4.0 < \eta < -2.5$
- Forward detectors: trigger, centrality, luminosity, reaction plane

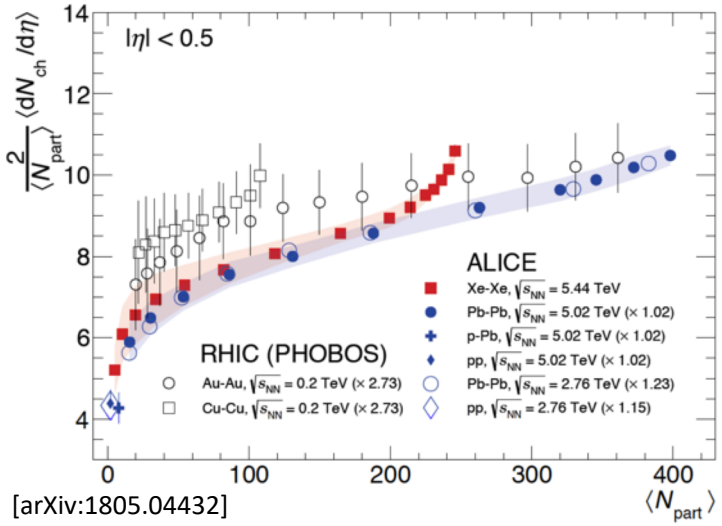
Operation in Run 1 and Run 2

- Tracking & PID in large kinematic range
- High resolution vertex reconstruction

A few physics highlights

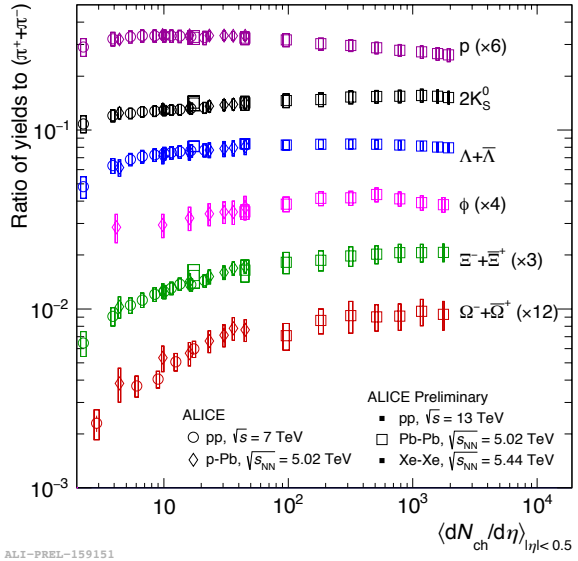
https://qm2018.infn.it

Scaling violations in ⟨dN/dη⟩ in Xe-Xe



[arXiv:1805.04432]

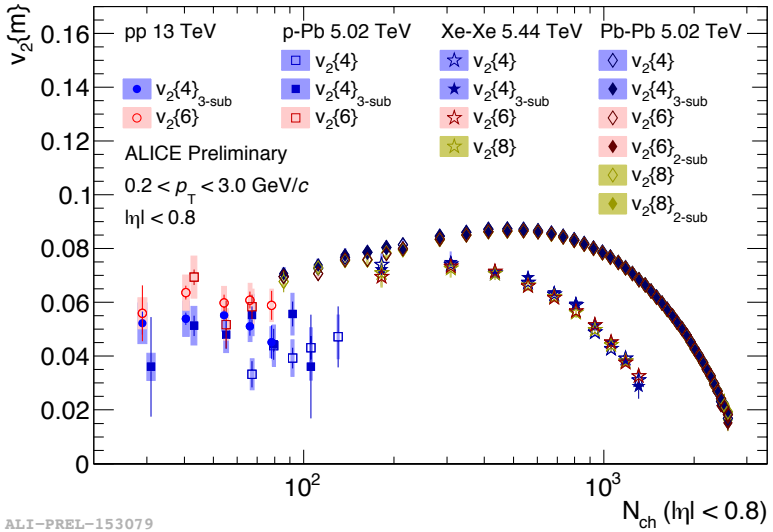
Particle chemistry across system size



ALI-PREL-159151

35 talks, **99** posters, and **16** new papers at **Quark Matter 2018**

Elliptic flow in different collisions



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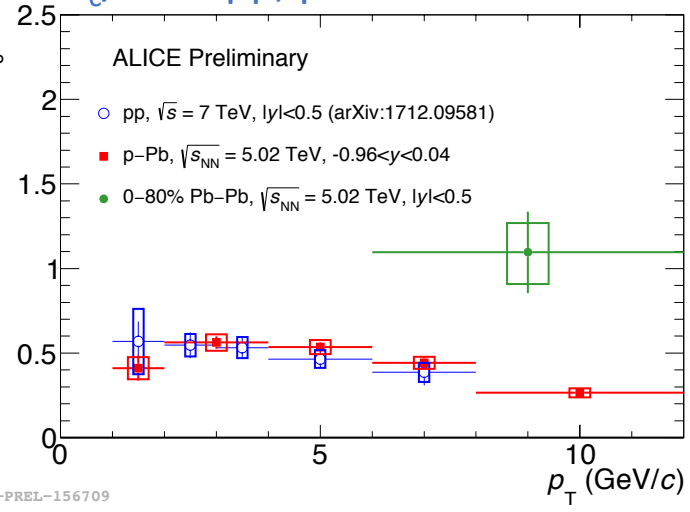
Λ_c/D^0 in pp, p-Pb and Pb-Pb



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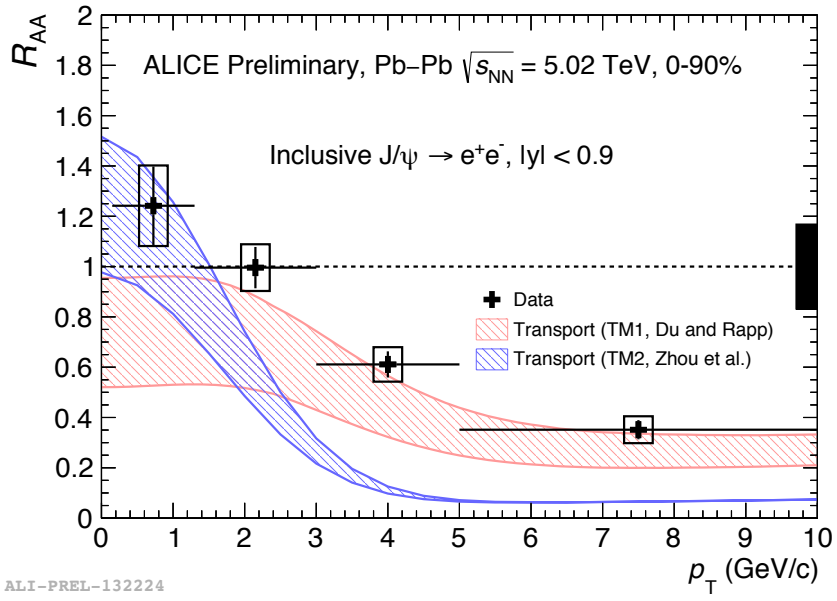
J/Ψ R_{AA} vs p_T



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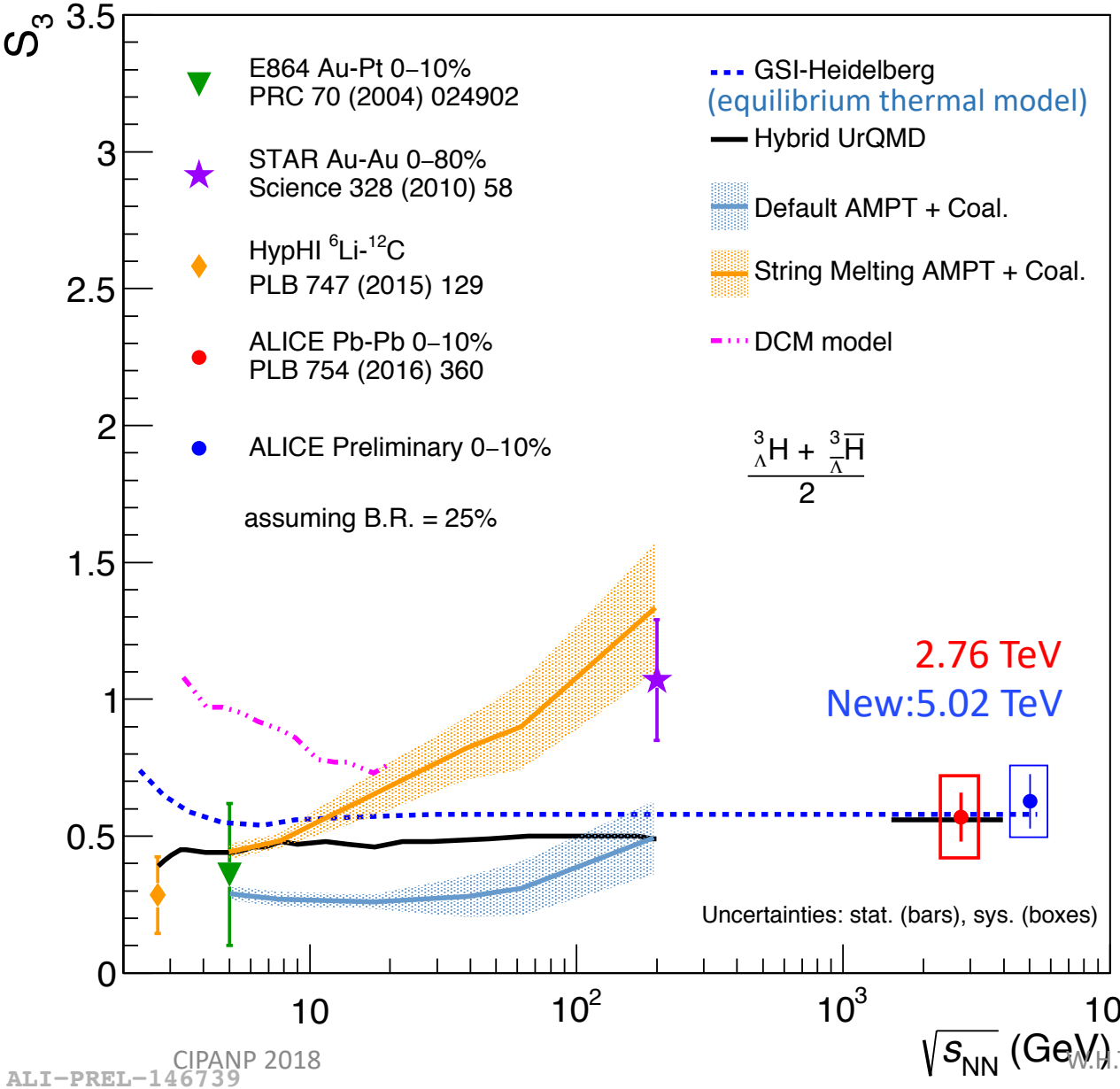
recombination of heavy quarks in the QGP

(anti-)hyper-triton in Pb-Pb collisions at 5.02 TeV



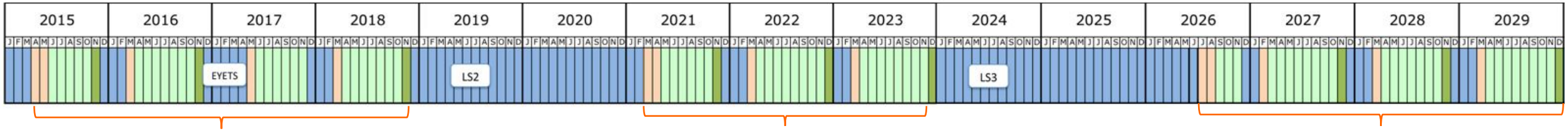
anti-hyper-triton

Strangeness population factor*:

$$S_3 = \frac{^3_\Lambda\mathrm{H}}{^3\mathrm{He}}\frac{p}{\Lambda}$$

***) E864 Collaboration, T. A. Armstrong et al. Phys. Rev. C 70, 024902 (2004)**
S. Zhang et al. Phys. Lett. B 684, 224-227 (2010)

LHC timeline for ALICE



Run 2: $\mathcal{L}_{Pb\text{-}Pb}$ = 1.0 nb^{-1}

Run 3: $\mathcal{L}_{Pb\text{-}Pb}$ = 6.0 nb^{-1}

Run 4: $\mathcal{L}_{Pb\text{-}Pb}$ = 7.0 nb^{-1}

ALICE strategy for Run 3 + Run 4:

- 50 kHz Pb-Pb interaction rate (now <10 kHz)
- Experiment upgrades (LS2)
- Collect $\mathcal{L}_{Pb\text{-}Pb}$ = 13 nb^{-1}

ALICE physics goals

- Heavy-flavour mesons and baryons (down to very low p_T) → mechanism of quark-medium interaction
- Charmonium states → dissociation/regeneration as tool to study de-confinement and medium temperature
- Di-leptons from QGP radiation and low-mass vector mesons → χ symmetry restoration, initial temperature and EOS
- High-precision measurement of light and hyper-nuclei → production mechanism and degree of collectivity
- Need MB readout at highest possible rate → no dedicated trigger possible

Upgrade Implementation

Un-triggered data sample

- Run 3 + Run 4: increase MB sample x 50-100 wrt. Run 2
- Write all Pb-Pb interactions at 50 kHz

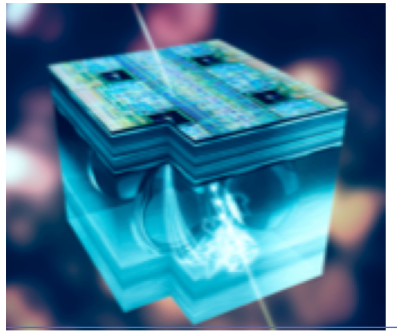
Improve tracking efficiency and resolution at low p_T

- Increase tracking granularity
- Reduce material thickness
- Minimize the distance to IP

Preserve particle identification (PID)

- Consolidate and speed-up main ALICE PID detectors

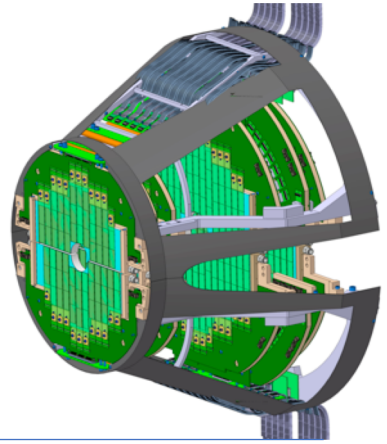
Key ALICE upgrades for Run 3



New Inner Tracking System (ITS)

-CMOS pixel, MAPS technology

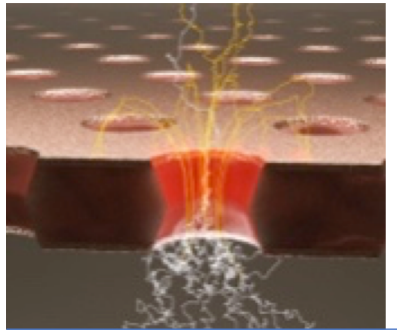
-Improved resolution, less material, faster readout



New Muon Forward Tracker (MFT)

-CMOS Pixels, MAPS technology

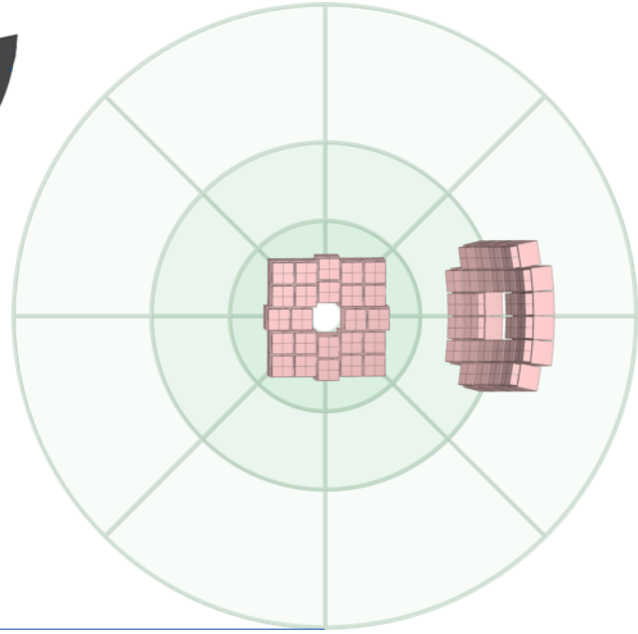
-Vertex tracker at forward rapidity



New TPC Readout Chambers (ROCs)

-Gas Electron Multiplier (GEM) technology

-New electronics (SAMPA), continuous readout



New Fast Interaction Trigger (FIT) Detector

-Centrality, event plane, luminosity, interaction time

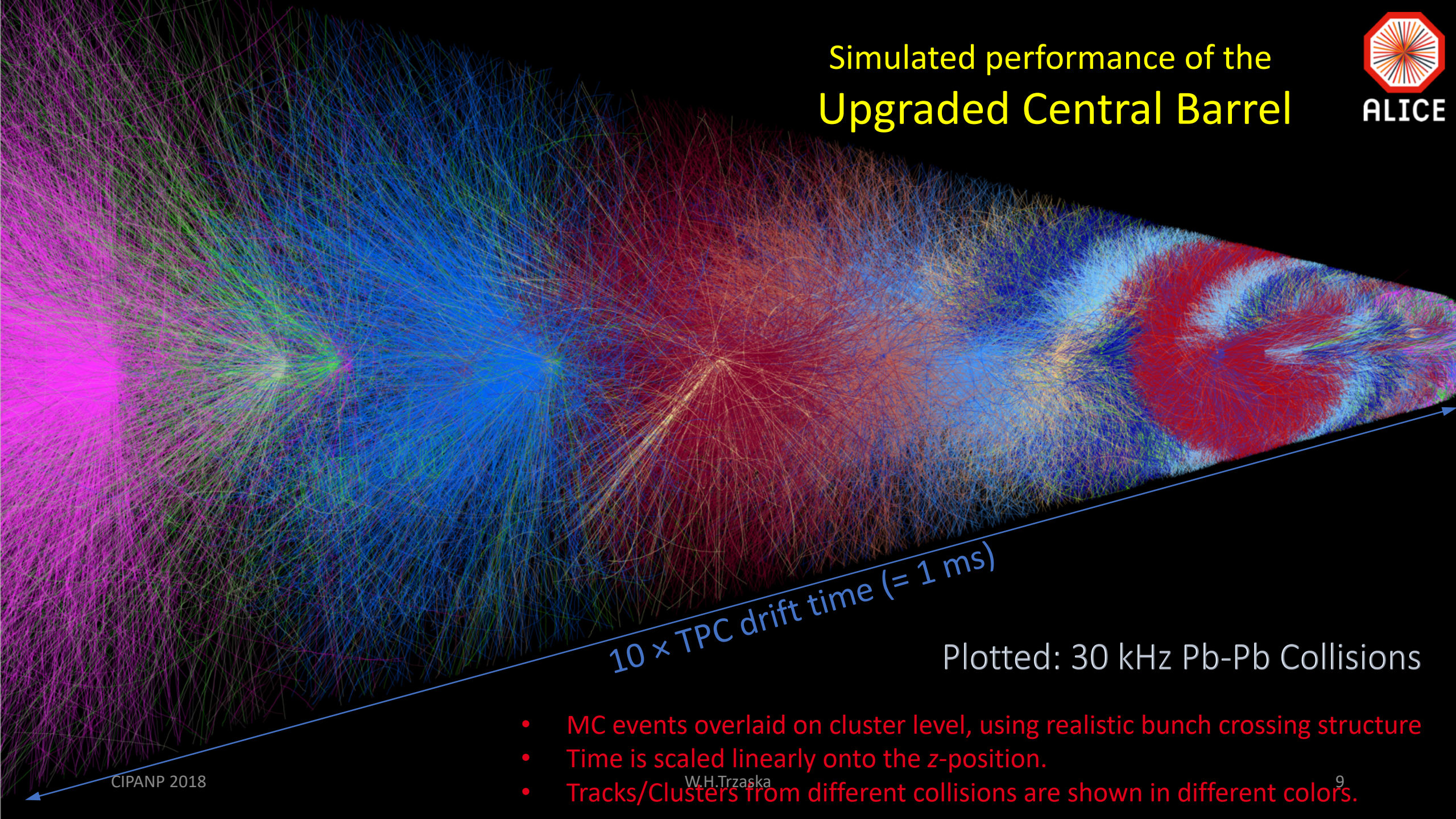
Readout upgrade

-TOF, TRD, MUON, ZDC, Calorimeters

Integrated Online-Offline system (O^2)

-Record MB Pb-Pb data at 50 kHz

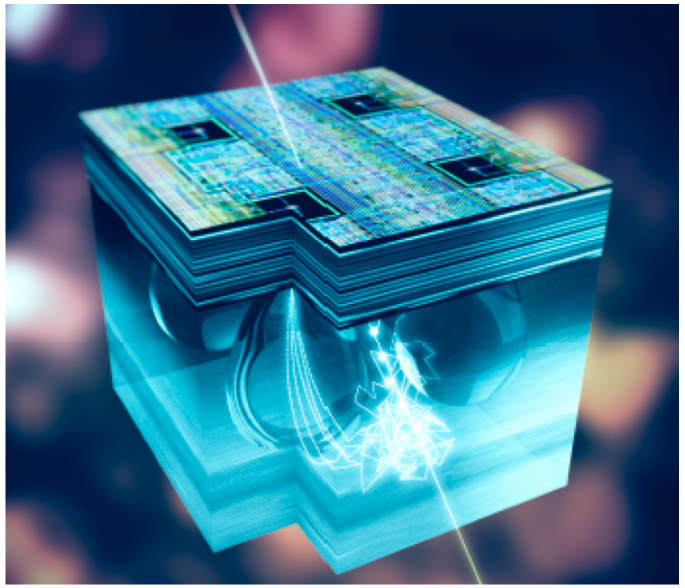
Simulated performance of the Upgraded Central Barrel

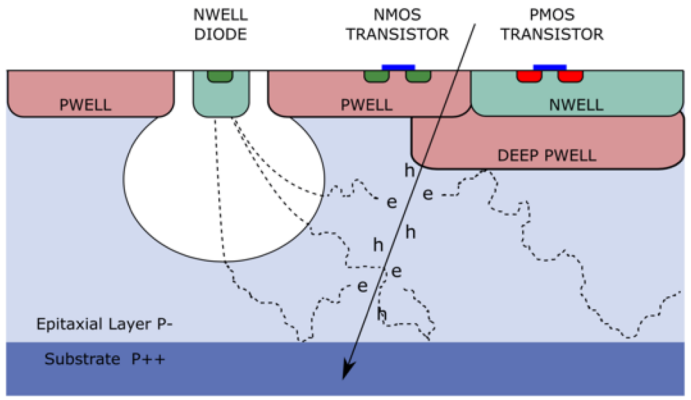


- MC events overlaid on cluster level, using realistic bunch crossing structure
- Time is scaled linearly onto the *z*-position.
- Tracks/Clusters from different collisions are shown in different colors.

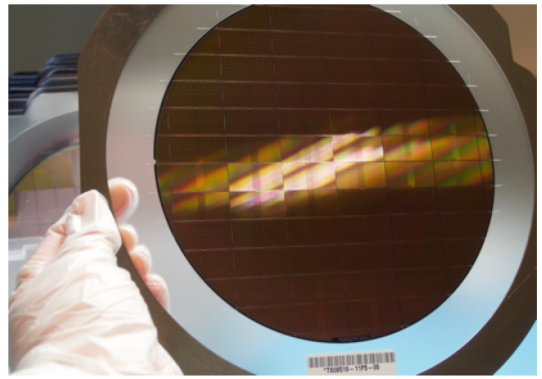
ALIPIDE is the core of the new ITS & MFT

CMOS Monolithic Active Pixel Sensors

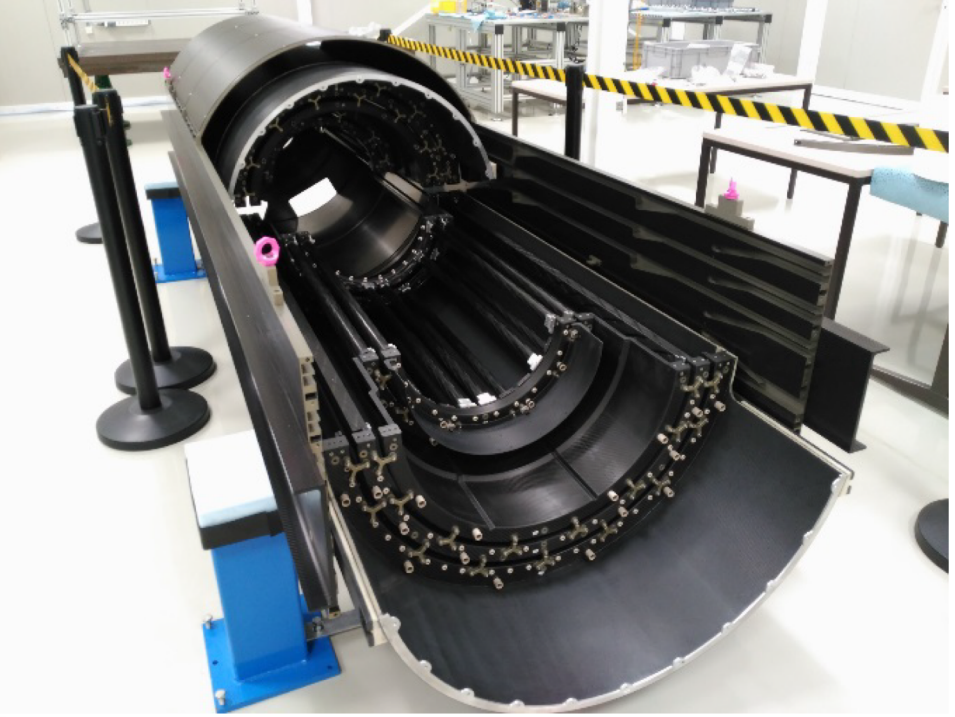




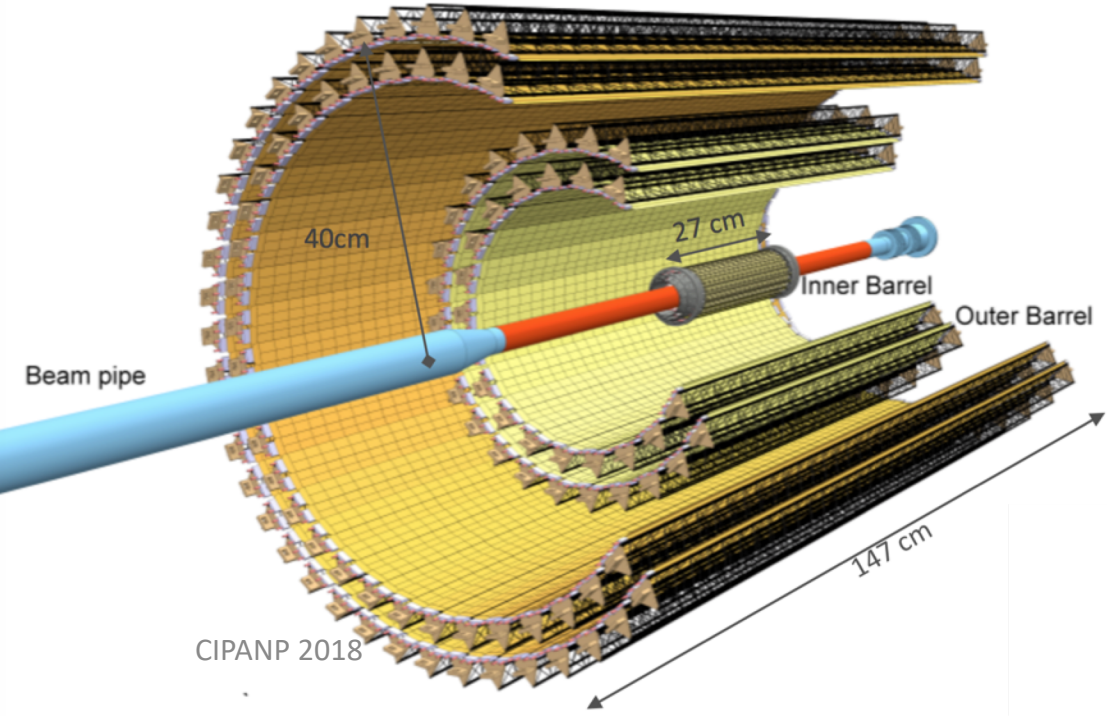
- TowerJazz 180 nm technology
- Primary electron collection efficiency 100%
- Pixel pitch: 29 × 27 µm^2



- **Low power consumption ~40 mW/cm^2**
- **Input capacitance C_{in} = 5 fF**
- **Input charge Q_{in}(MIP) = 1300 e ⟶ V = 40 mV**
- **Spatial resolution 5 µm**
- Event time resolution < 1 µs
- Radiation hardness:
  expected in Run 3 and 4 < 300 krad (< 2.0 × 10^{12} 1 MeV n_{eq}/cm^2)



Dry assembly and insertion tests: Outer Barrel



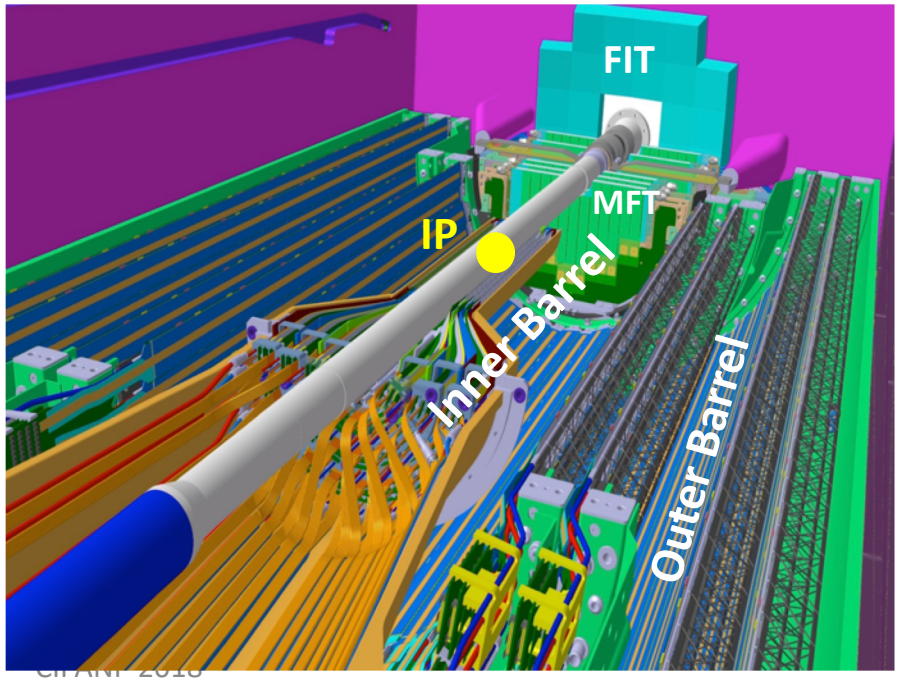
The new Inner Tracking System

10 m^2 active silicon area, 12.5×10^9 pixels

- Closer to IP: 39 mm ⟶ 22 mm
- Thinner (X_0 for each innermost layer): ~1.14 % ⟶ ~0.30 %
- Smaller pixels: 50 × 425 µm^2 ⟶ 27 × 29 µm^2
- Granularity: 20 ch/cm^3 ⟶ 2000 pixels/cm^3
- Readout rate: 1 kHz ⟶ 100 kHz
- 130 000 pixels/cm^2
- Max. particle rate: ~100 MHz/cm^2
- Spatial resolution: ~5 µm

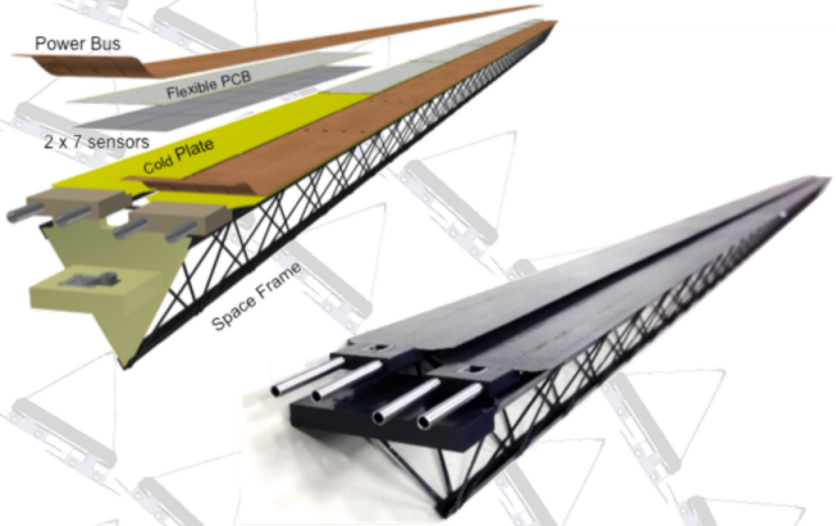
ITS Layout

- 7 layers (inner/middle/outer): 3/2/2
  from R = 22 mm to R = 400 mm
- 192 staves (IL/ML/OL): 48/54/90
- Ultra-lightweight support structure and cooling
- Possible to remove and re-install the detector for maintenance during the yearly shutdowns



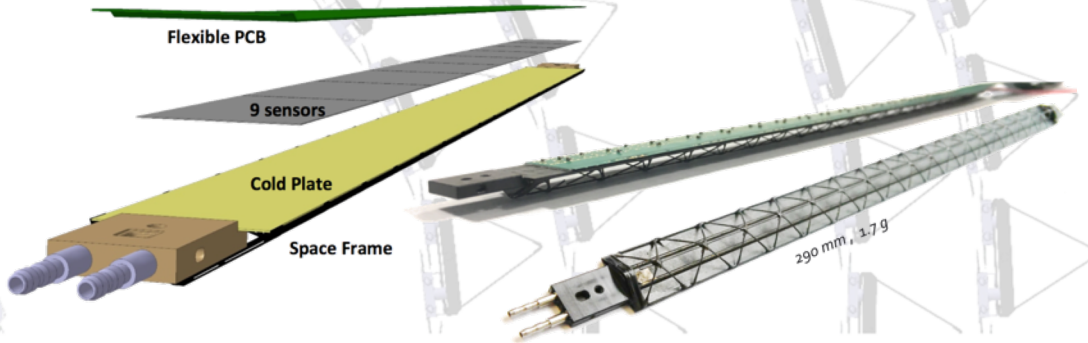
Outer Barrel Staves

OL



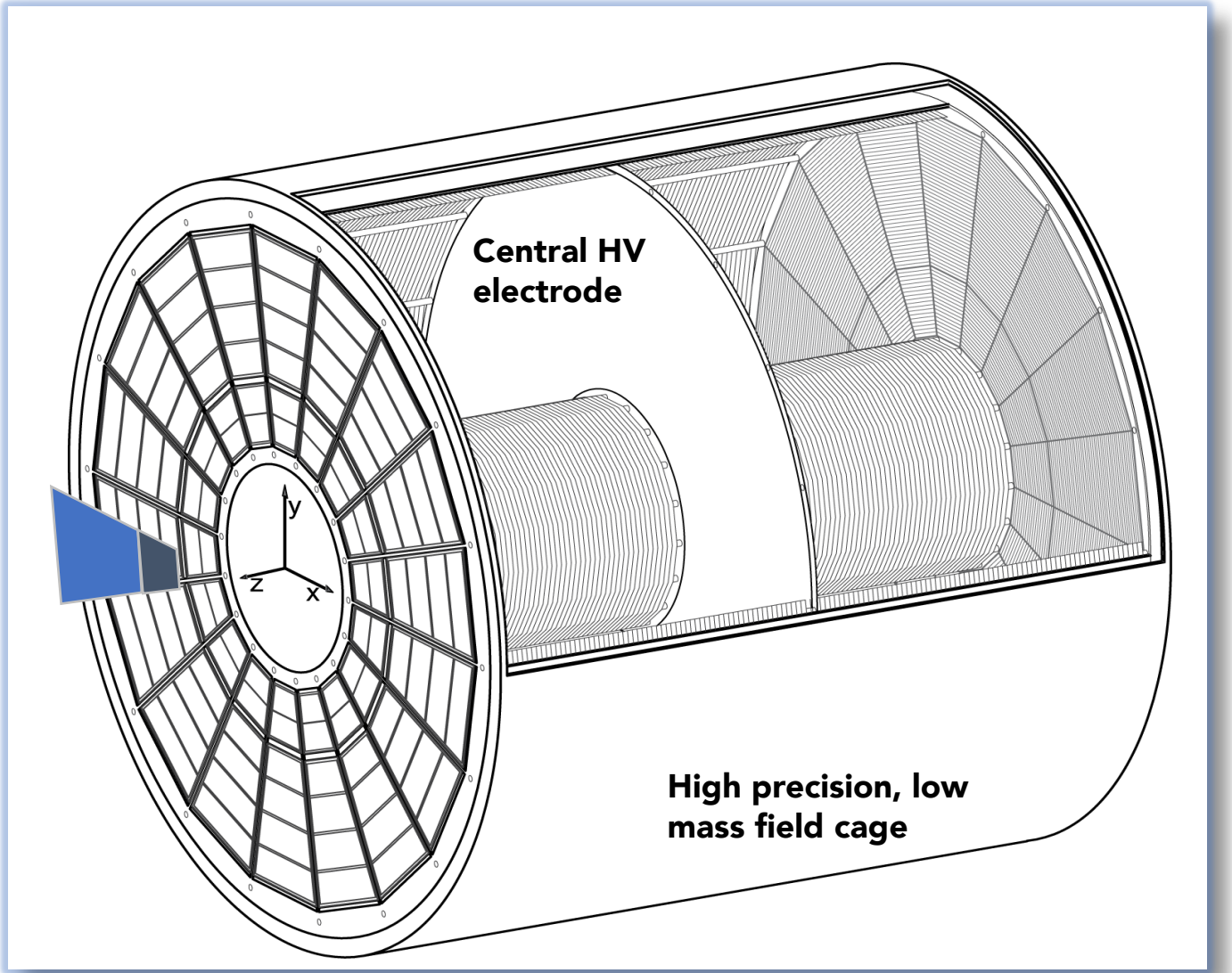
ML

Inner Barrel Staves



IL

ALICE Time Projection Chamber



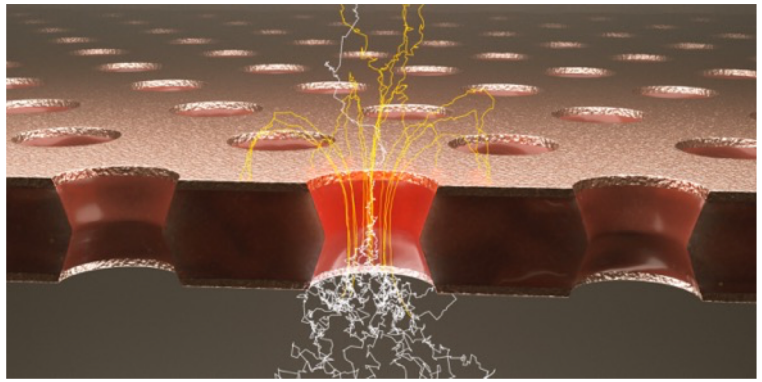
- Diameter: 5 m, length: 5 m
- Gas: Ne-CO_2-N_2, Ar-CO_2
- Max. drift time: ~100 µs
- 18 sectors on each side
- Inner and outer readout chambers: IROC, OROC

- Current detector (Run 1, Run 2):
  - 72 MWPCs
  - ~550 000 readout pads
  - Wire gating grid (GG) to minimize Ion Back-Flow (IBF)
  - Rate limitation: few kHz

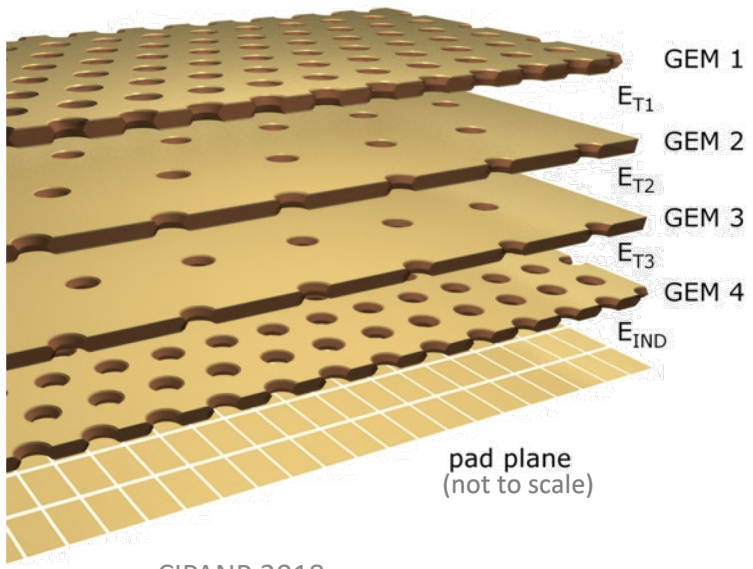
Operate TPC at 50 kHz ⟶ no gating grid

Continuous Readout with GEMs

TPC Upgrade requirements:

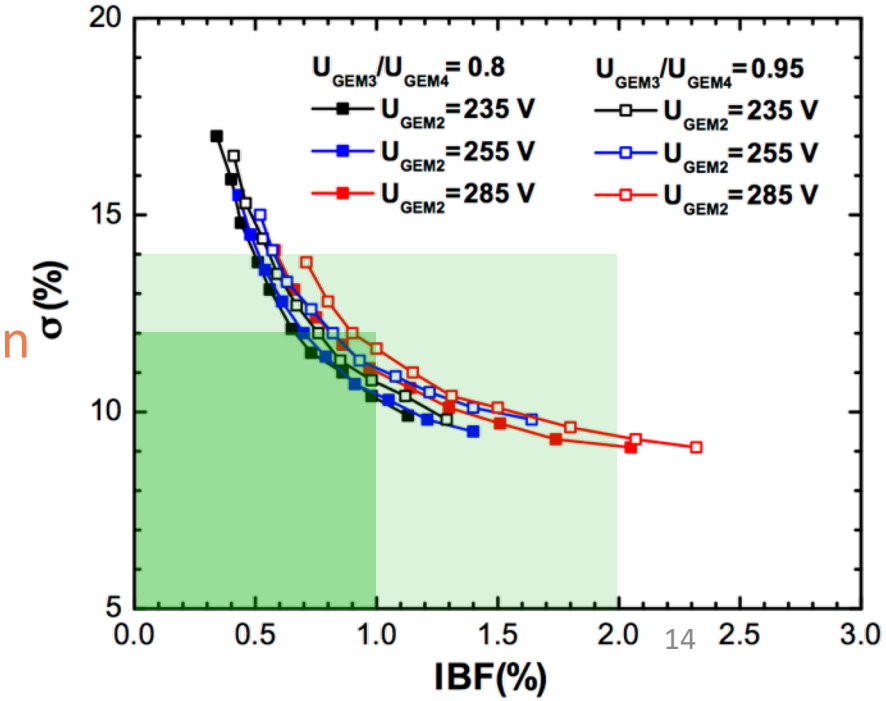


- Nominal gain = 2000 in Ne-CO_2-N_2 (90-10-5)
- IBF < 1% (ε = 20)
- Energy resolution: σ_E/E < 12% for ^{55}Fe
- Stable operation under LHC Run 3 conditions
- Unprecedented challenges in terms of loads and performance



Baseline solution: 4-GEM stack

- Combination of standard (S) and large pitch (LP) GEM foils
- Highly optimized HV configuration
- Result of intensive R&D



Read-Out Chambers (ROCs)

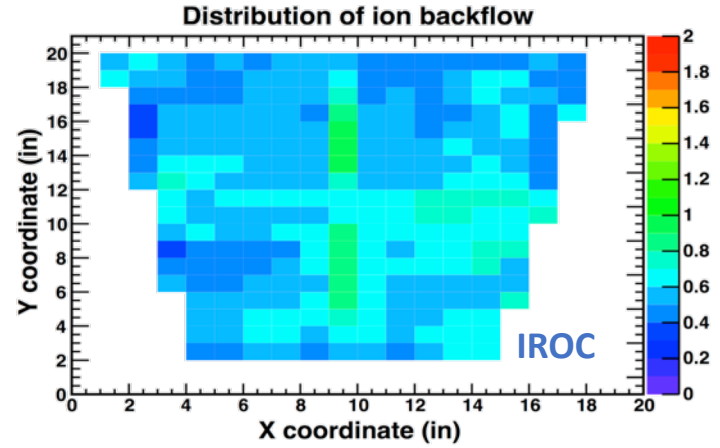
- Production of 40 IROCs and 40 OROCs until September 2018

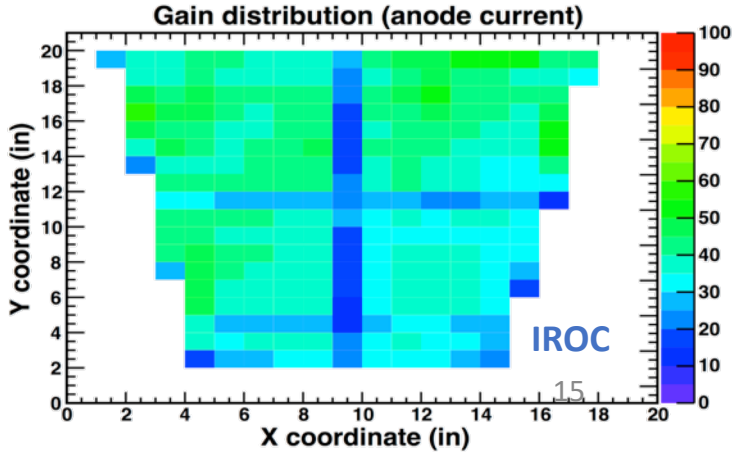
  ROC assembly: Yale (IROC), GSI (OROC), HPD Bucharest (OROC);
  ROC bodies: Heidelberg, Frankfurt, UT Knoxville

- Production of 640 GEM foils and spares finishes within the next weeks

  GEM QA: CERN, Budapest, Helsinki;
  GEM framing: Munich, Bonn, GSI, Wayne State

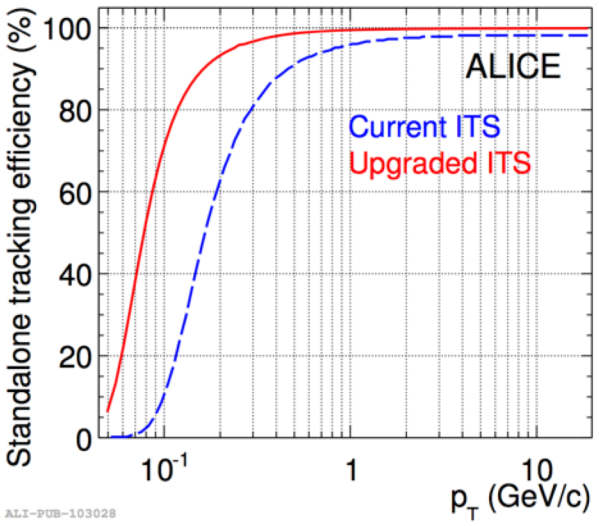
- All chambers thoroughly qualified:
  - Gas tightness
  - Gain and ion backflow uniformity
  - Stability (long-term irradiation with X-rays)
- Selected chambers tested at the LHC

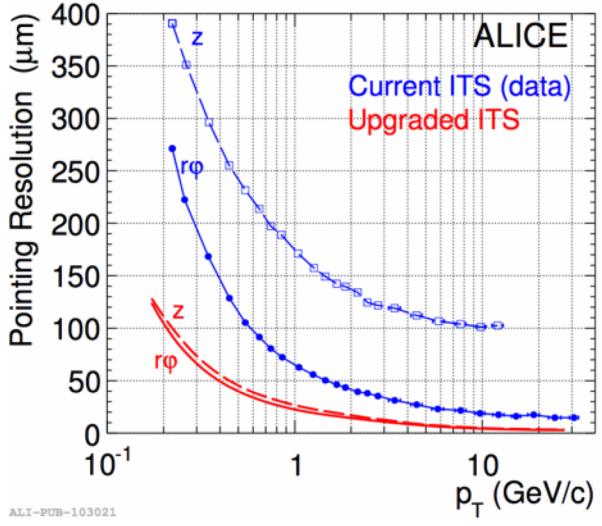




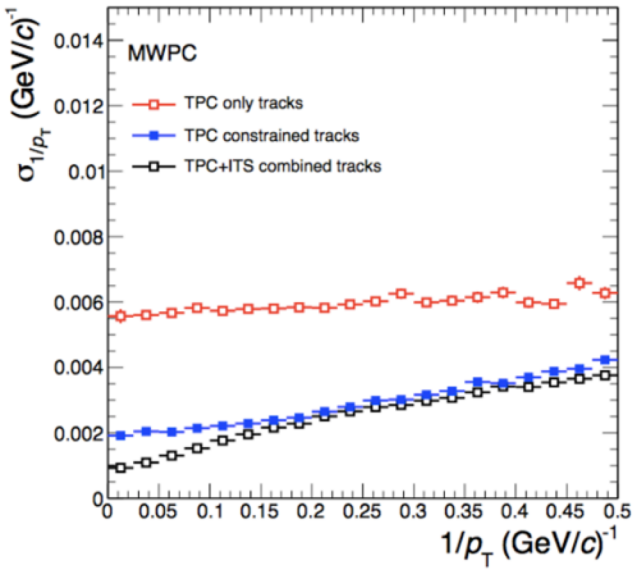
GEM QA in Helsinki

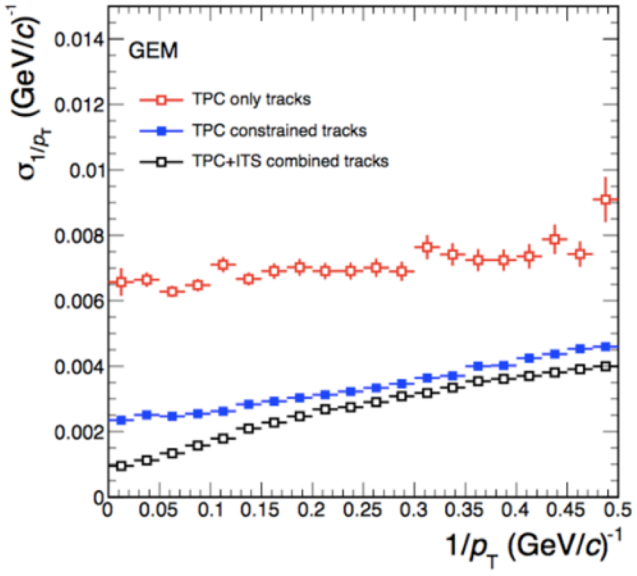
Detector Performance in Run 3 and Run 4





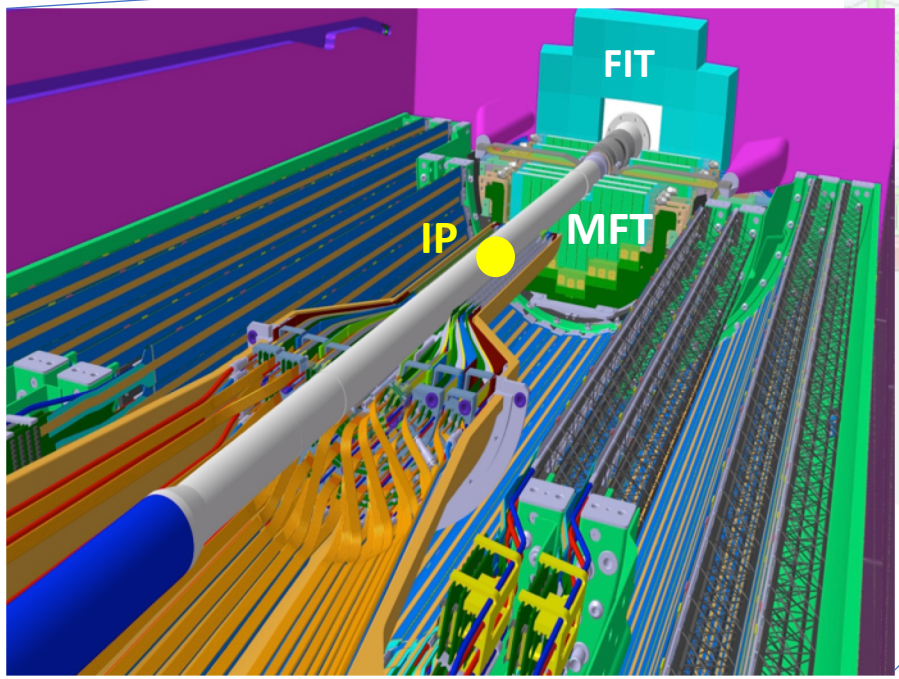
- New ITS
  - Improved tracking efficiency
  - Improved tracking resolution
  - Pointing resolution ×3 better in transverse plane (×6 along beam)

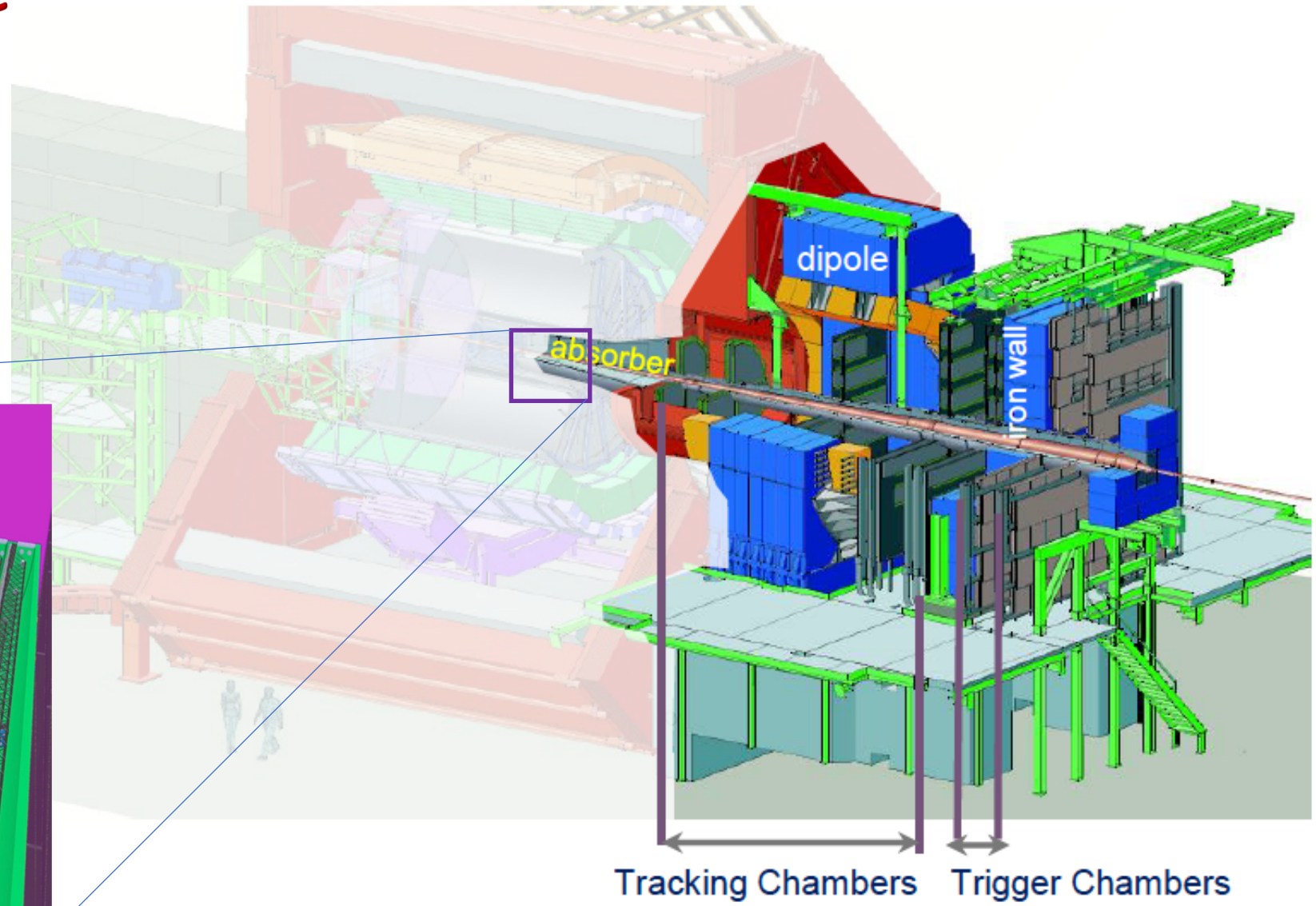




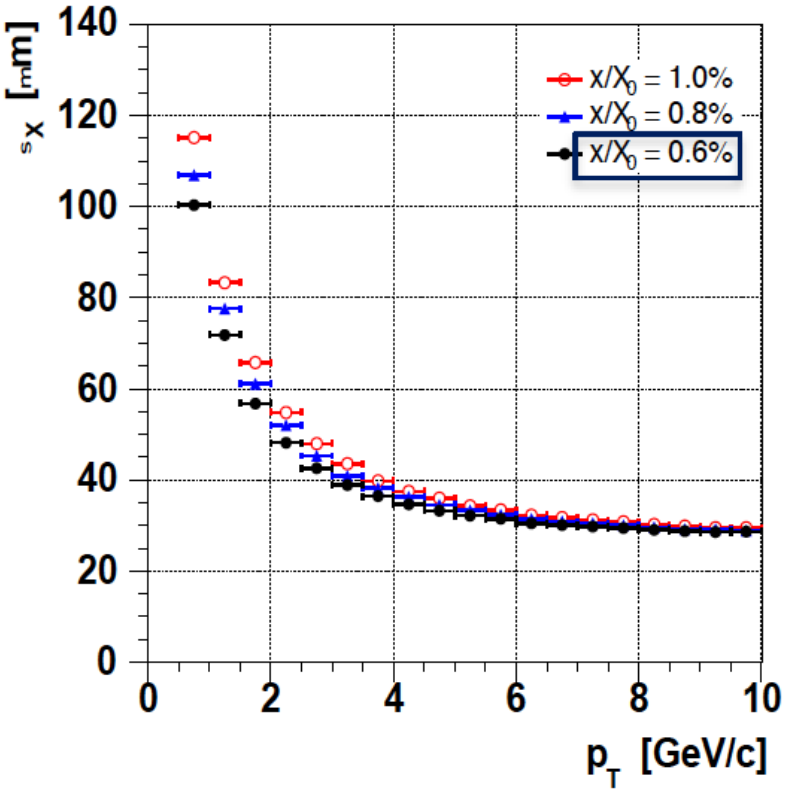
- New TPC Readout Chambers (GEM):
  - Preserve momentum resolution for TPC + ITS tracks
  - Preserve particle identification via d*E*/d*x* (arXiv:1805.03234, submitted to NIM A)

ALICE Upgrade at Forward Rapidity





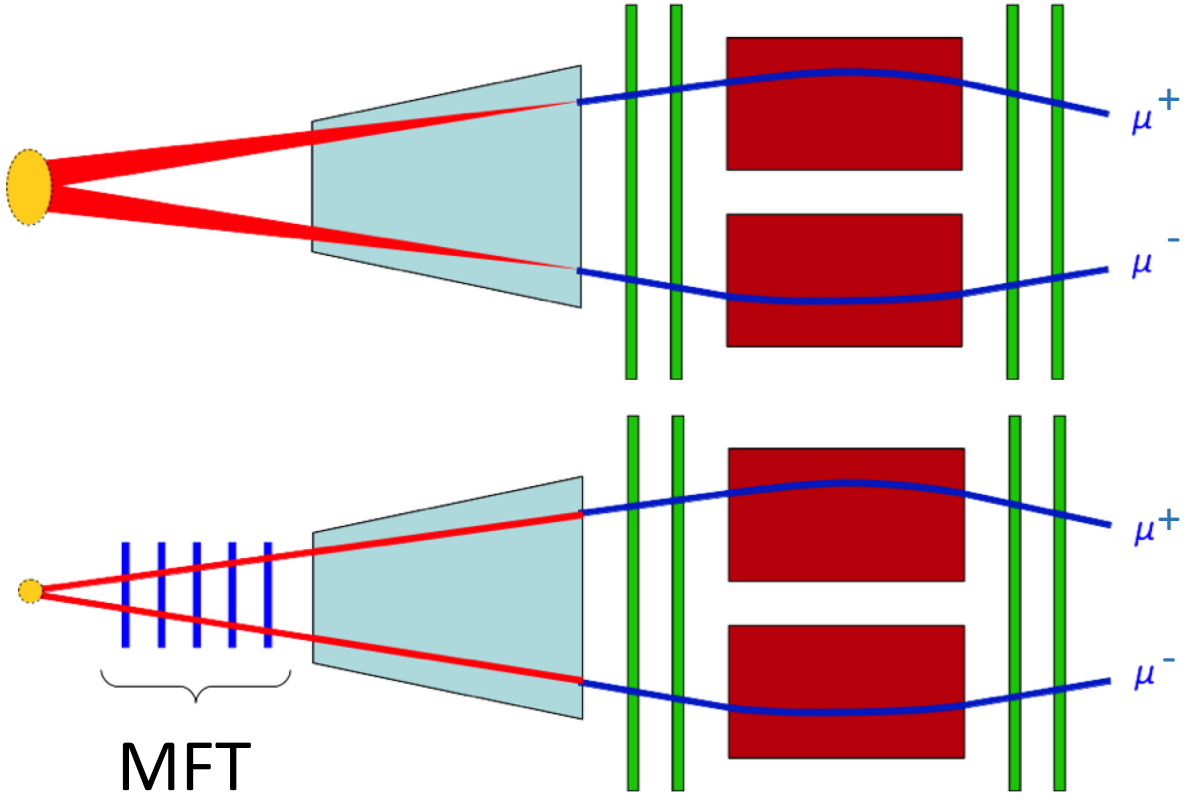
Impact of the Muon Forward Tracker



CERN-LHC-2015-001

Now →

Run3 →



High pointing accuracy gained by matching muon tracks with MFT tracks in the pseudorapidity window of $2.5 < \eta < 3.6$

MFT

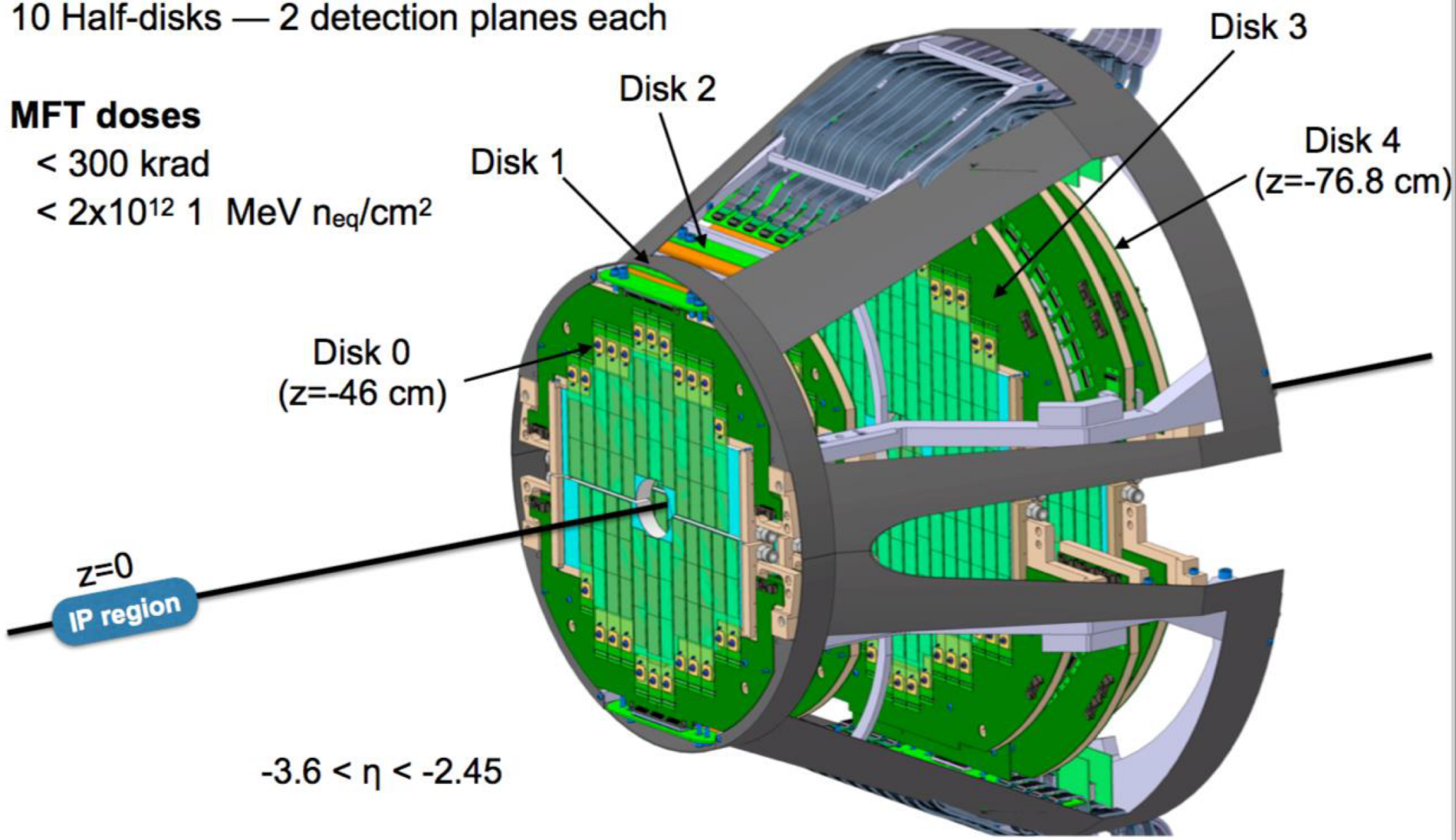
920 silicon pixel sensors (0.4 m²) on 280 ladders of 2 to 5 sensors each

10 Half-disks — 2 detection planes each

MFT doses

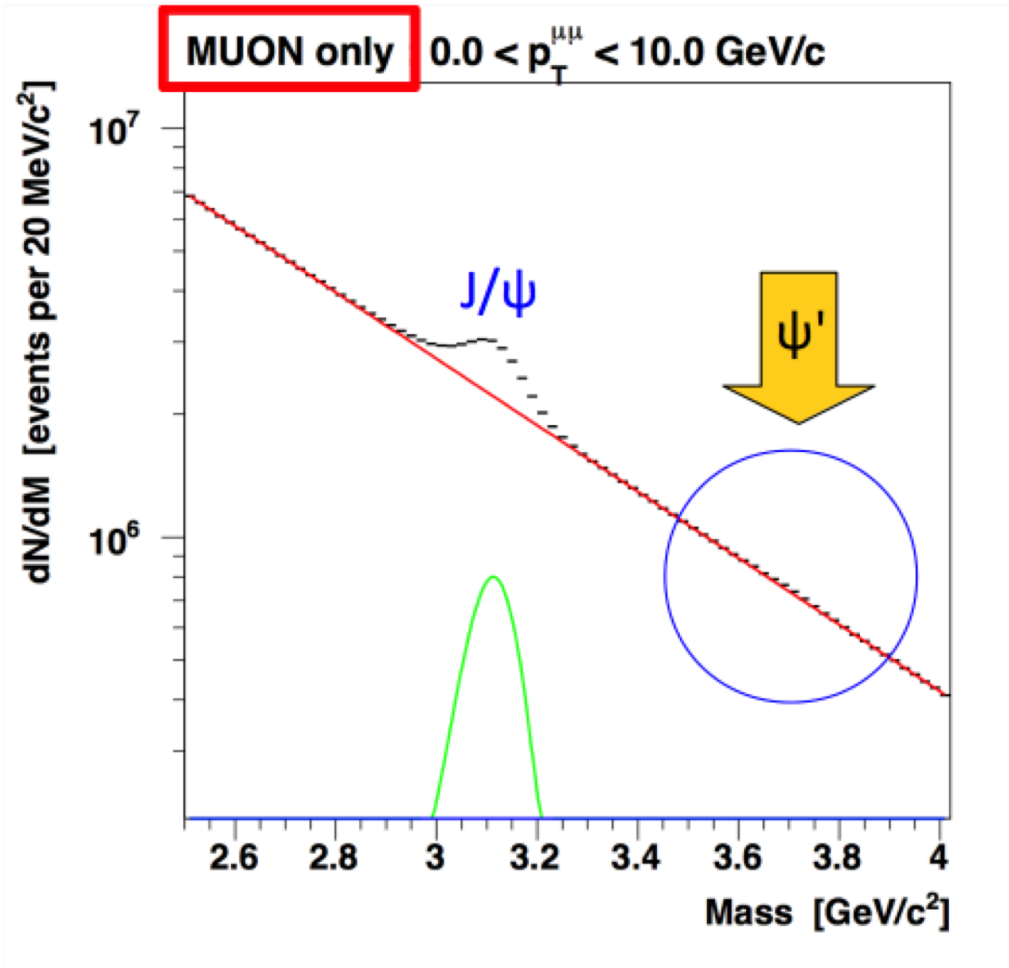
< 300 krad

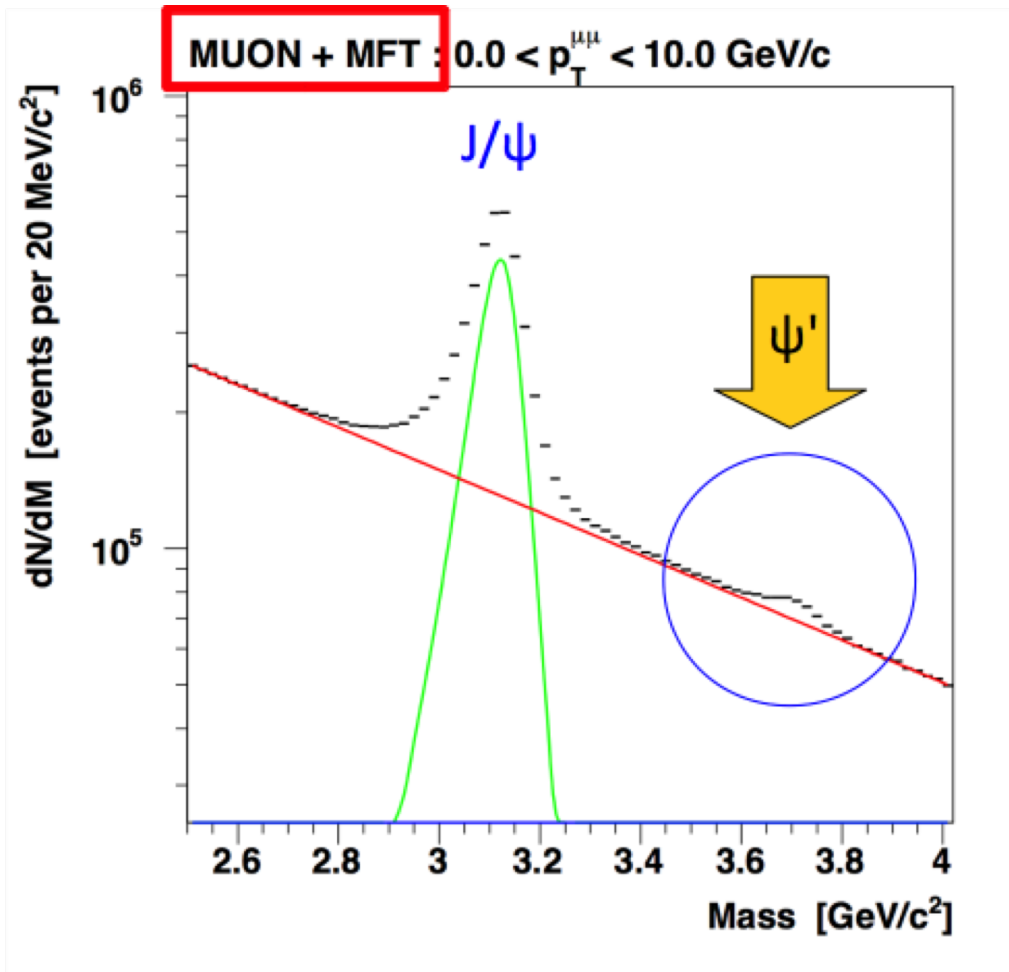
< 2×10^{12} 1 MeV n_{eq}/cm^2



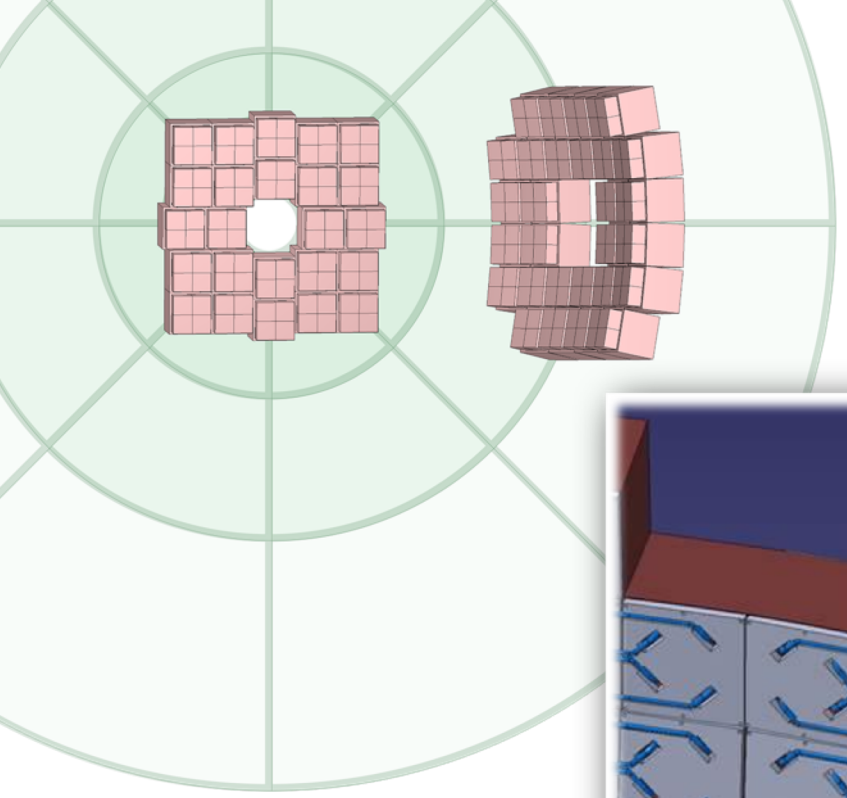
$-3.6 < \eta < -2.45$

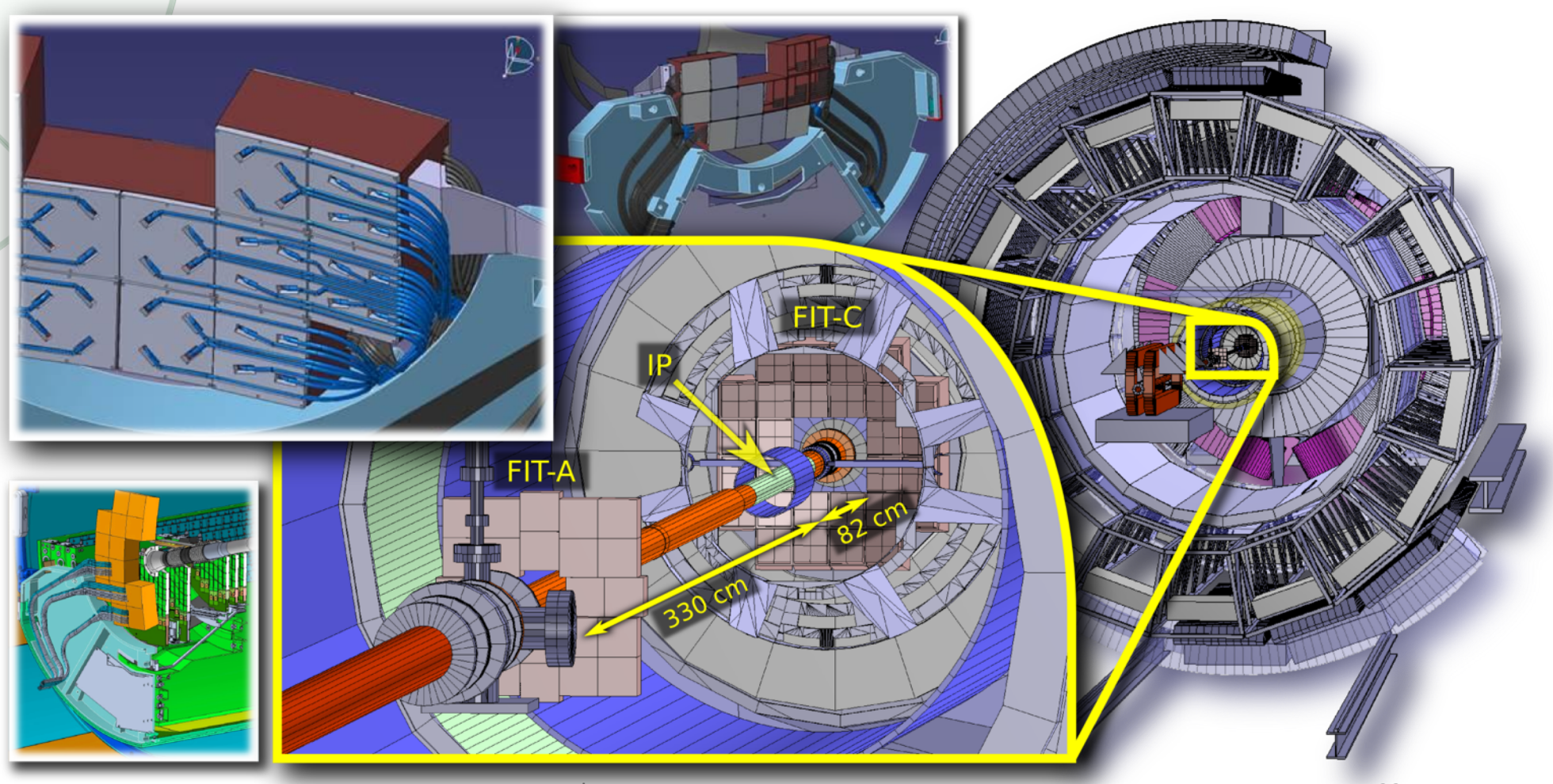
MFT will provide a robust ψ(2S) measurement
by improving the S/B by a factor 5 to 6





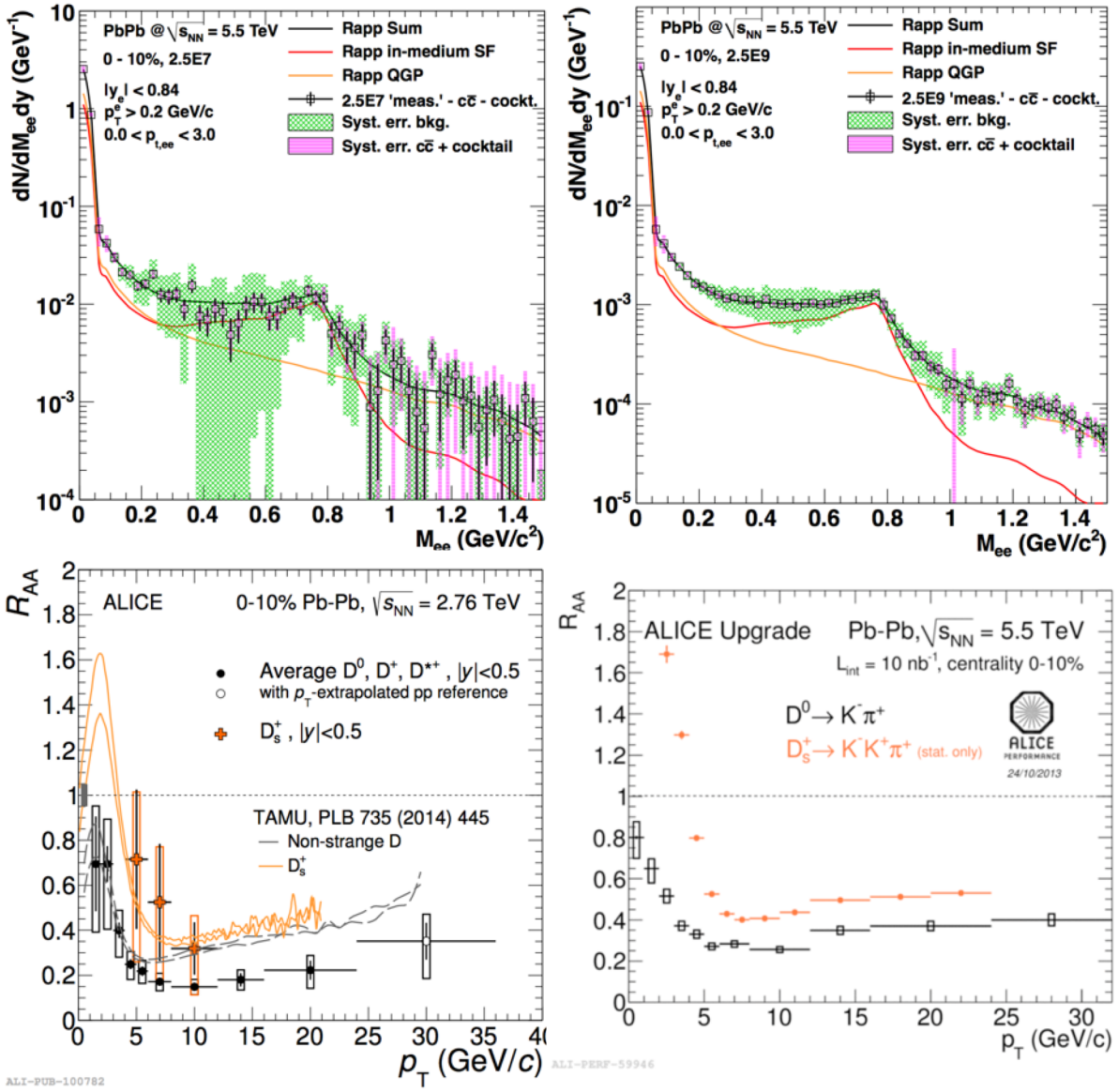
Fast Interaction Trigger (FIT)





- Trigger latency < 425 ns
- T_0 resolution < 45 ps
- Online luminosity
- Forward multiplicity
  - Centrality
  - Event plane

Physics Performance in Run 3 and Run 4

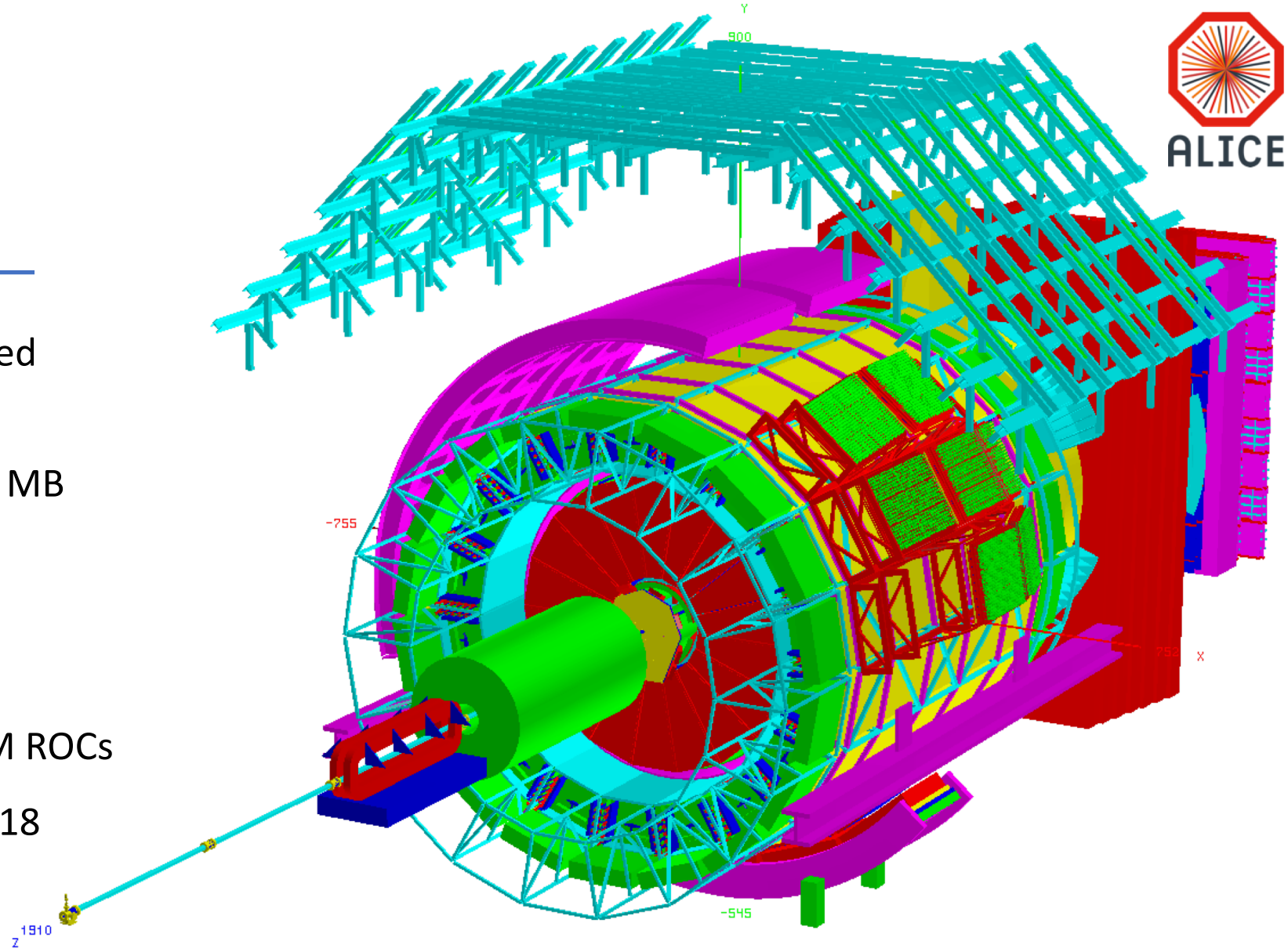


- Low Mass di-electrons
  - Initial temperature from EM radiation
  - Cocktail-subtracted distributions $|\eta| < 0.9$
  - Improved uncertainty figures in Run 3 and 4

- D^0, D^+, D_s production
  - Measure R_{AA} with percent-level precision down to low p_T
  - Precise comparison between strange and non-strange D mesons

Summary and Outlook

- Ten-fold increase of Pb-Pb delivered luminosity in Run 3 and Run 4
- Two orders of magnitude more of MB events at 50 kHz Pb-Pb collisions
- Enhanced tracking and vertexing performance
- Continuous readout TPC with GEM ROCs
- Installation starts in December 2018
- Run3 starts in March 2021
- Addition of FoCal in Run4?
  - forward-rapidity photon measurements



Thank you for your attention!