ALICE upgrades for Run 4 and Beyond

Sebastian Scheid
for the ALICE Collaboration

Quark Matter, 7th April 2022, Kraków

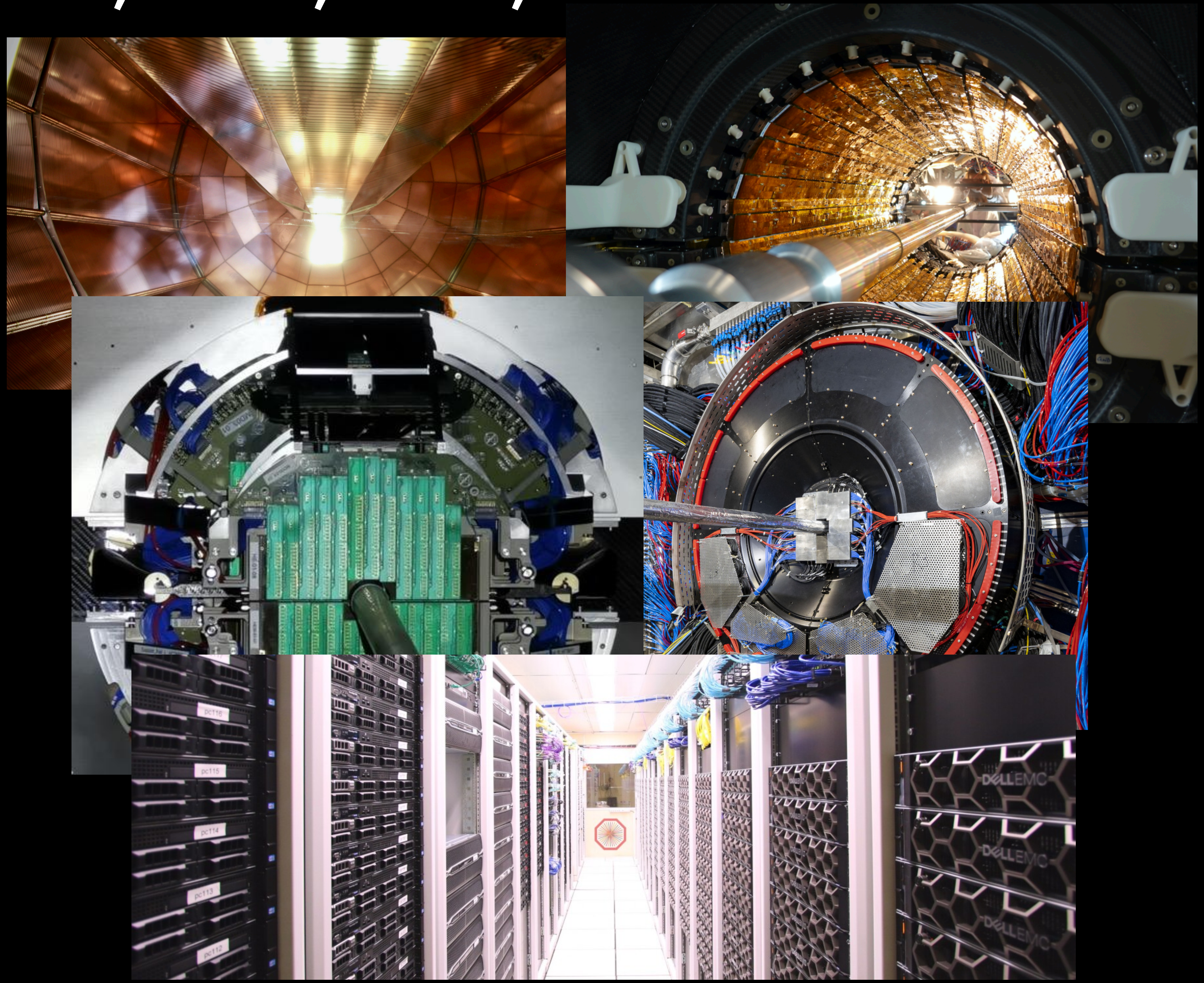
GOETHE UNIVERSITÄT FRANKFURT AM MAIN

Upgrade time line

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035

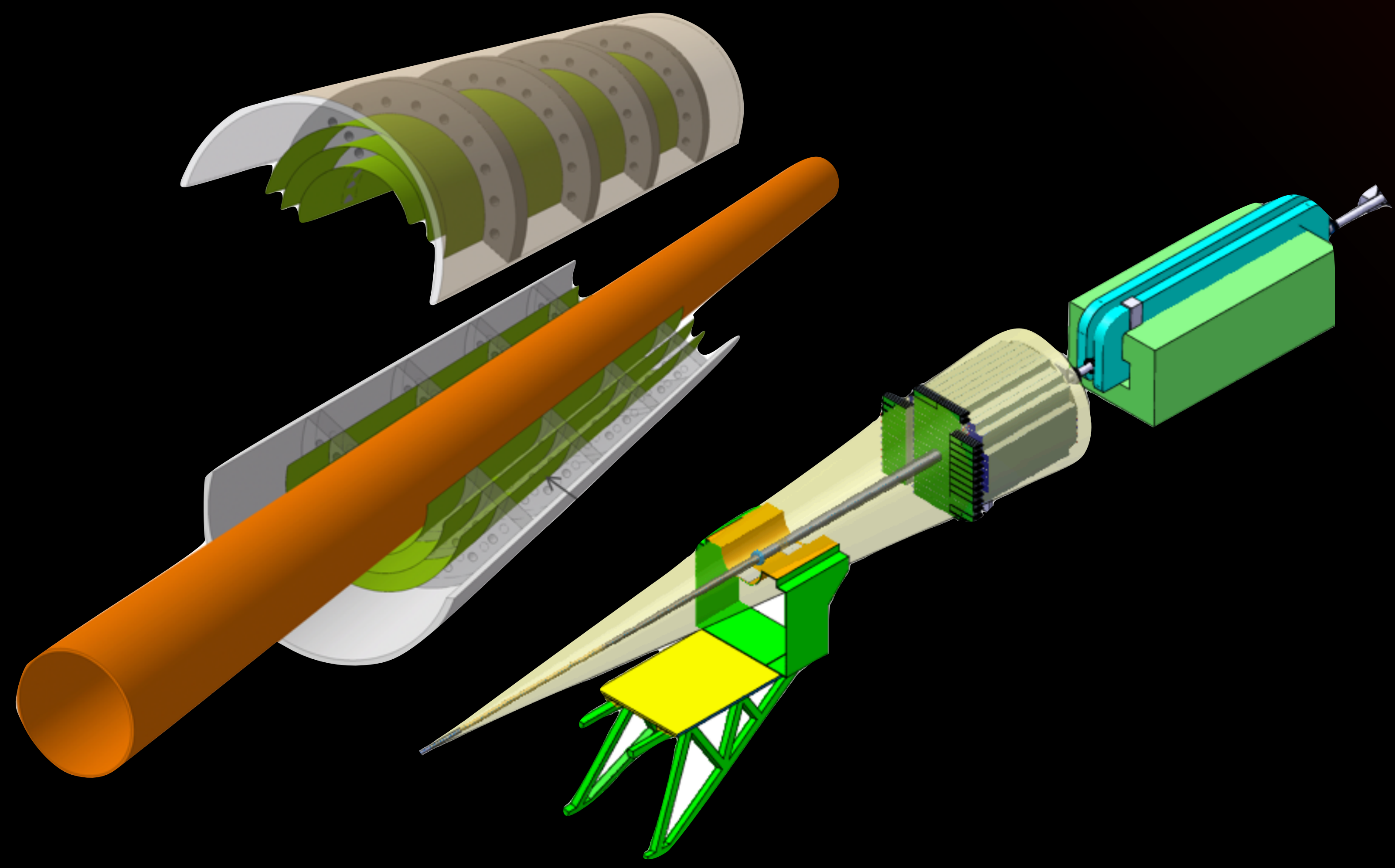
LS2 → Run 3 → LS3 → Run 4 → LS4 → Run 5

TPC, ITS2, MFT, FIT & O^2



presented by A. Alkin in the previous talk

ITS3 & FoCal



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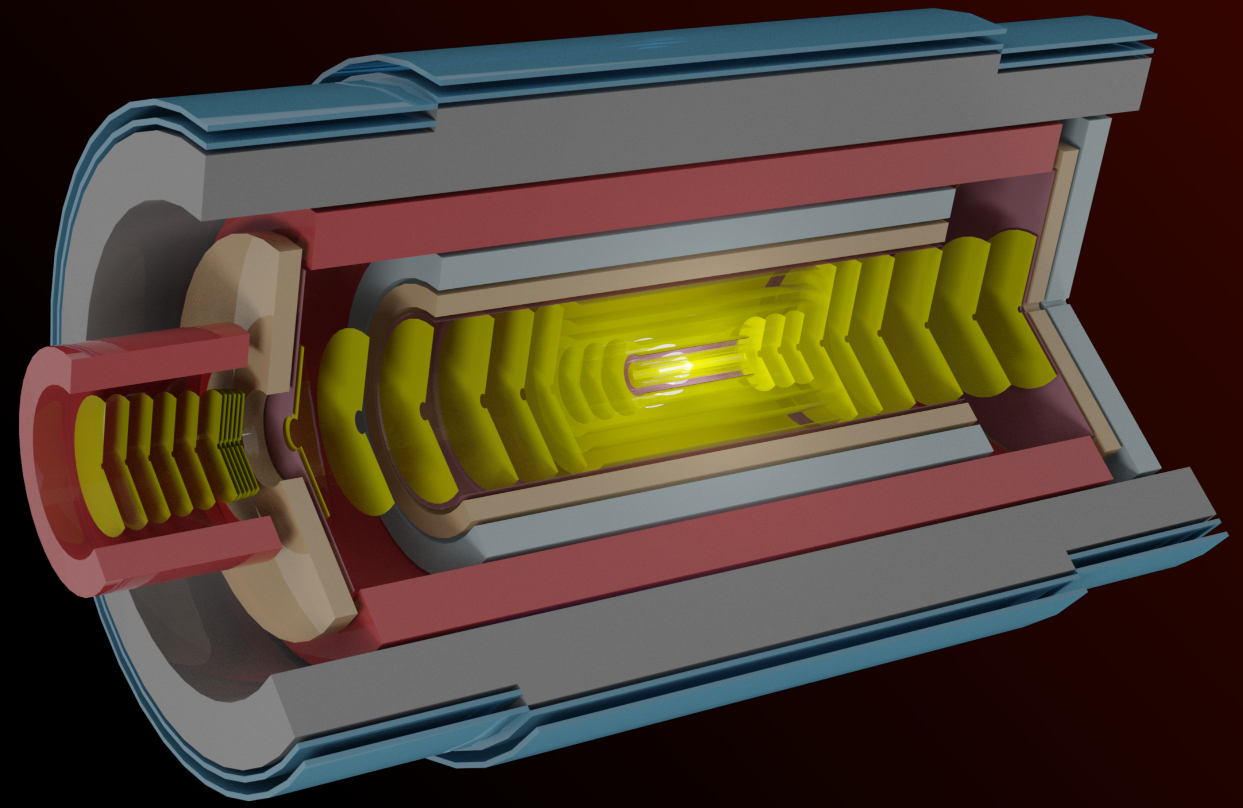
ALICE 3



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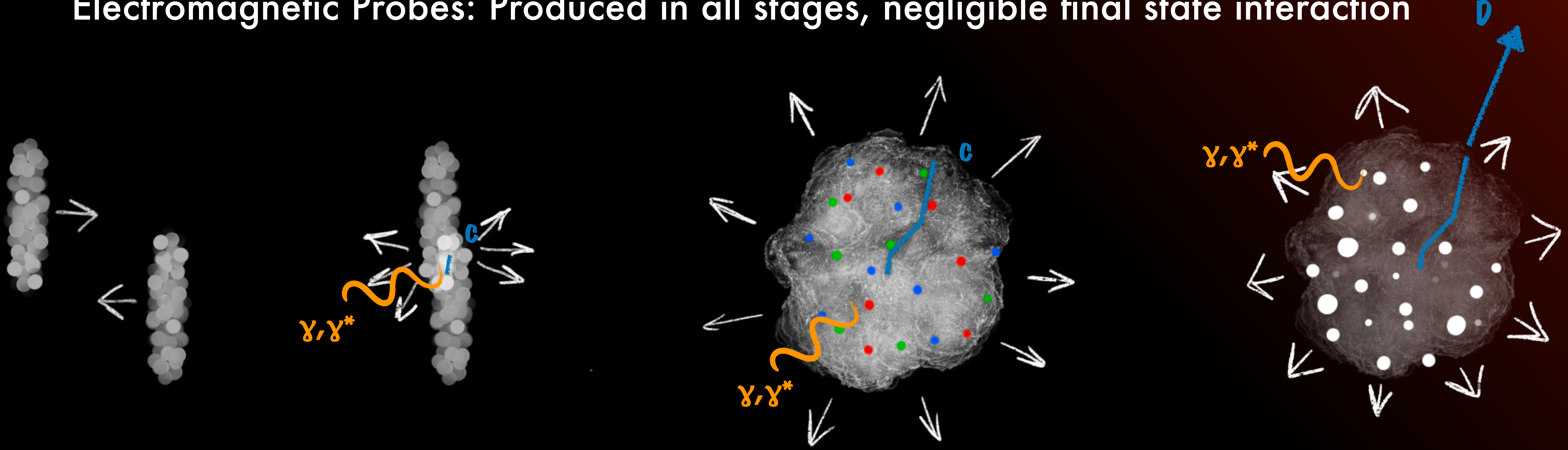
Physics in Run 4 and beyond

Heavy Flavour: Experience the full medium evolution (QGP and hadronic)

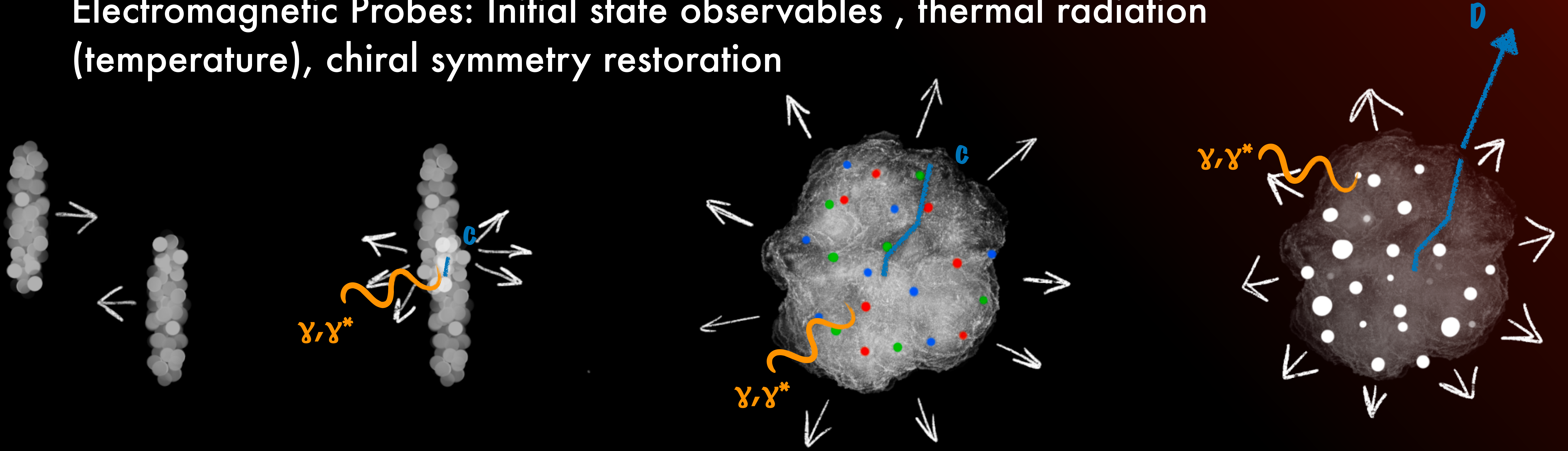
Electromagnetic Probes: Produced in all stages, negligible final state interaction



Physics in Run 4 and beyond

Heavy Flavour: Medium effects and hadronisation

Electromagnetic Probes: Initial state observables , thermal radiation (temperature), chiral symmetry restoration

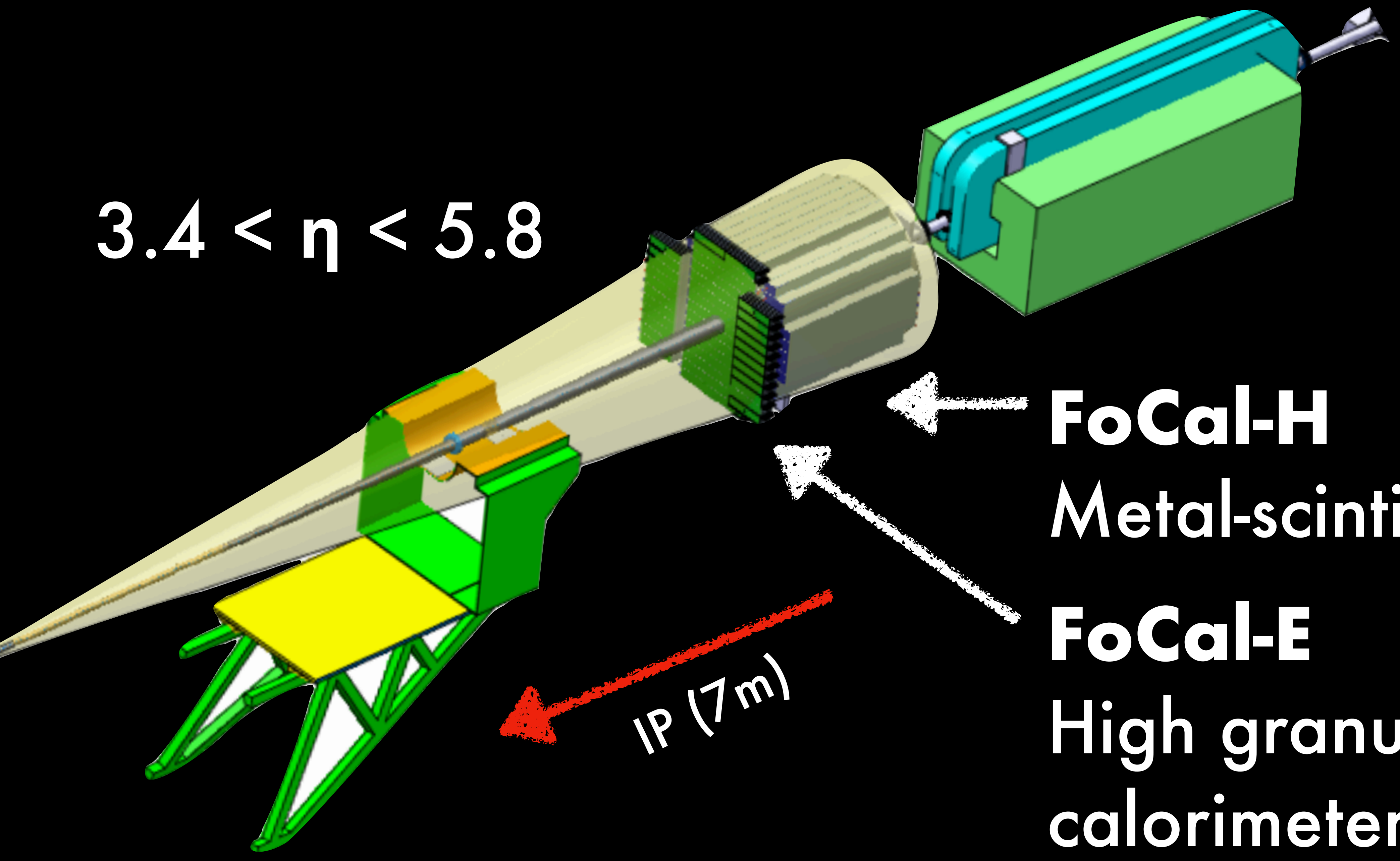


FoCal

Measure direct photon and π^0 and associated hadrons

- ➠ Quantify nuclear modification of gluons at small-x and Q^2
- ➠ Access non-linear QCD

$3.4 < \eta < 5.8$



FoCal-H
Metal-scintillator sampling calorimeter

FoCal-E
High granularity Si-W sampling sandwich calorimeter

FoCal

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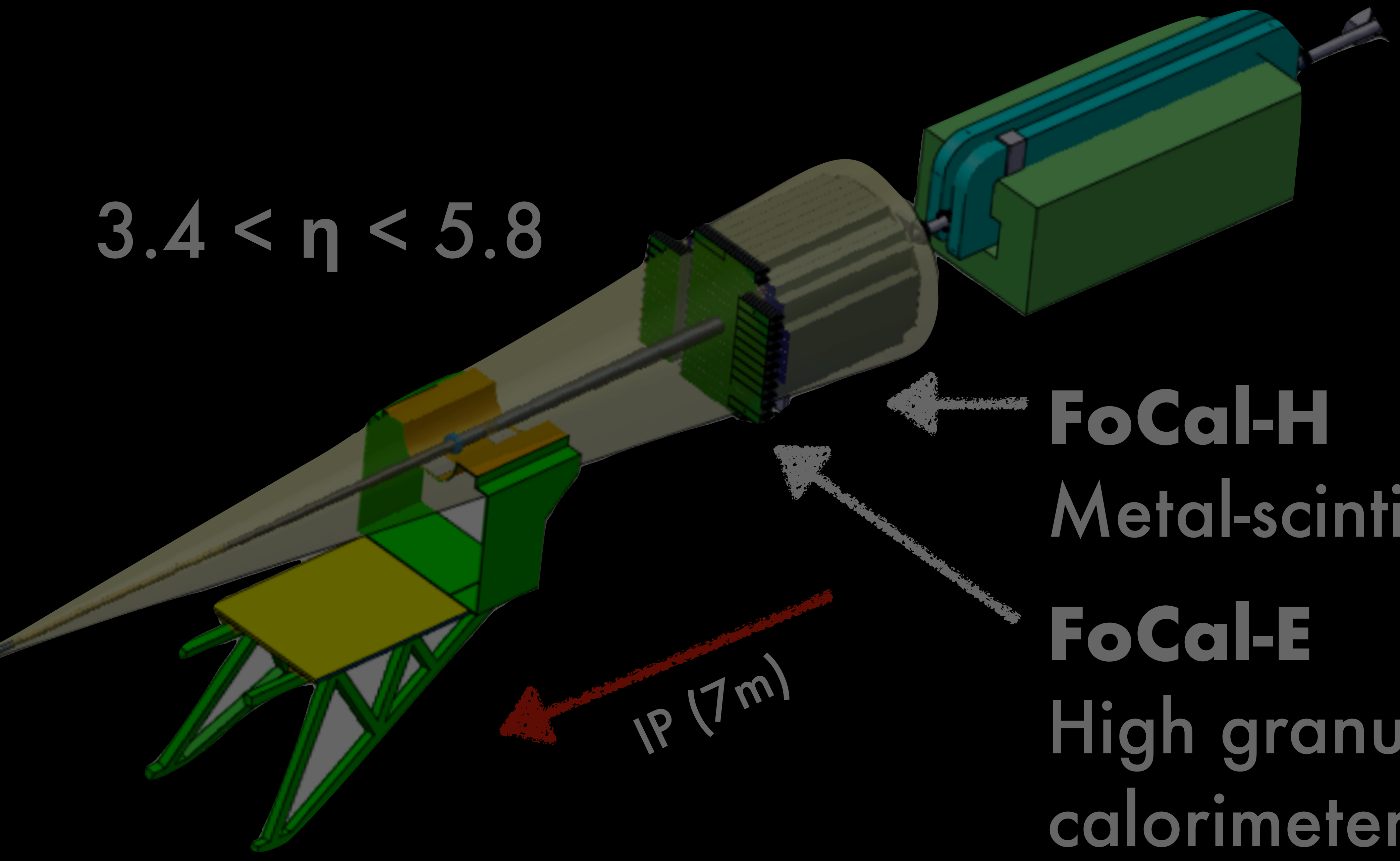

FoCal-H
Metal-scintillator samp

FoCal-E
High granularity Si-W
calorimeter

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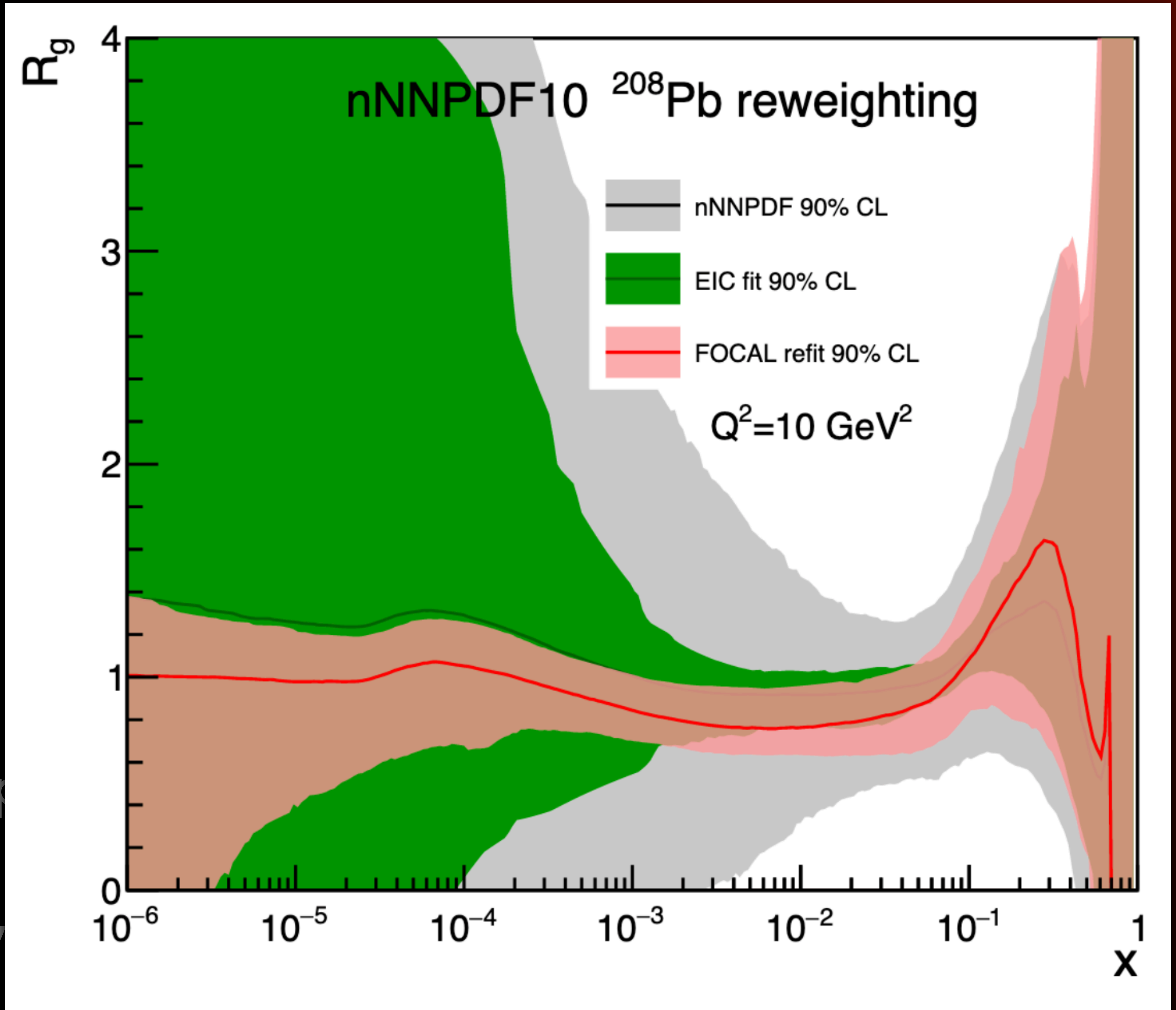
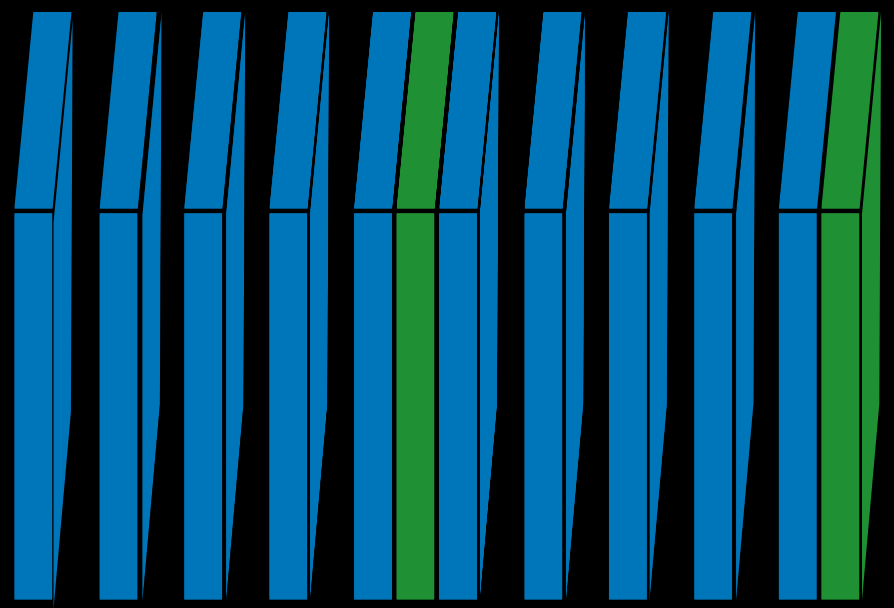


FoCal-E

Test beam at SPS in summer 2021 with 4 different energies (20/40/60/80 GeV)

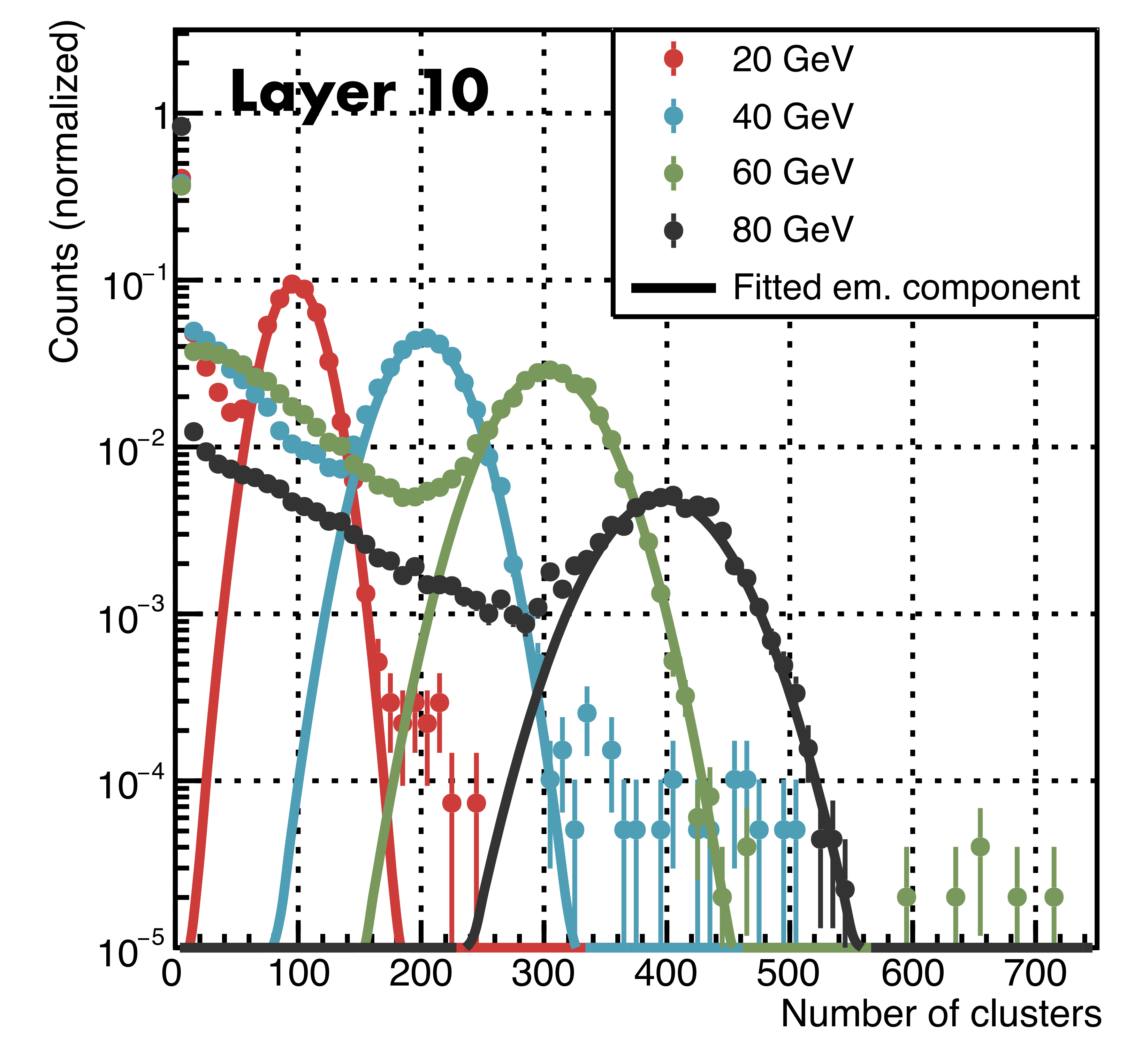
Electron peak visible in all energies, described well in MC simulations

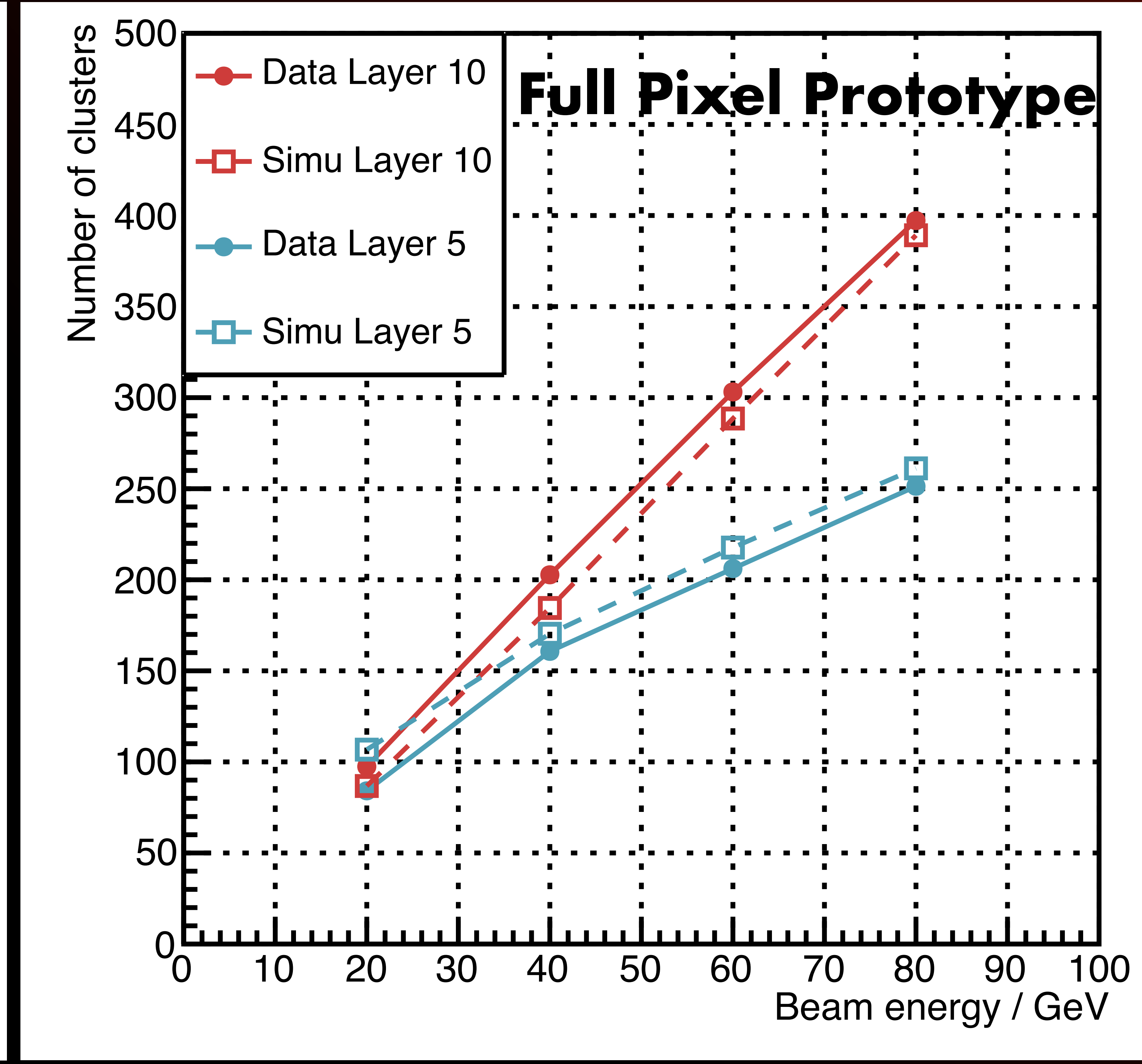
Setup



Absorber: 3.5mm W

High Granularity: 30x30 μm² pixel, digital readout (ALPIDE)





FoCal-E

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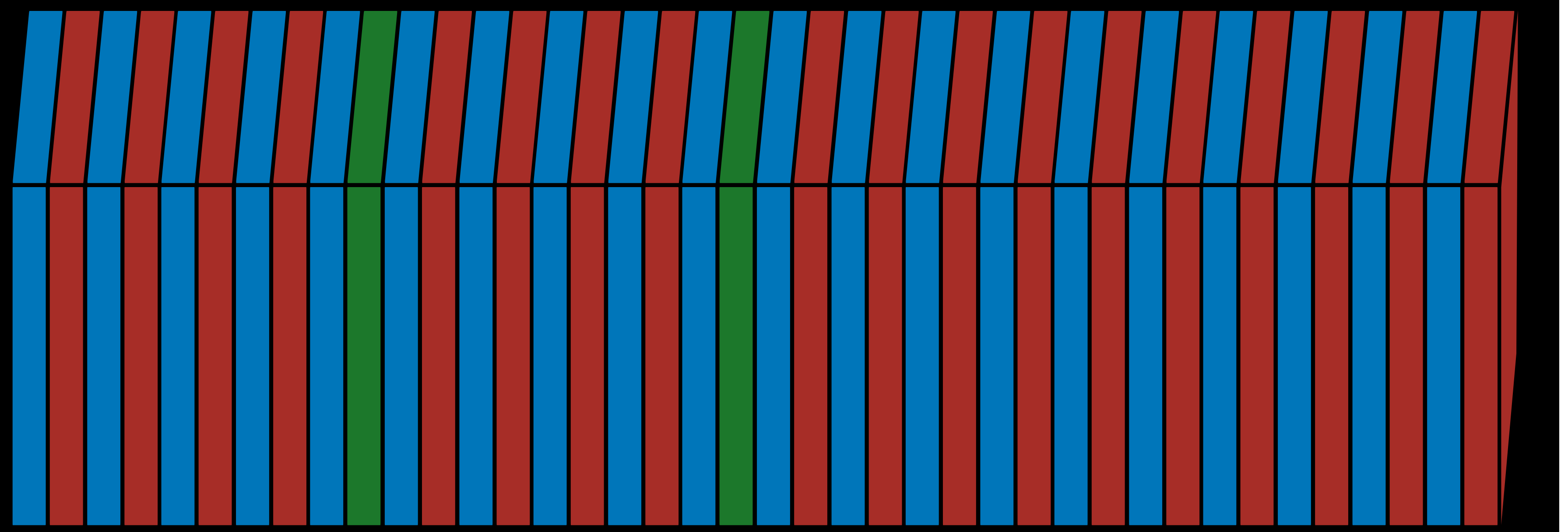
Electron peak visible in all energies, described well in MC simulations

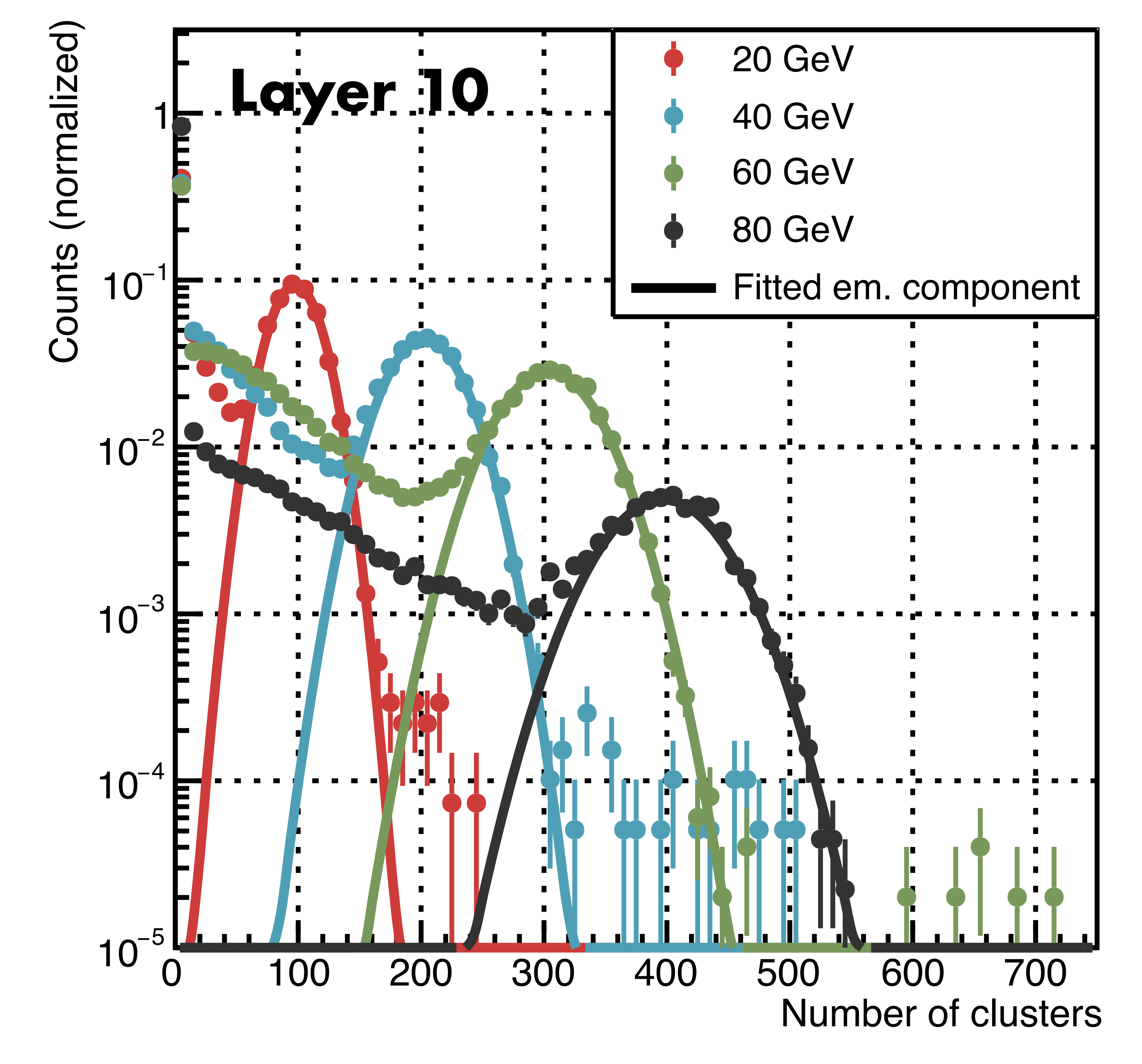
Planned for 2022 test beam

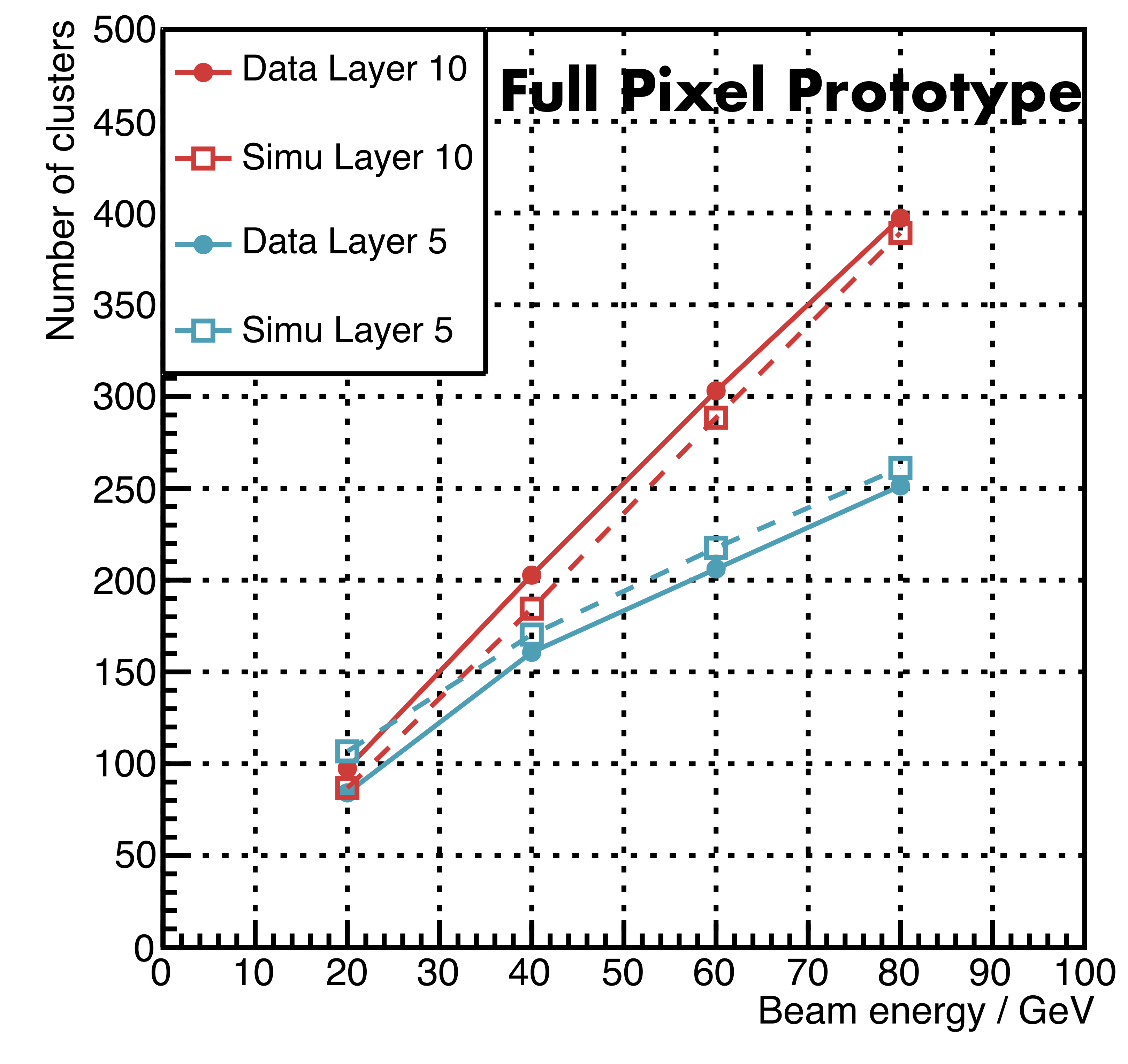


Absorber: 3.5mm W

High Granularity: 30x30 µm² pixel, digital readout (ALPIDE)

Low Granularity: 1x1 cm2, analogue





ITS3

Pointing resolution $\propto r_0 \times \sqrt{x/X_0}$

Silicon only contributes 15%

Improves with removing material in the first layers

- ➟ Move from water to air cooling
- ➟ Integrate power and data on chip
- ➟ Self-supporting structure

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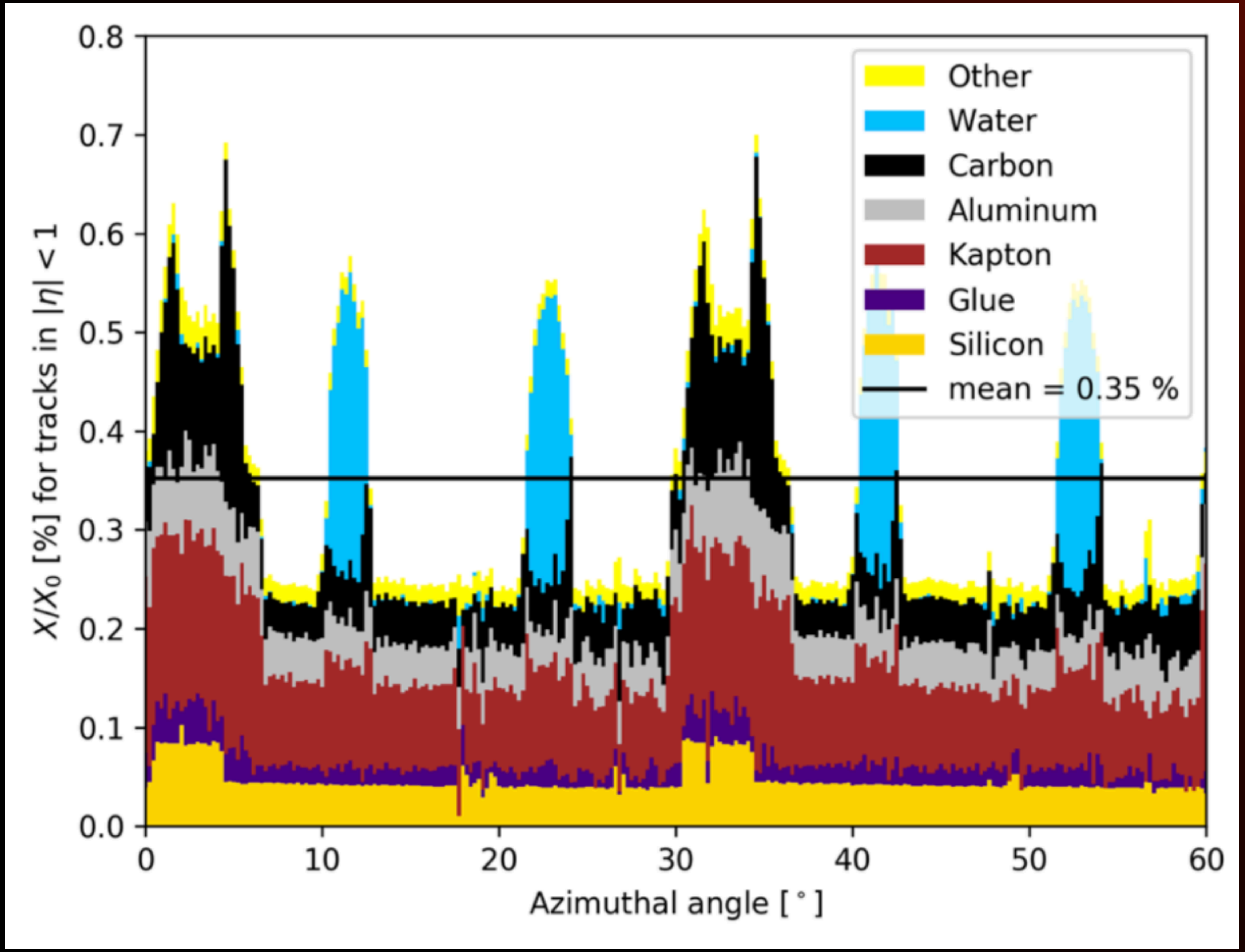

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Dielectron and HF measurements

- Secondary vertexing increases significance of both measurements

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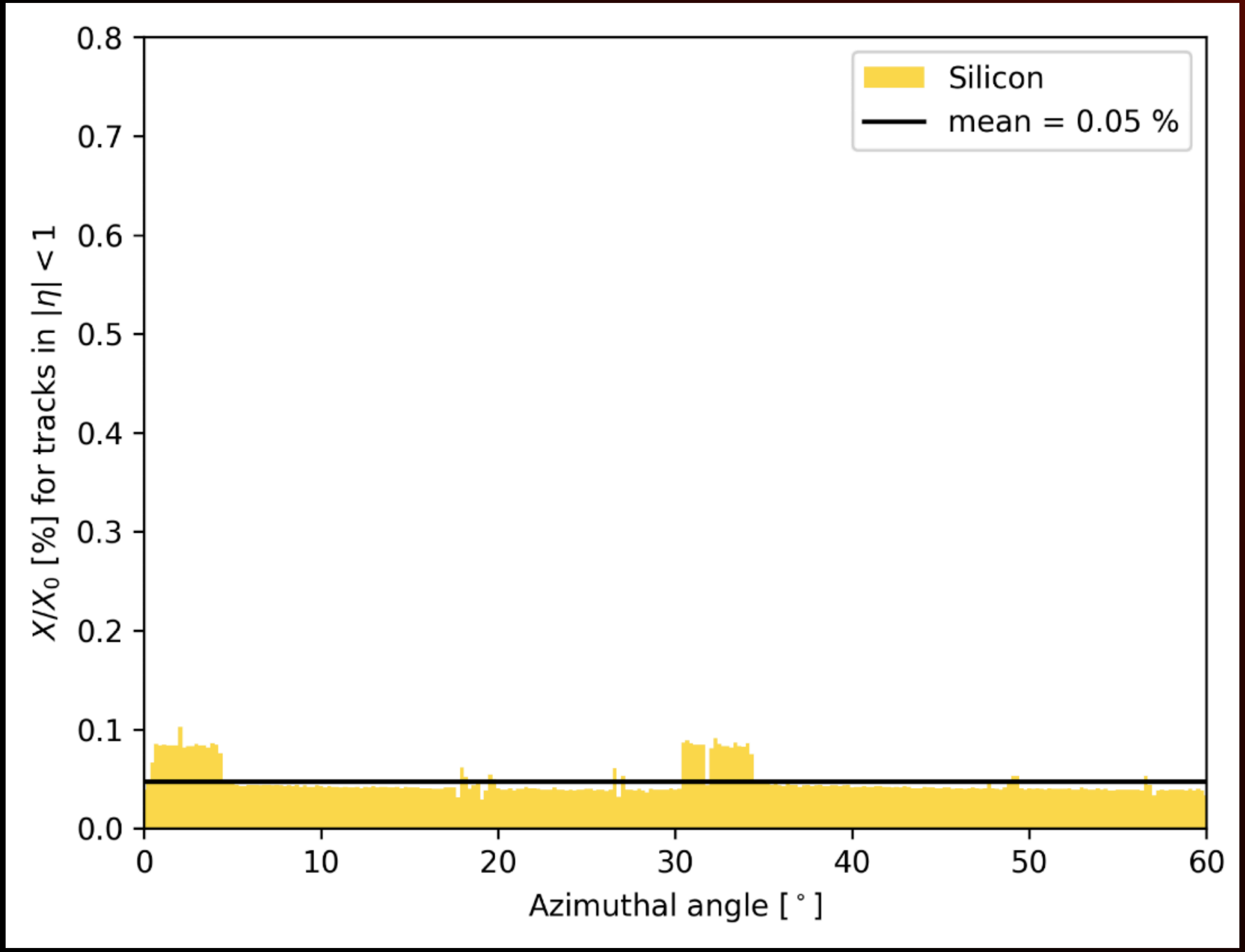
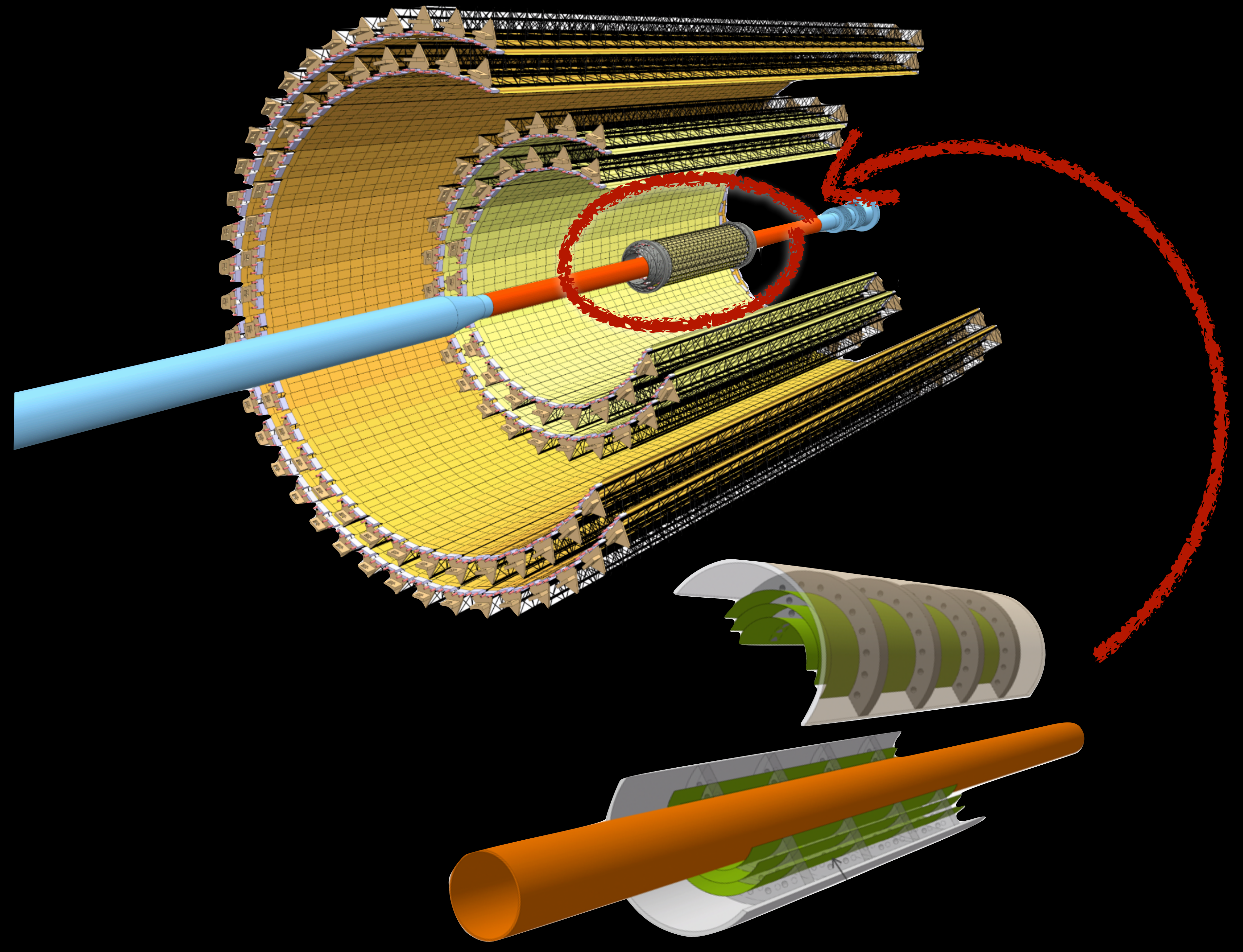


ITS3

Replace beam pipe and three inner layers of ITS2 (1st layer 22 mm → 18 mm)



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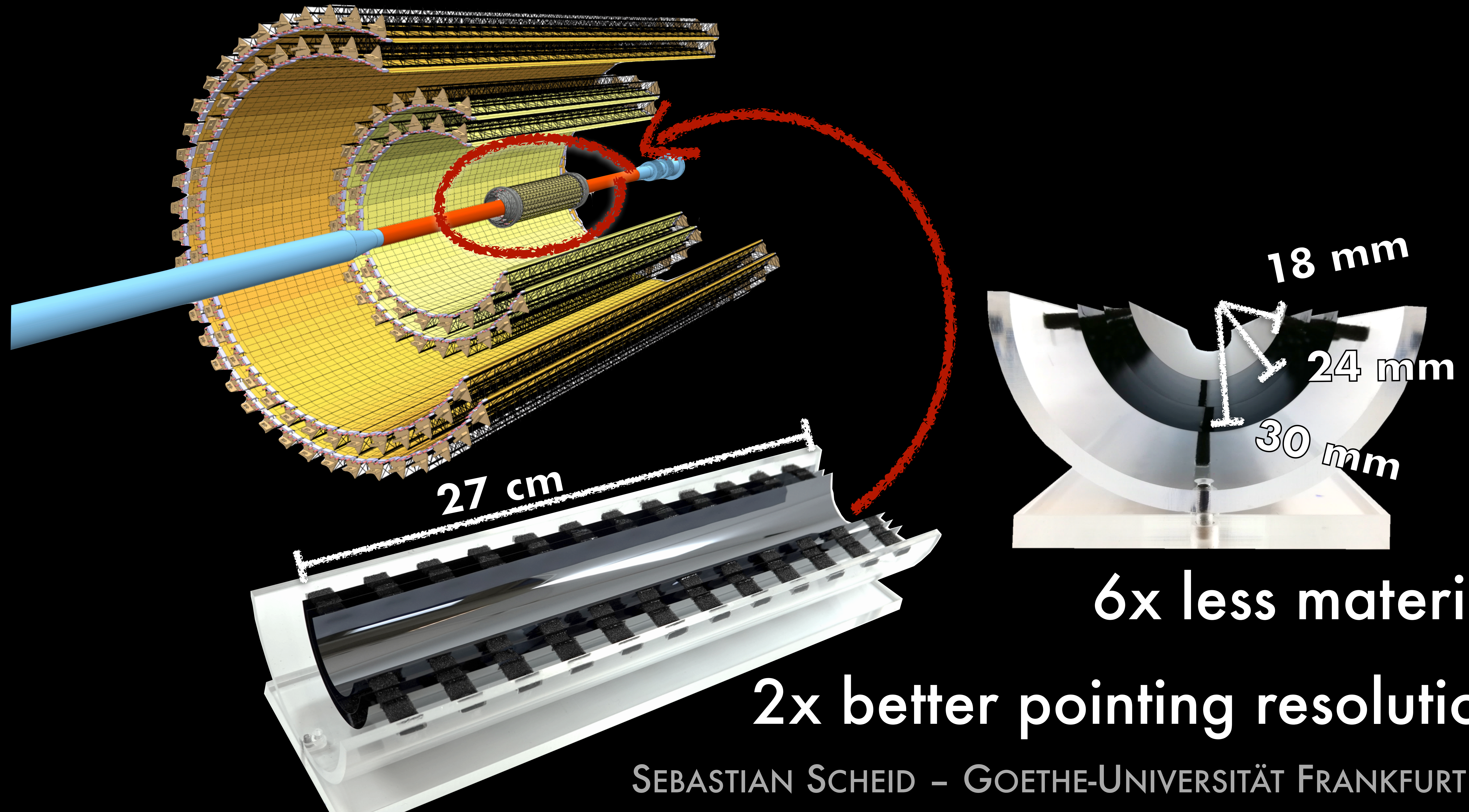
Replace beam pipe and three inner layers of ITS2 (1st layer 22 mm → 18 mm)

50 µm thick silicon (dummy) can be bent and kept in place by carbon foam ribs



6x less material

2x better pointing resolution

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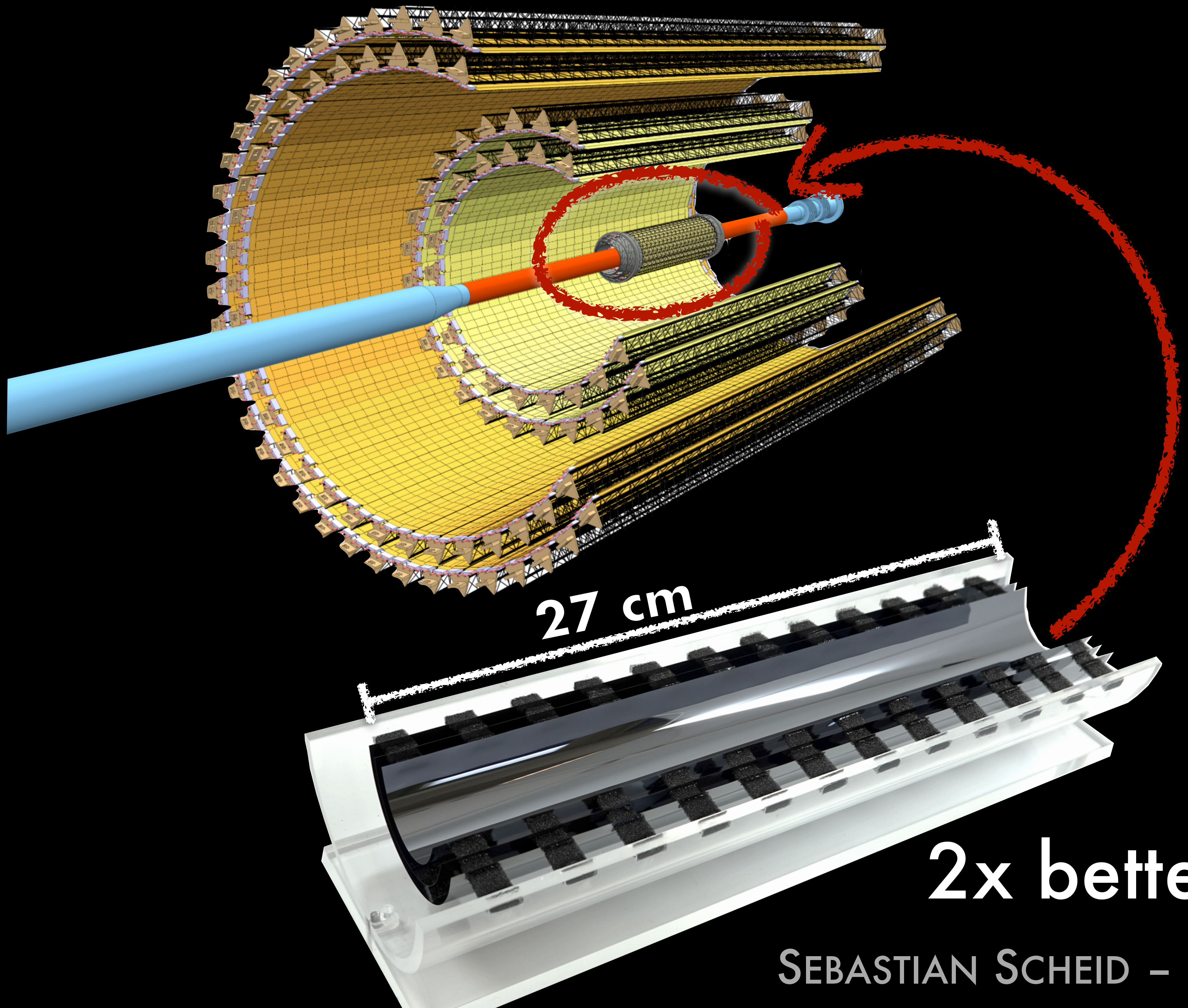

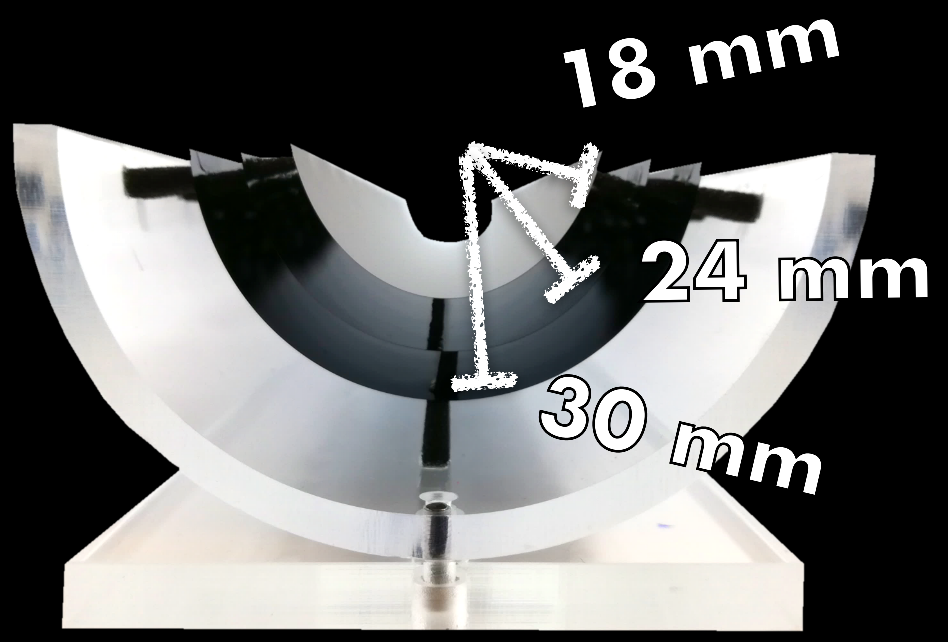

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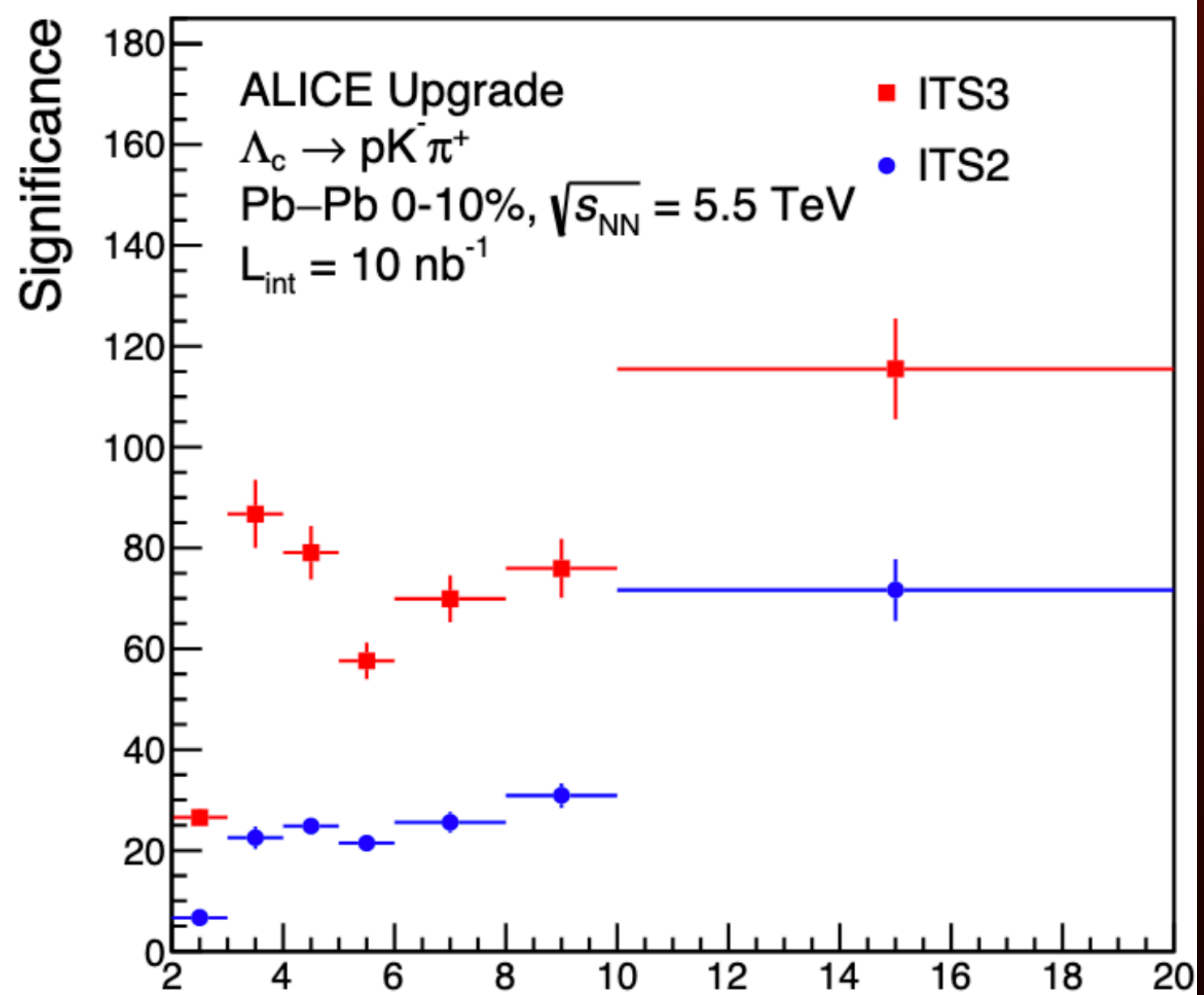

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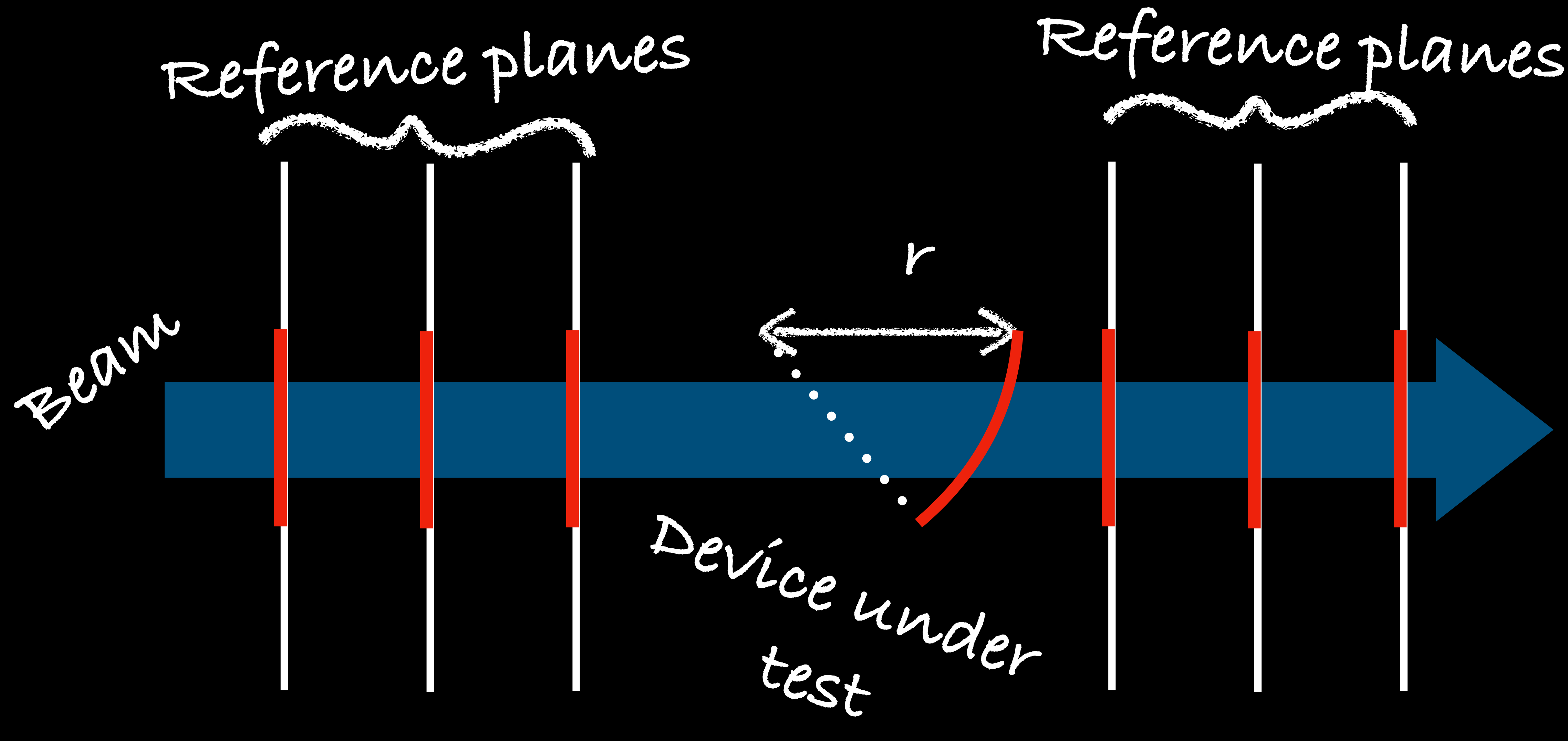
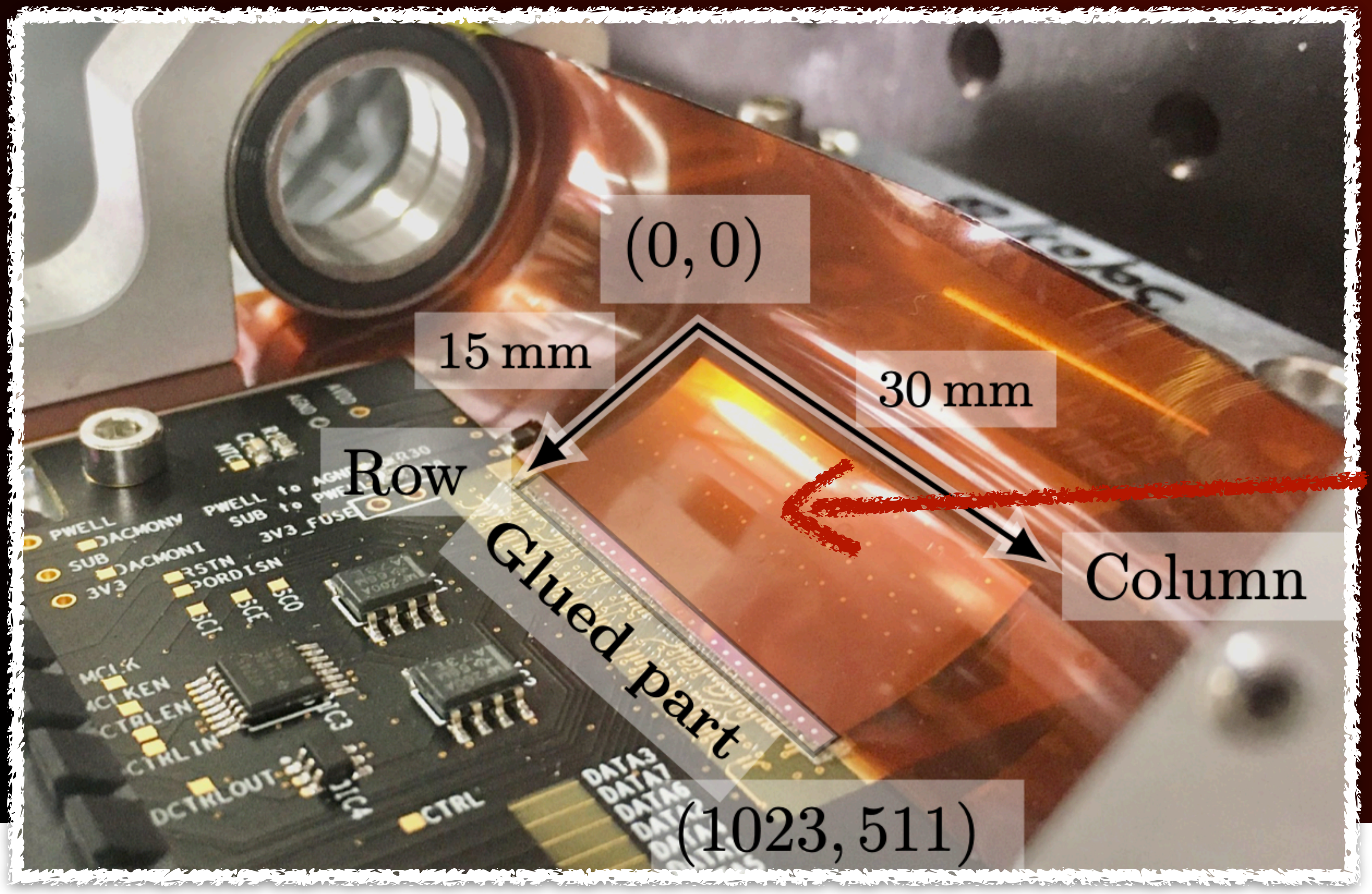
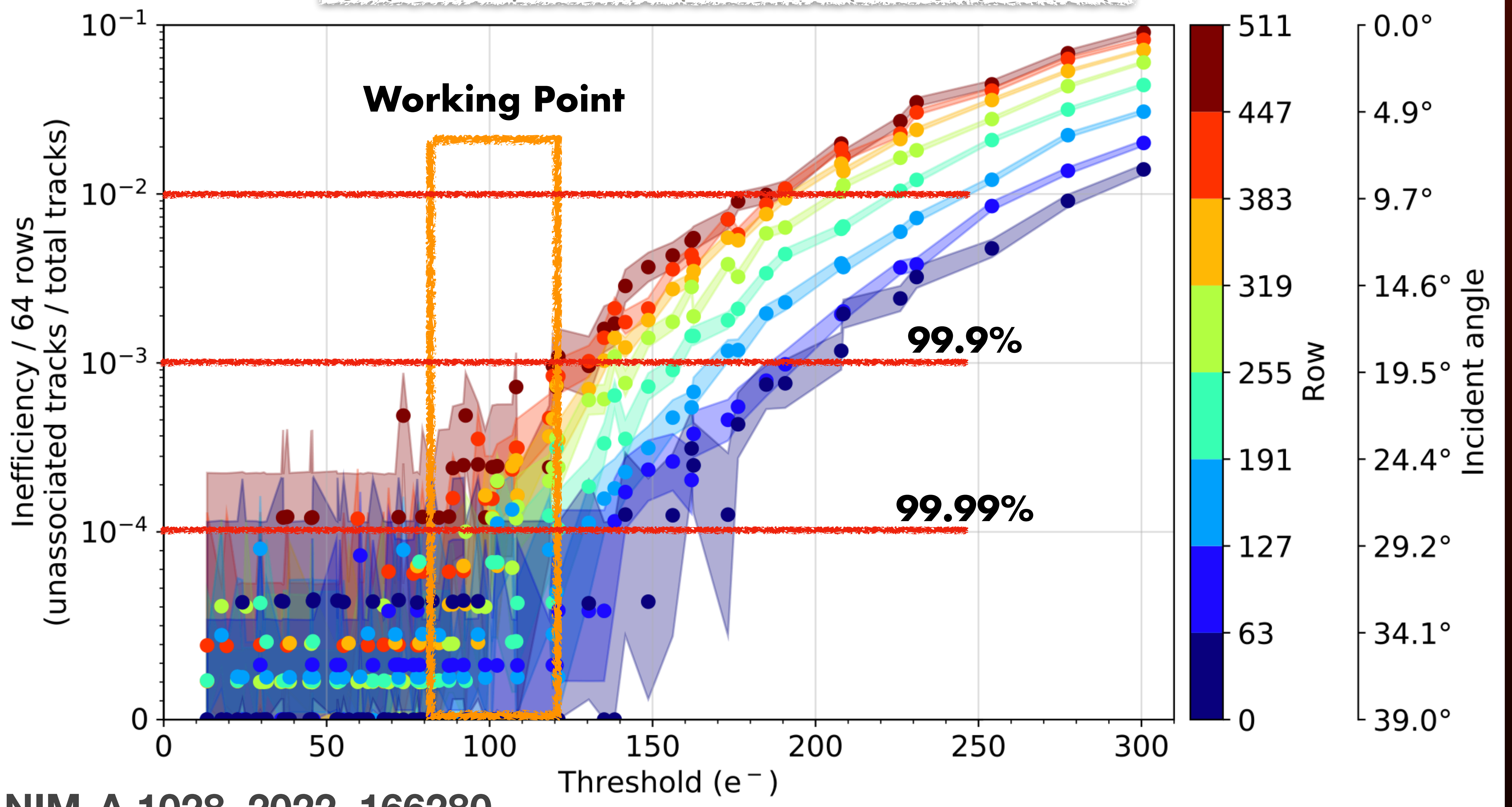
ITS3

Use ALPIDE telescope to test different devices:





Bent ALPIDE



NIM-A 1028, 2022, 166280

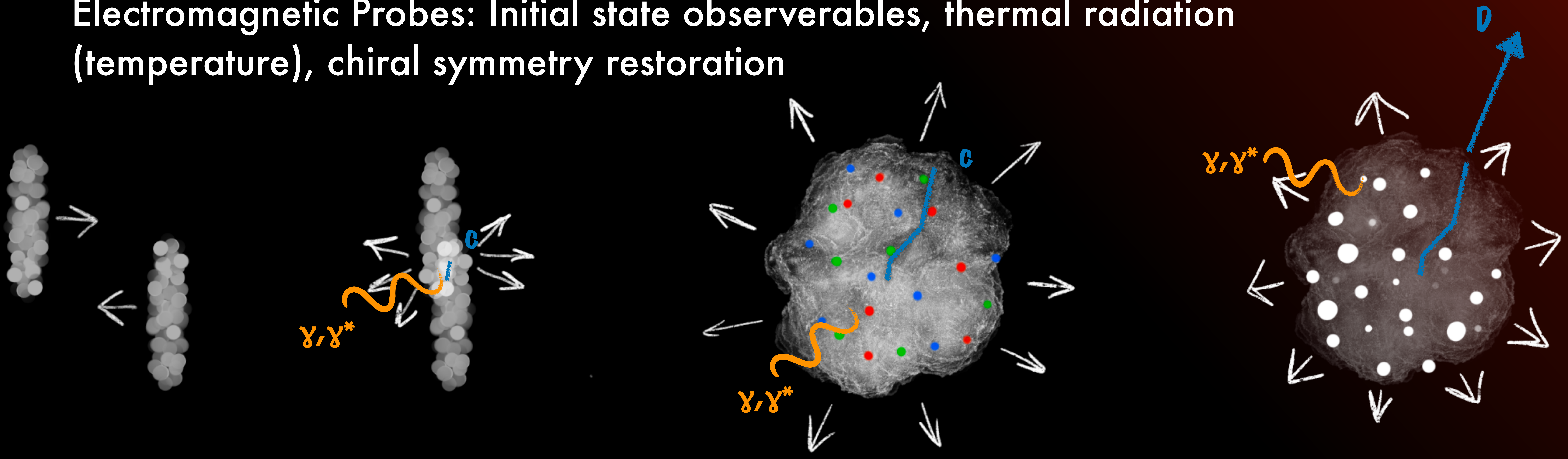
Bent ALPIDE (180 nm) efficiency > 99.9%

Digital pixel test structure (65 nm) efficiency > 99 %

Physics ~~in~~ Run 4 ~~and~~ beyond

Heavy Flavour: Medium effects and hadronisation

Electromagnetic Probes: Initial state observerables, thermal radiation (temperature), chiral symmetry restoration



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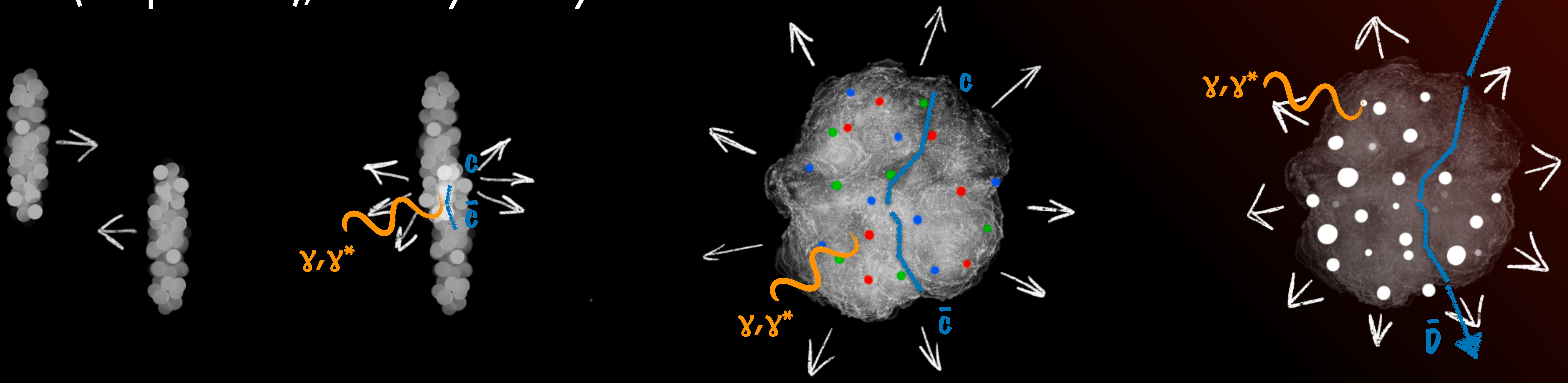

ALICE 3

A selection of topics

Precision measurements of dileptons

- ➟ evolution of the quark-gluon plasma
- ➟ mechanisms of chiral symmetry restoration

Systematic measurements of (multi-)heavy-flavour hadrons

- ➟ transport properties in the quark-gluon plasma
- ➟ mechanisms of hadronisation from the quark-gluon plasma

Hadron correlations

- ➟ interaction potentials
- ➟ susceptibility to conserved charges

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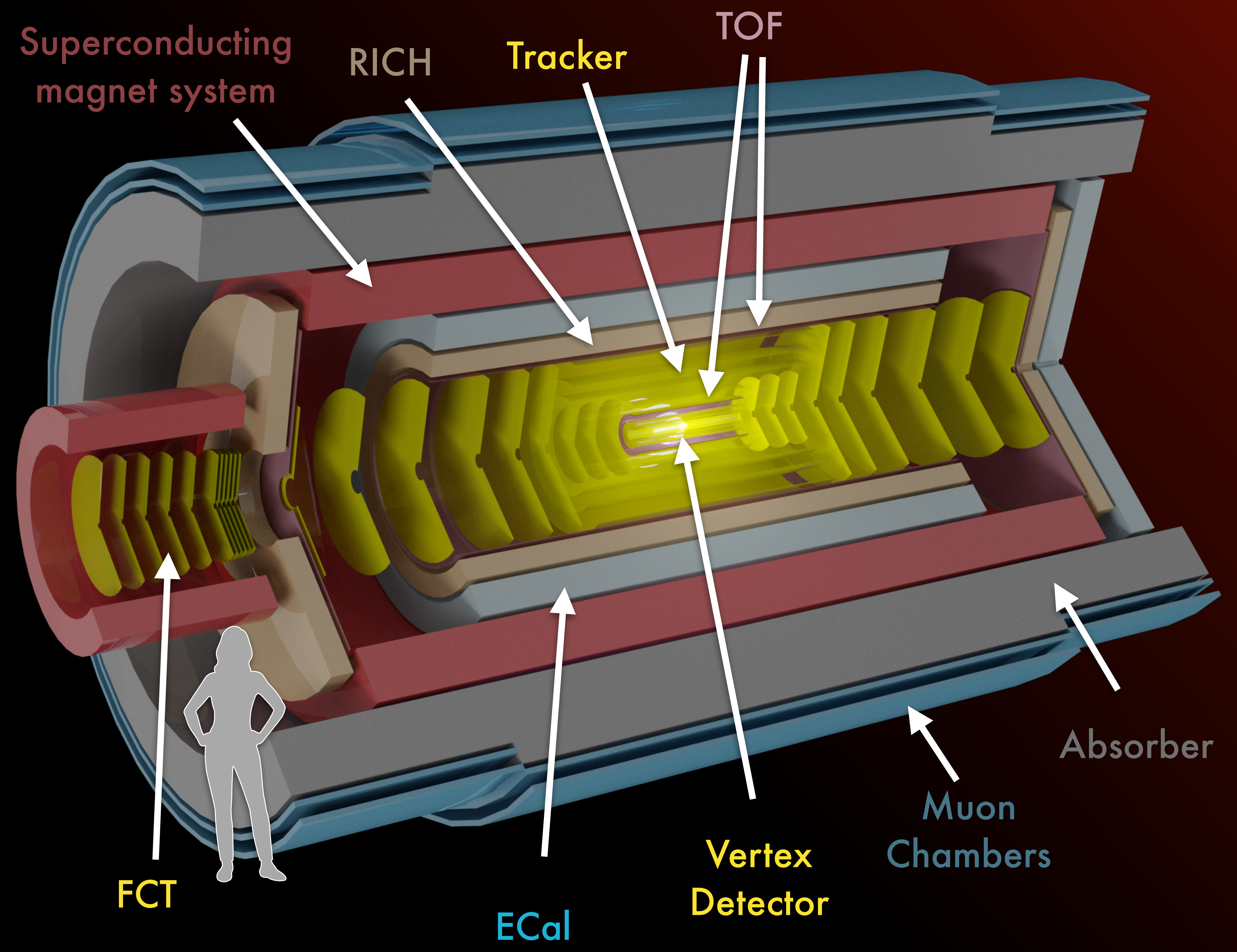


ALICE 3

The IRIS tracker

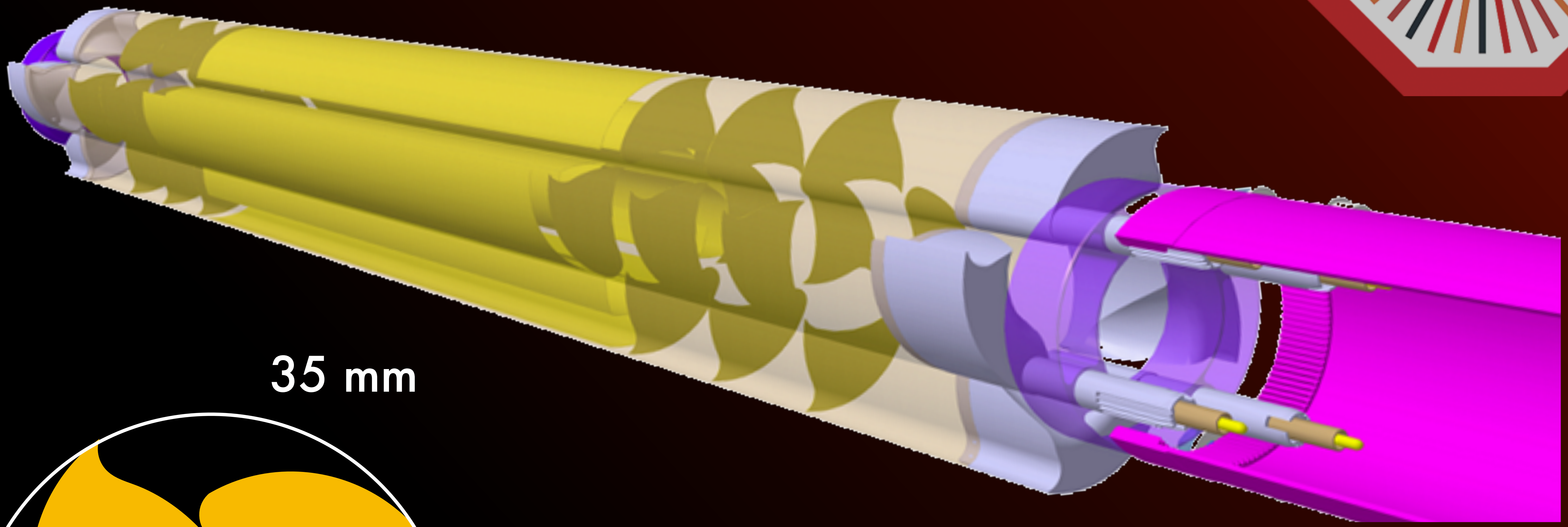
Pointing resolution $\propto r_0 \times \sqrt{x/X_0}$

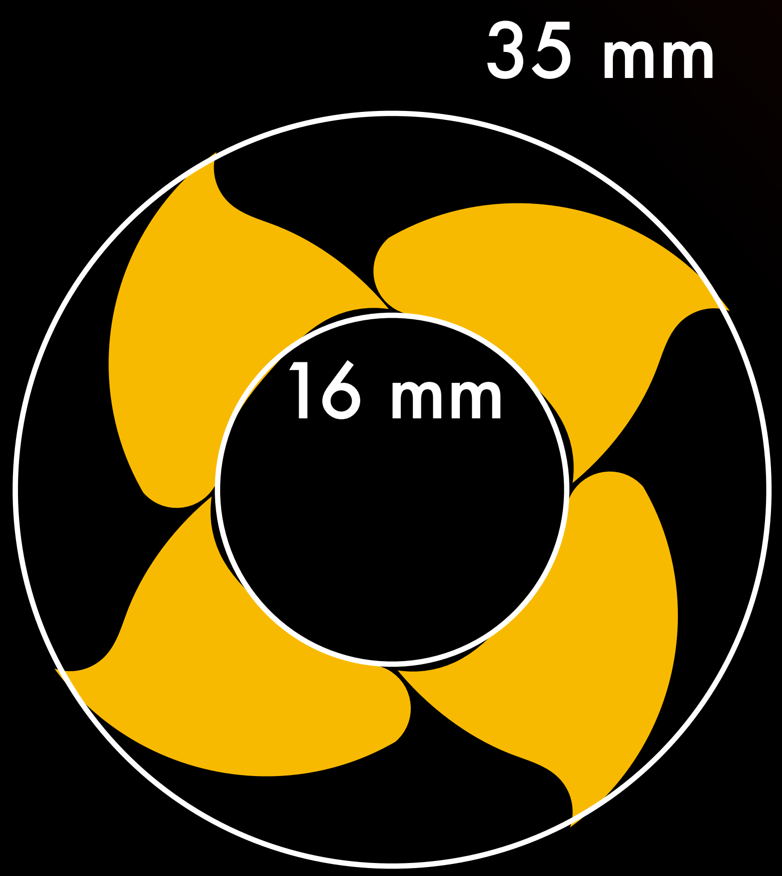
Potential improvements wrt ITS3

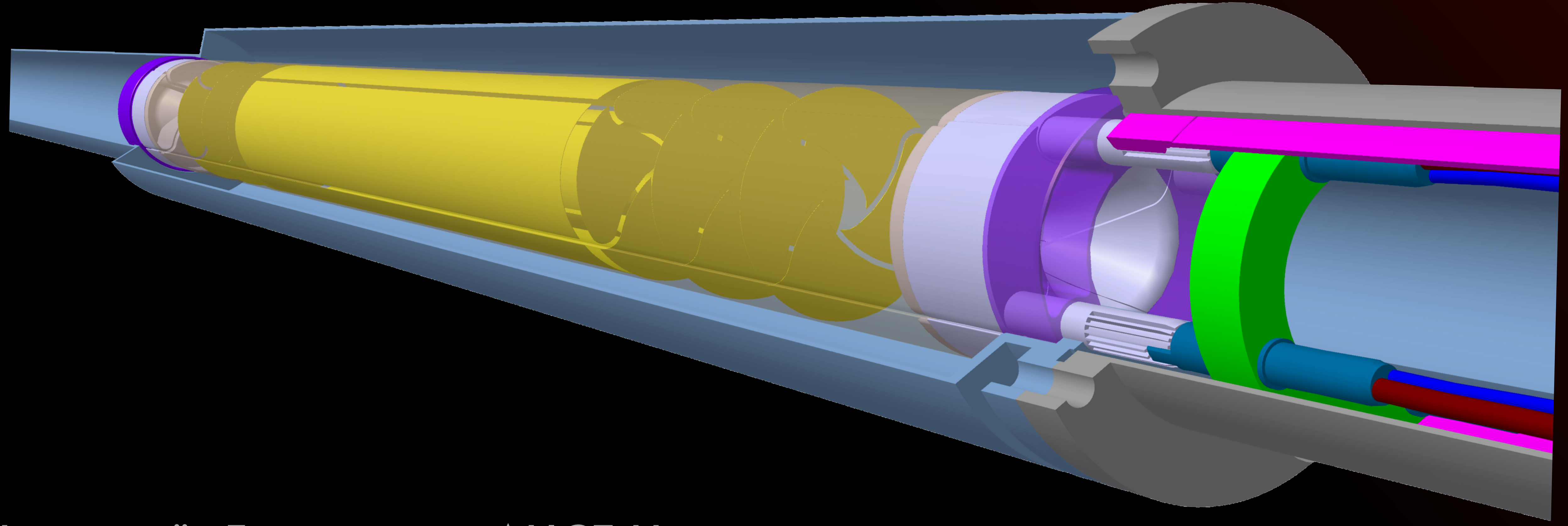
- ➟ Remove material in front of 1st layer by moving detector into beam pipe
- ➟ Move closer to interaction point

Limited by LHC beam aperture at injection energy (16 mm)

- ➟ Place detector in secondary vacuum, move into position for data taking (5 mm)







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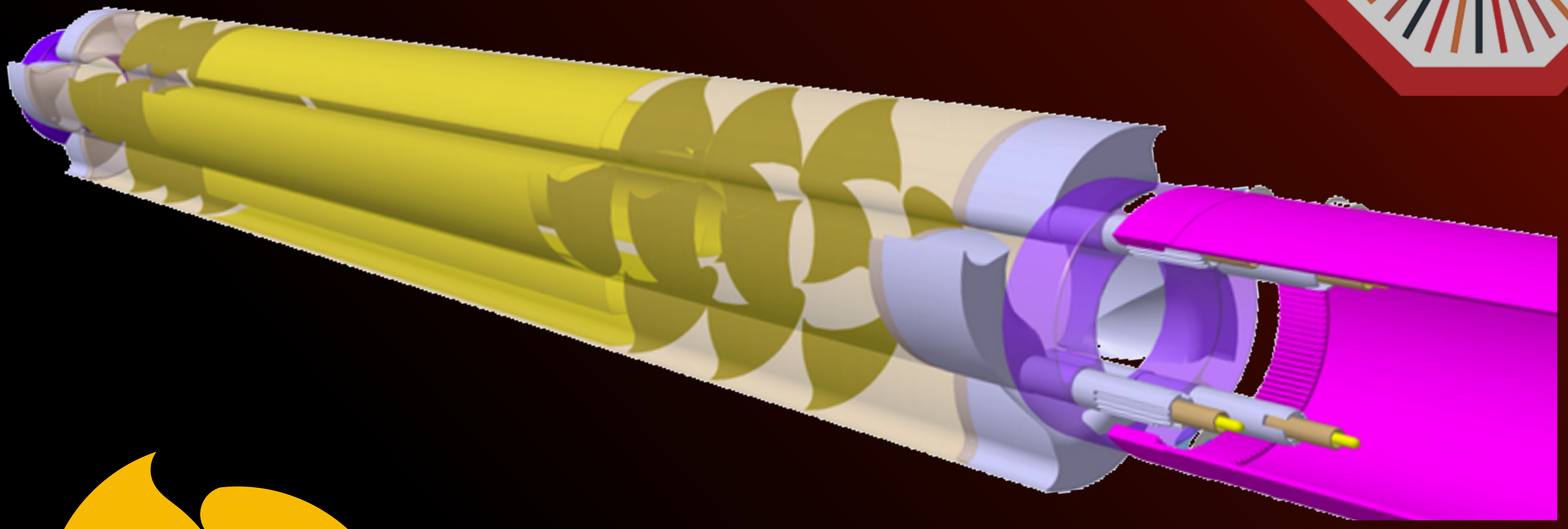

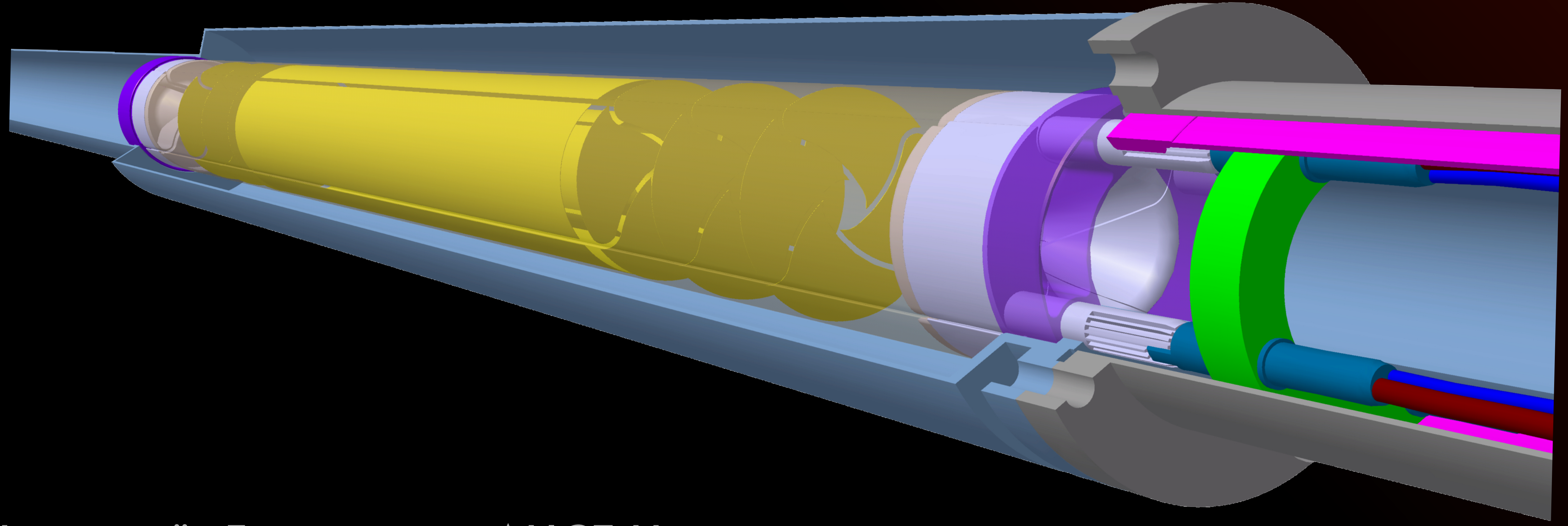

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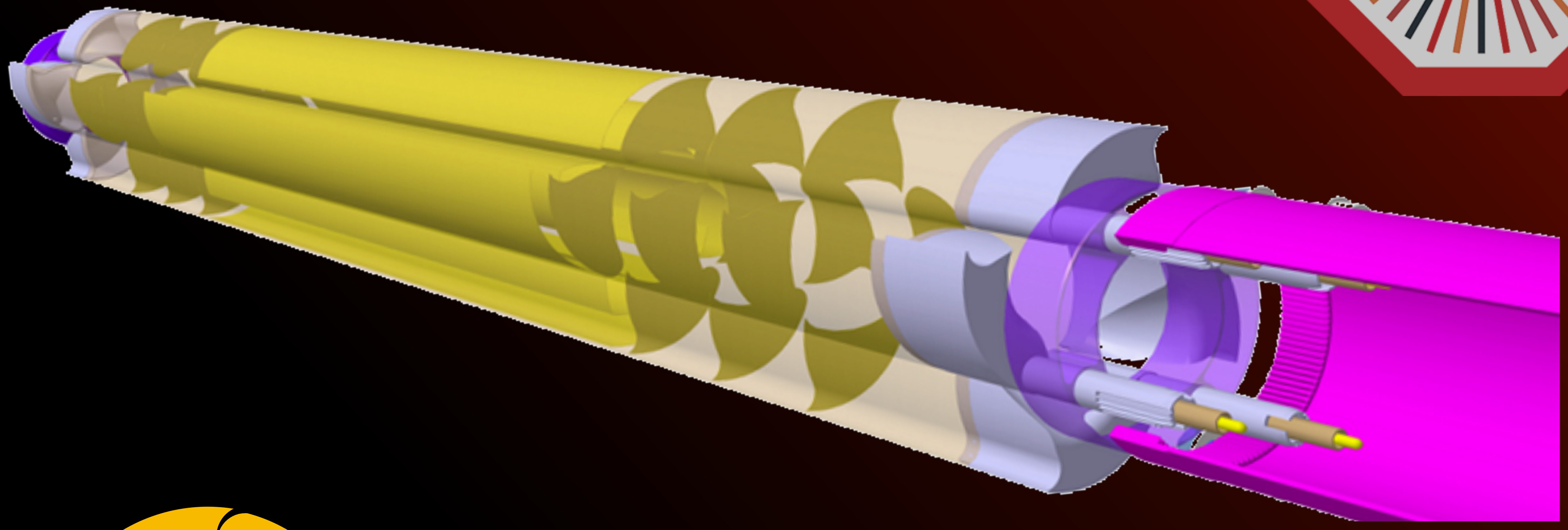

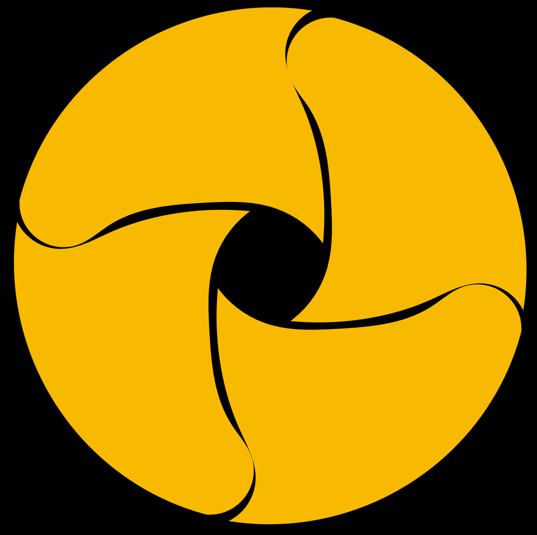

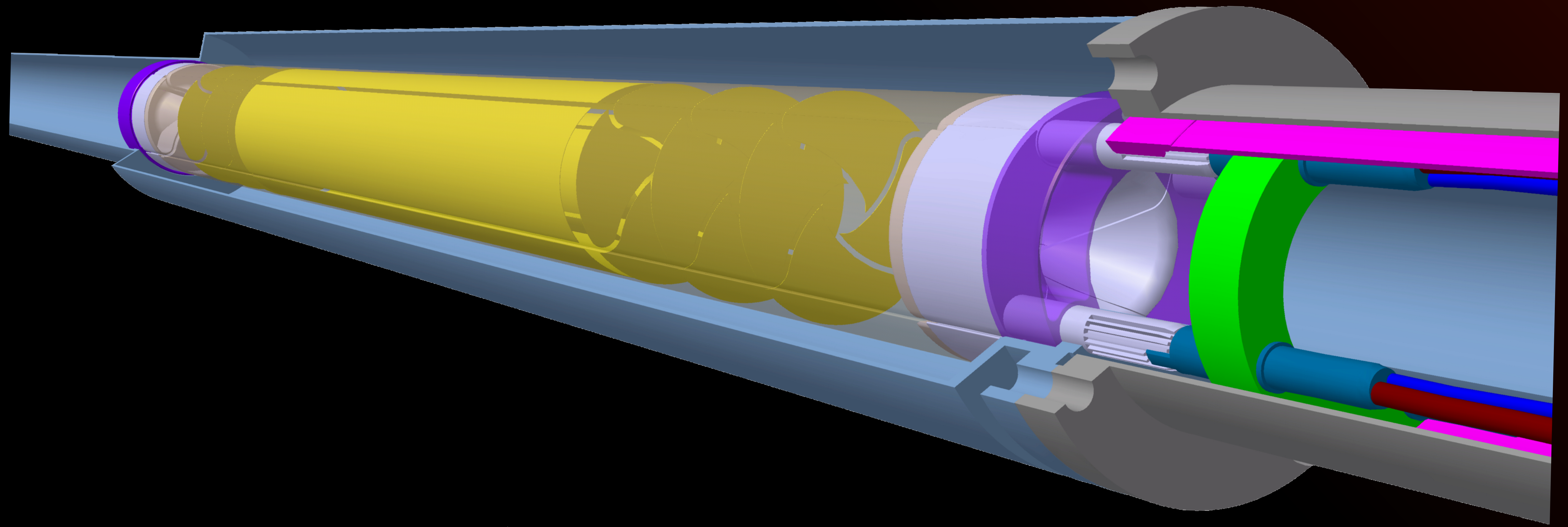

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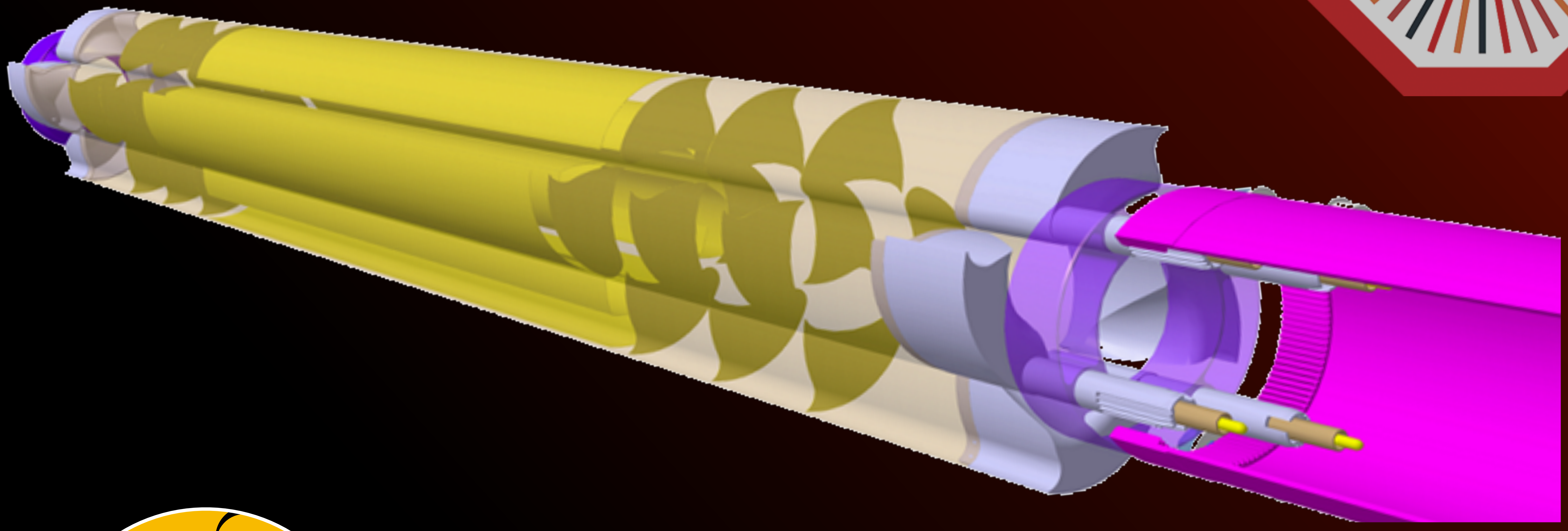
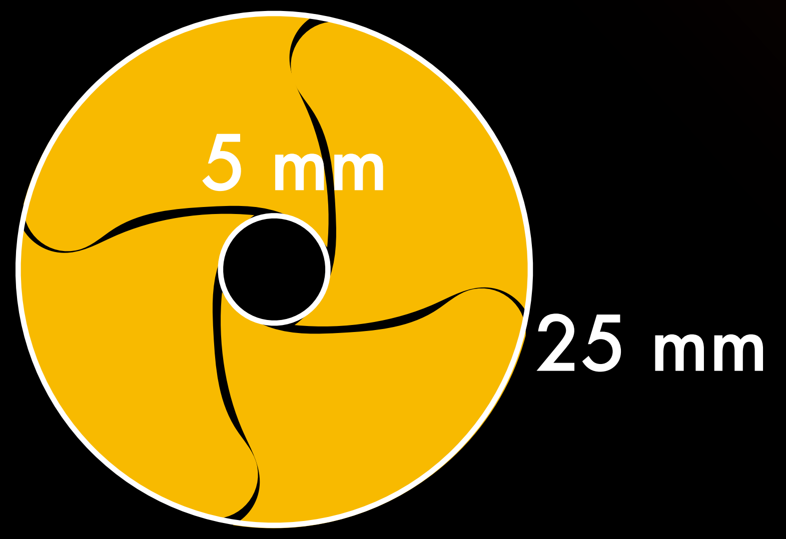
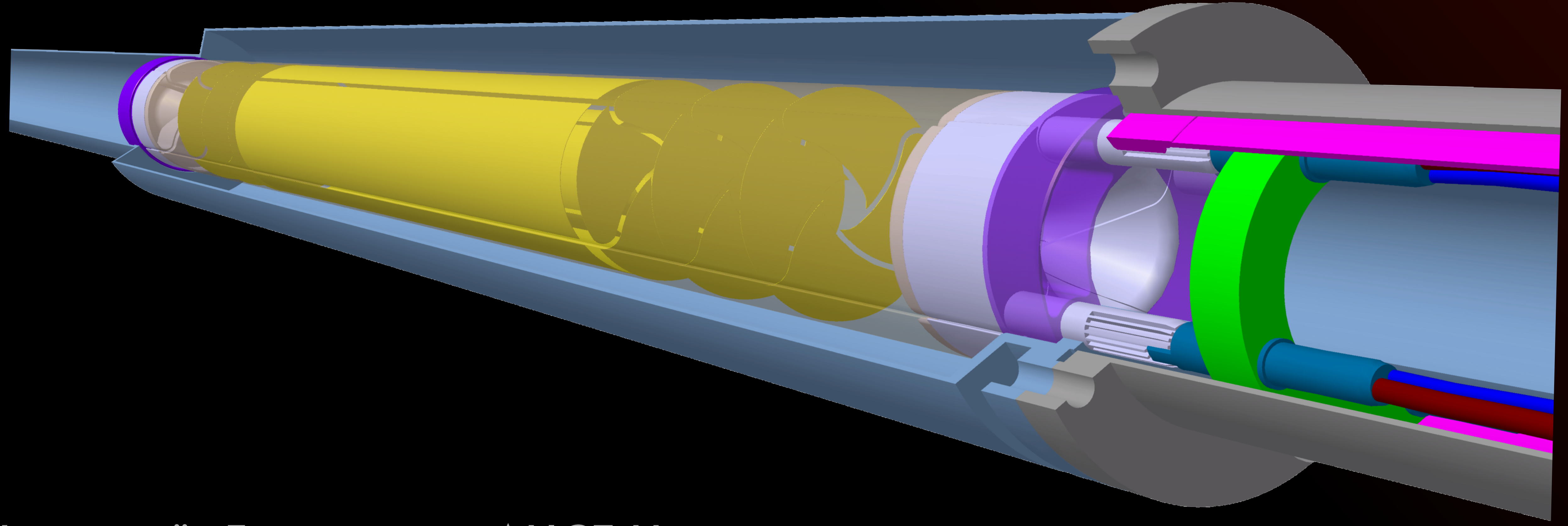






ALICE 3

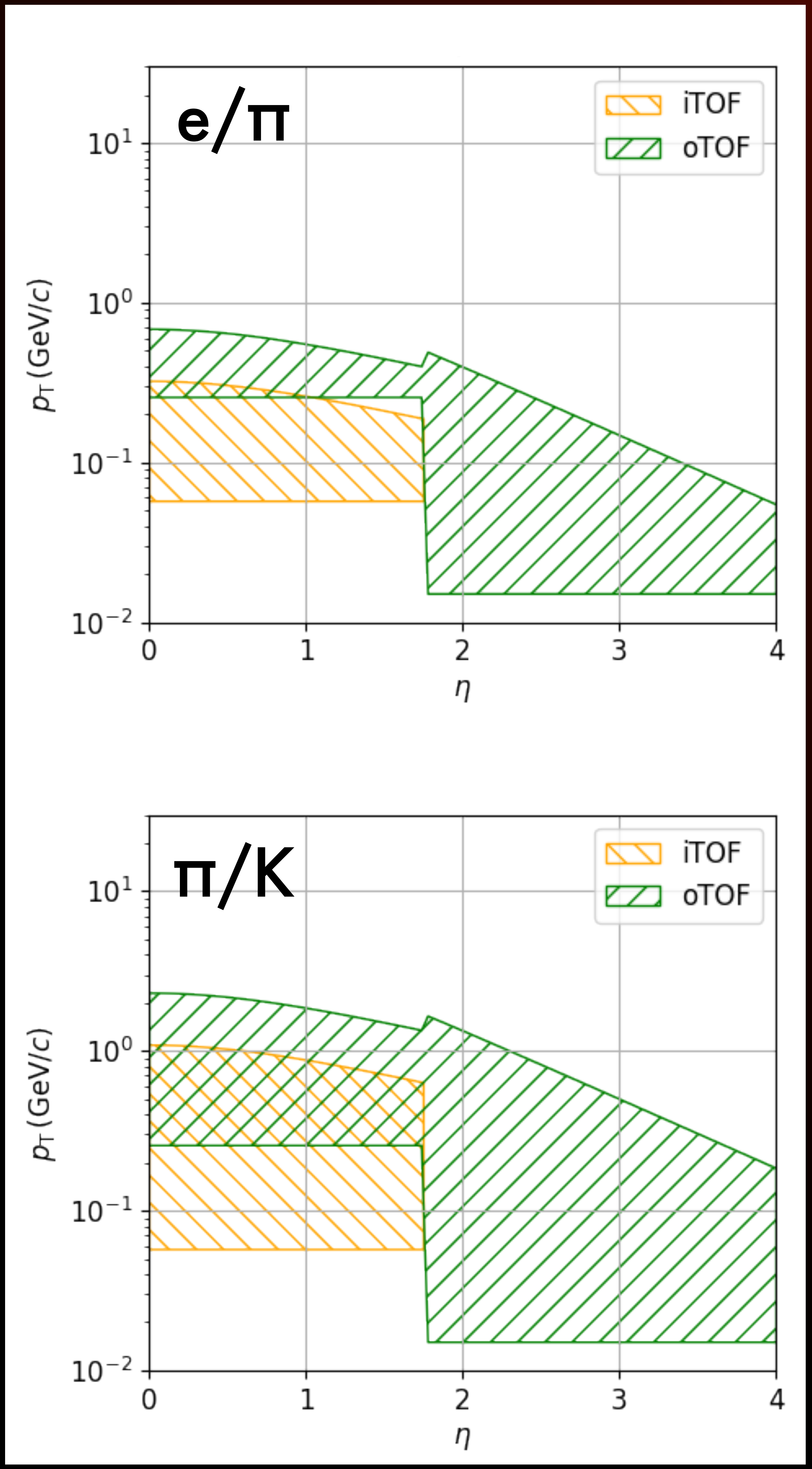
Particle identification TOF

Separation power $\propto \dfrac{L}{\sigma_{\mathrm{tof}}}$

- distance and time resolution crucial
- larger radius results in lower p_T bound

- **2 barrel + 1 forward TOF layers**
  - outer TOF at R ≈ 85 cm
  - inner TOF at R ≈ 19 cm
  - forward TOF at z ≈ 405 cm

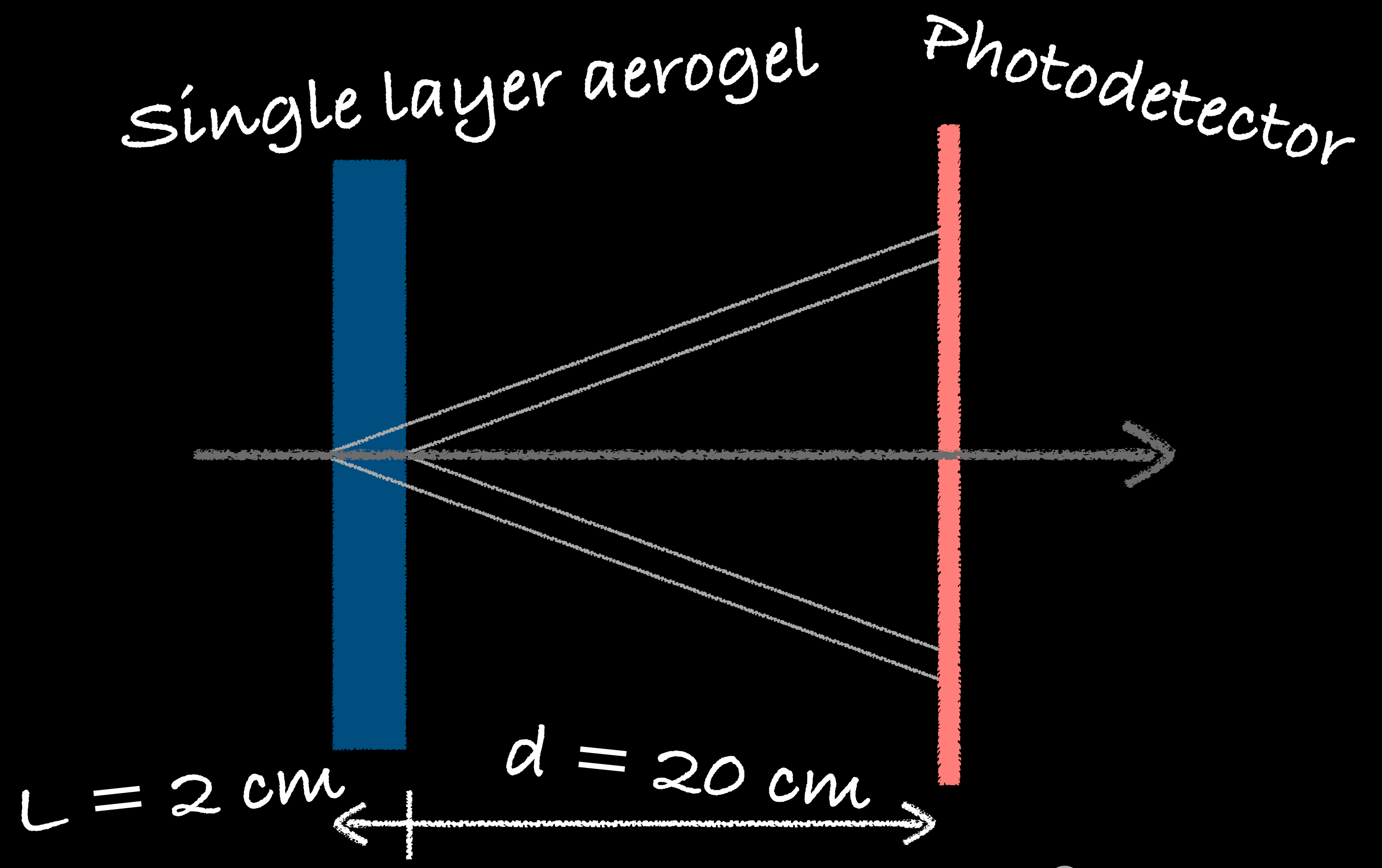
- **Silicon timing sensors** (σ_{TOF} ≈ 20 ps)

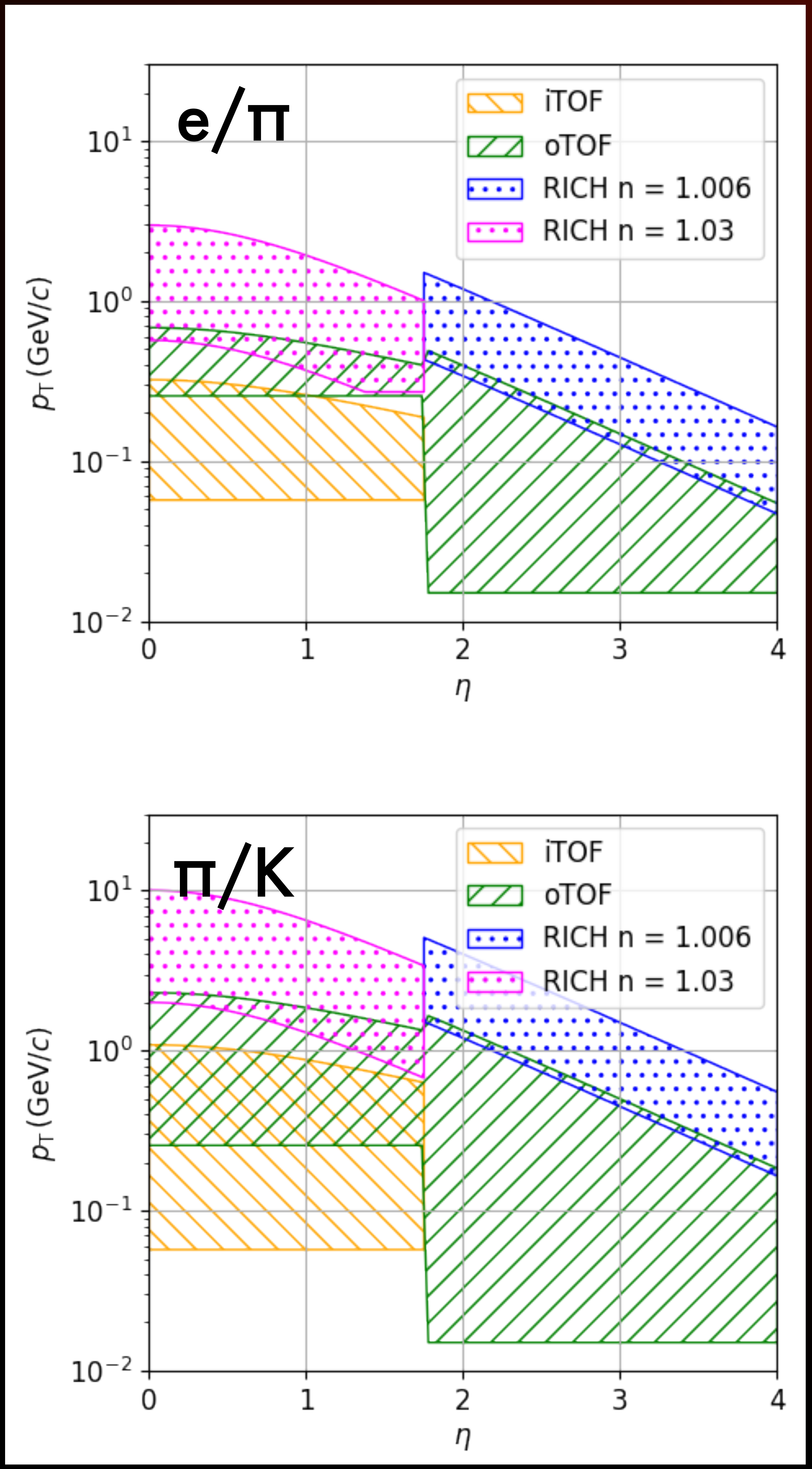


ALICE 3

Particle identification RICH

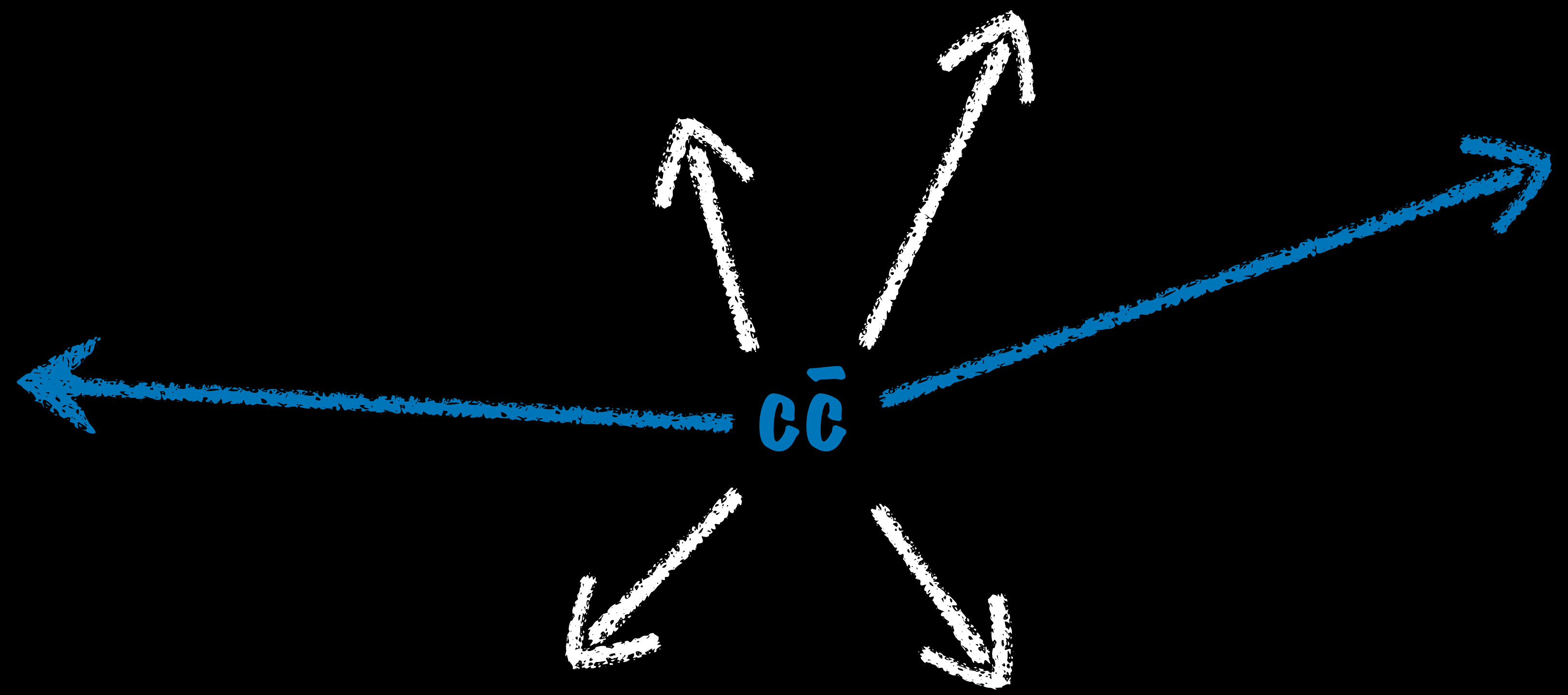
- **Extend PID reach of outer TOF to higher p_T with Cherenkov**
  - **aerogel radiator**
    to ensure continuous coverage from TOF
    → refractive index n = 1.03 (barrel)
    → refractive index n = 1.006 (forward)

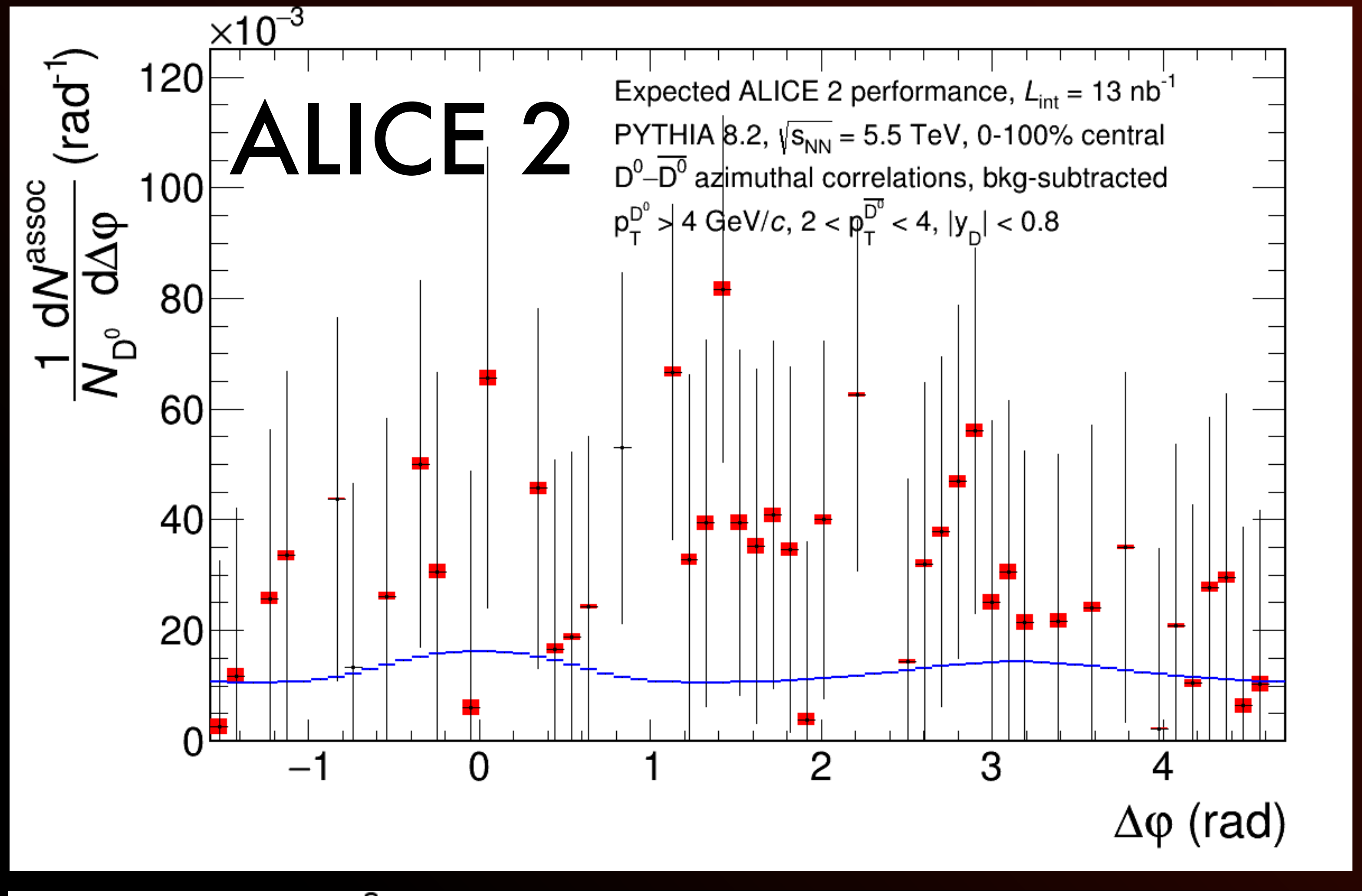


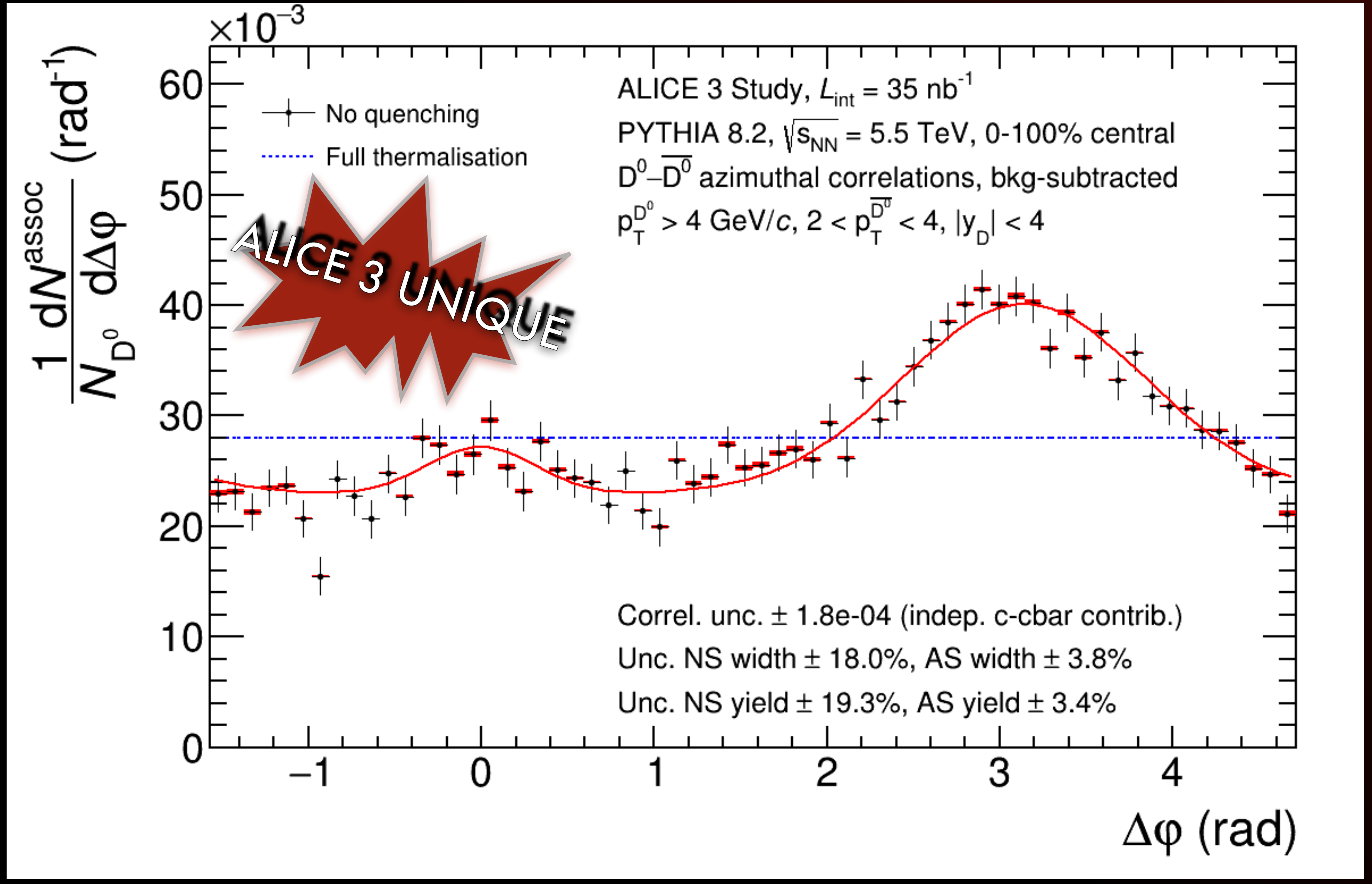


$D\bar{D}$ azimuthal correlations

E. Frajna – Poster Session T15 2







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Angular decorrelation of HF as direct probe of the QGP

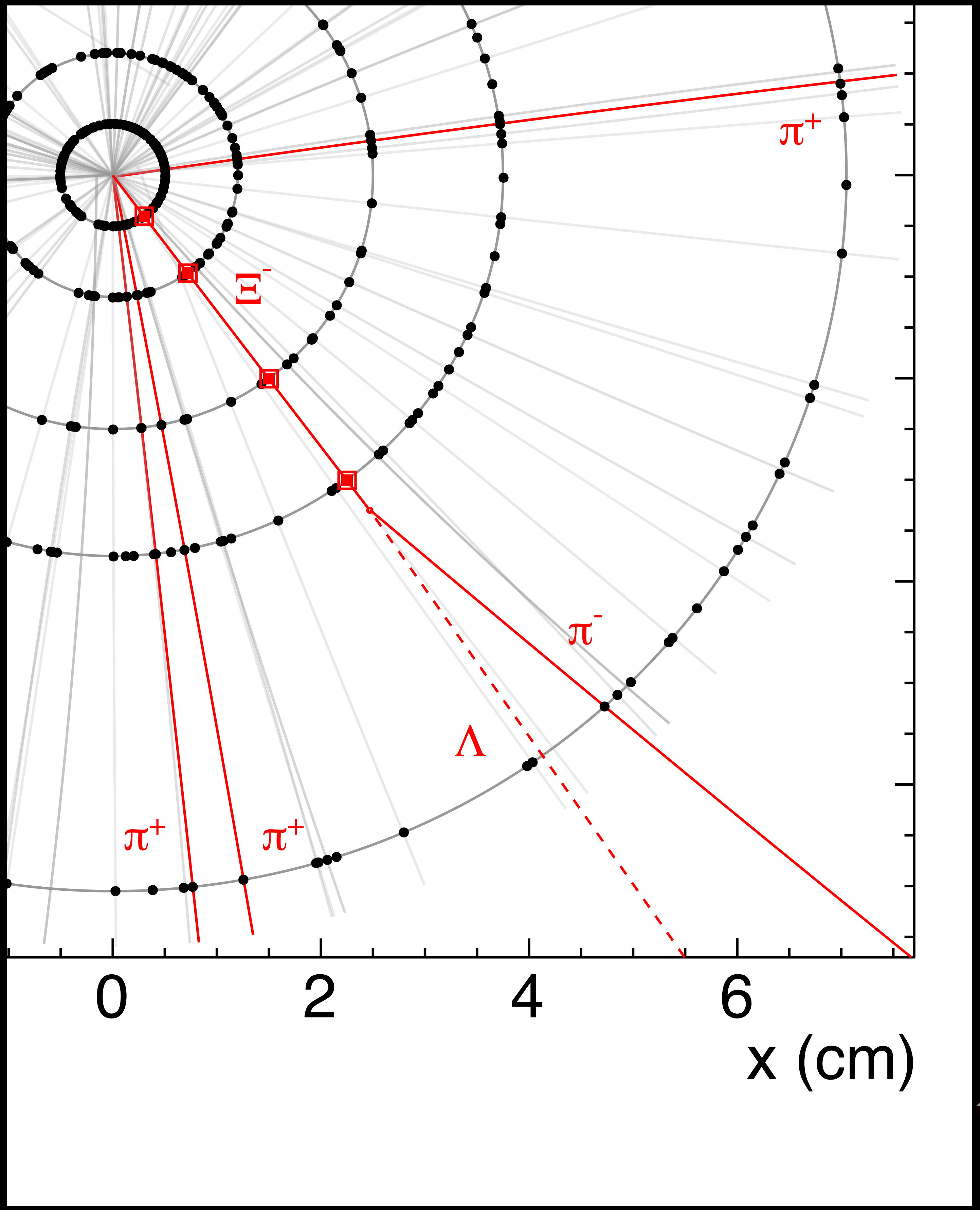
- ➟ Strongest signal at low p_T

Requires high purity, efficiency and large η coverage

- ➟ Measurement in heavy-ion collisions only feasible with ALICE 3

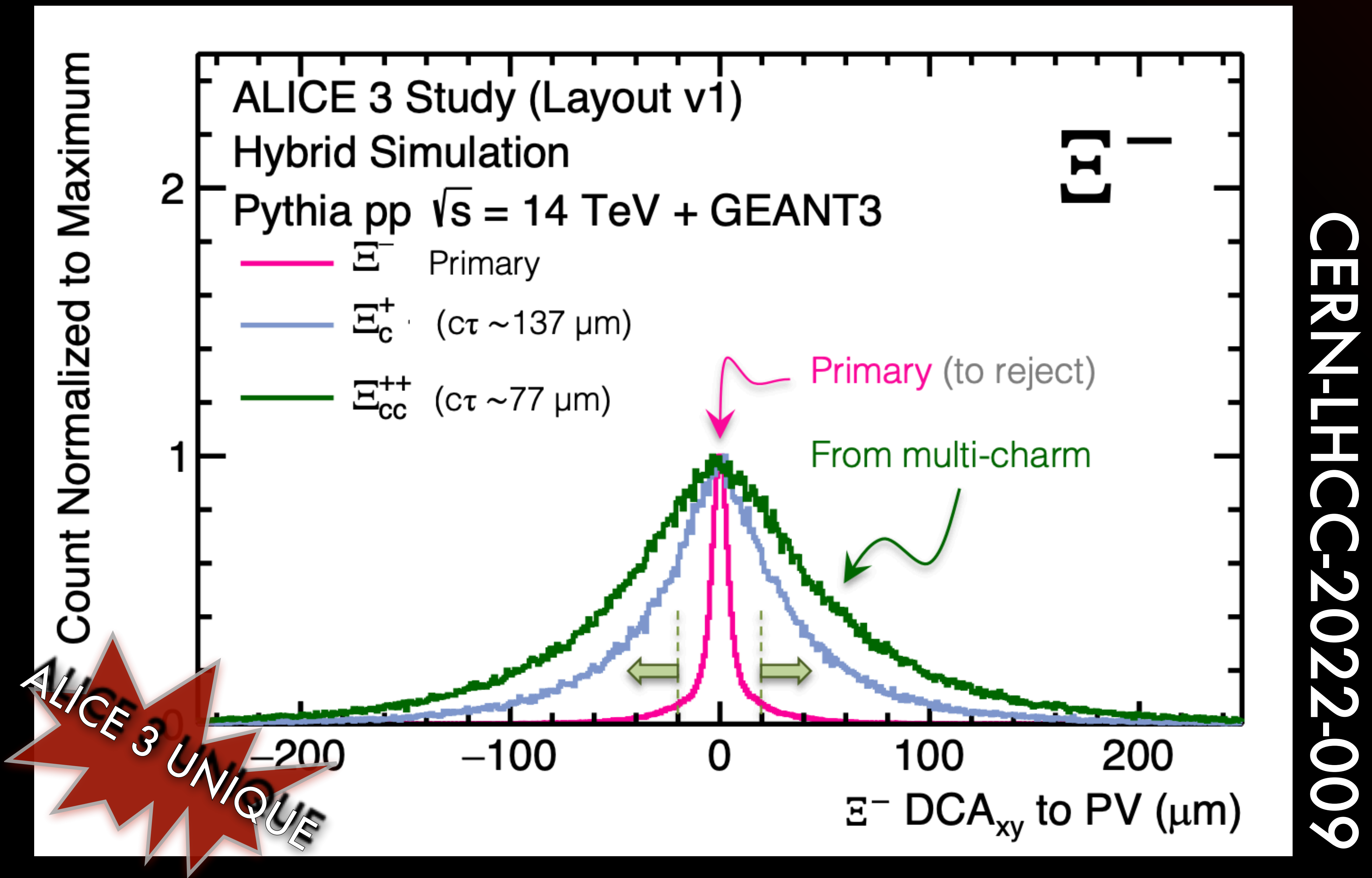
Multi-Charm Baryons

Strangeness Tracking



Pointing of Ξ baryon provides high selectivity

$$\Xi_{cc}^{++} \rightarrow \Xi_c^+ + \pi^+$$
$$\Xi_c^+ \rightarrow \Xi^- + 2\pi^+$$

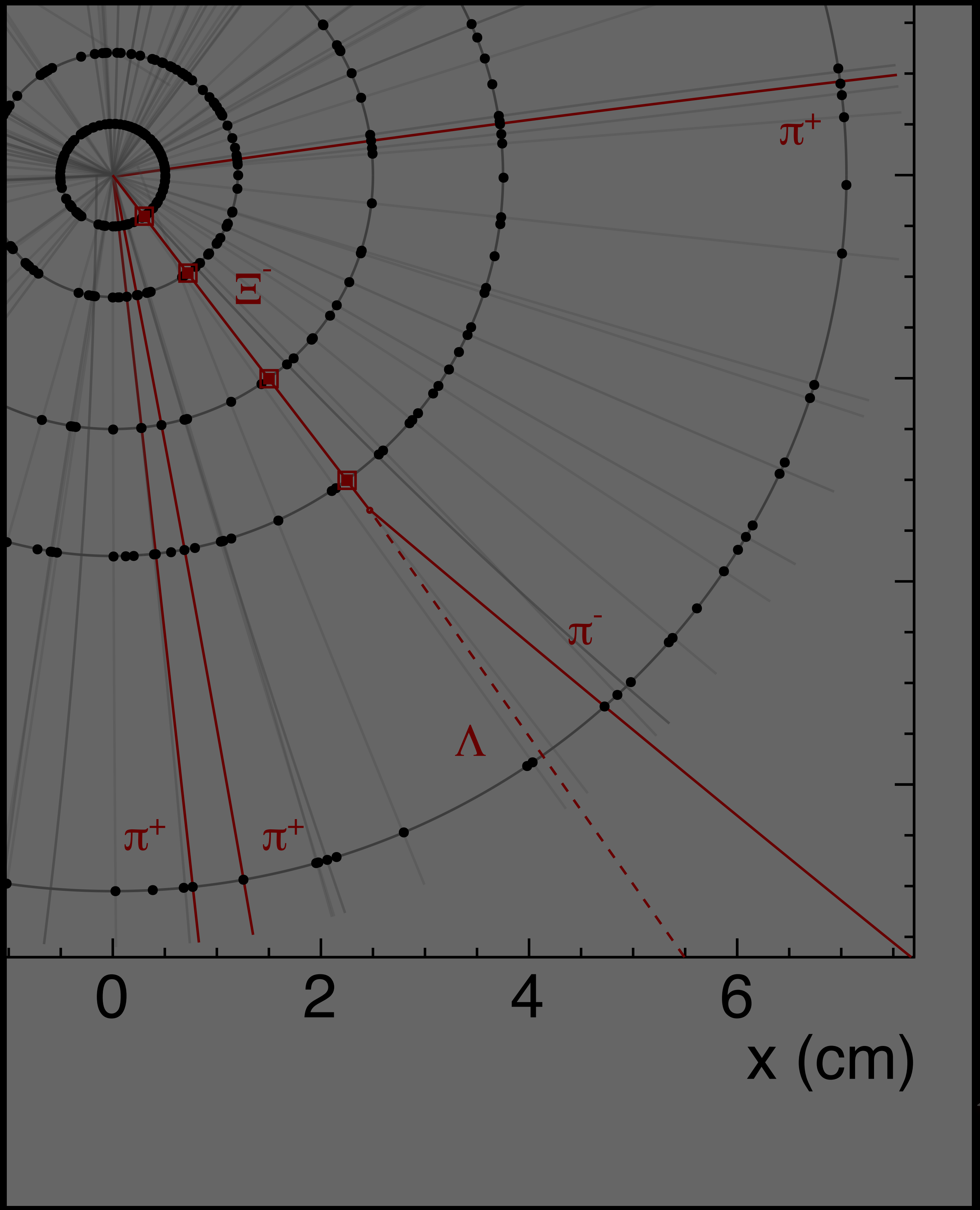


J. Seo – Poster Session T15 1

Multi-Charm Baryons

Strangeness Tracking

Large enhancements: unique sensitivity to
thermalisation and hadronisation



Pointing of Ξ baryon p

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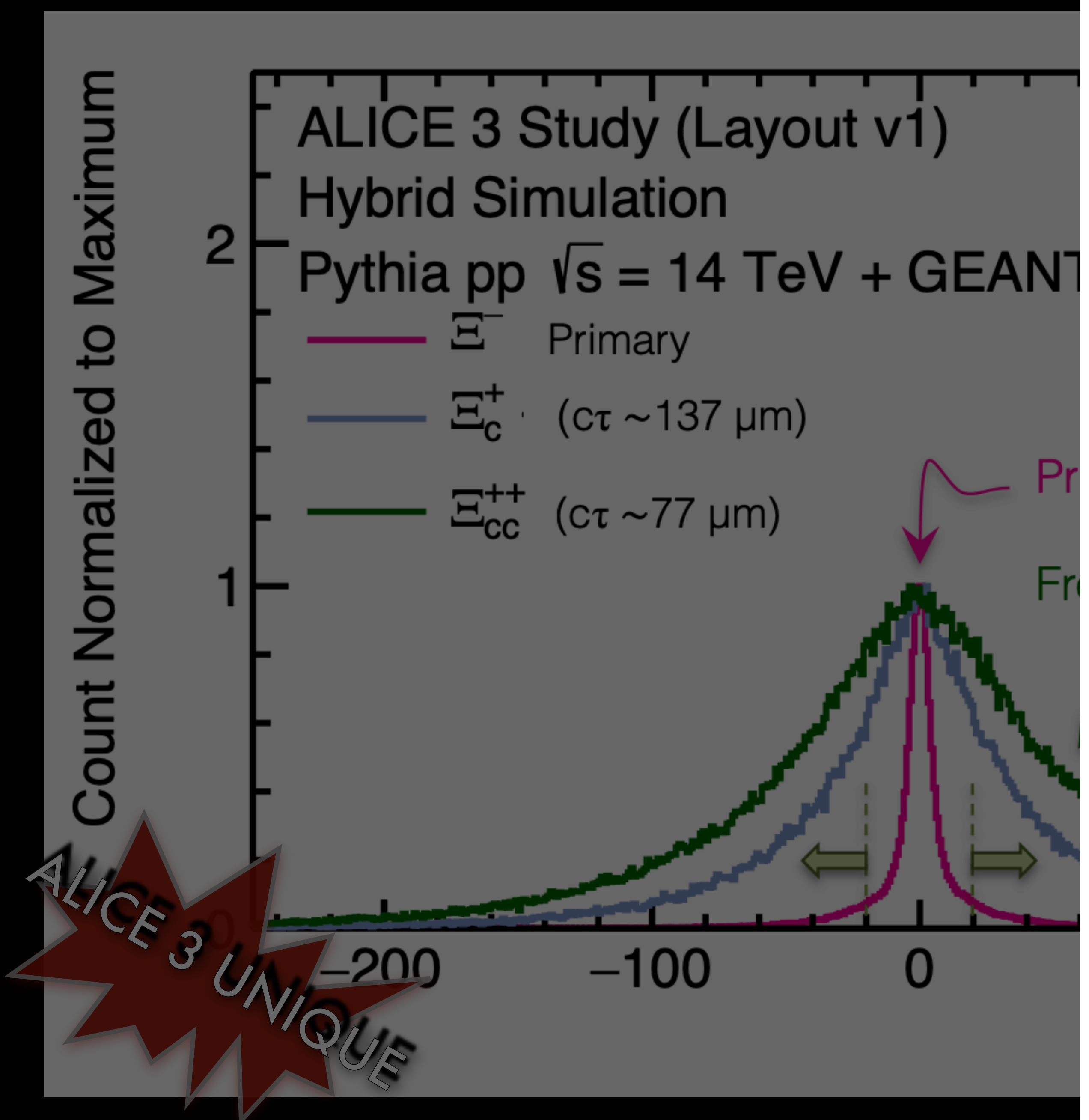

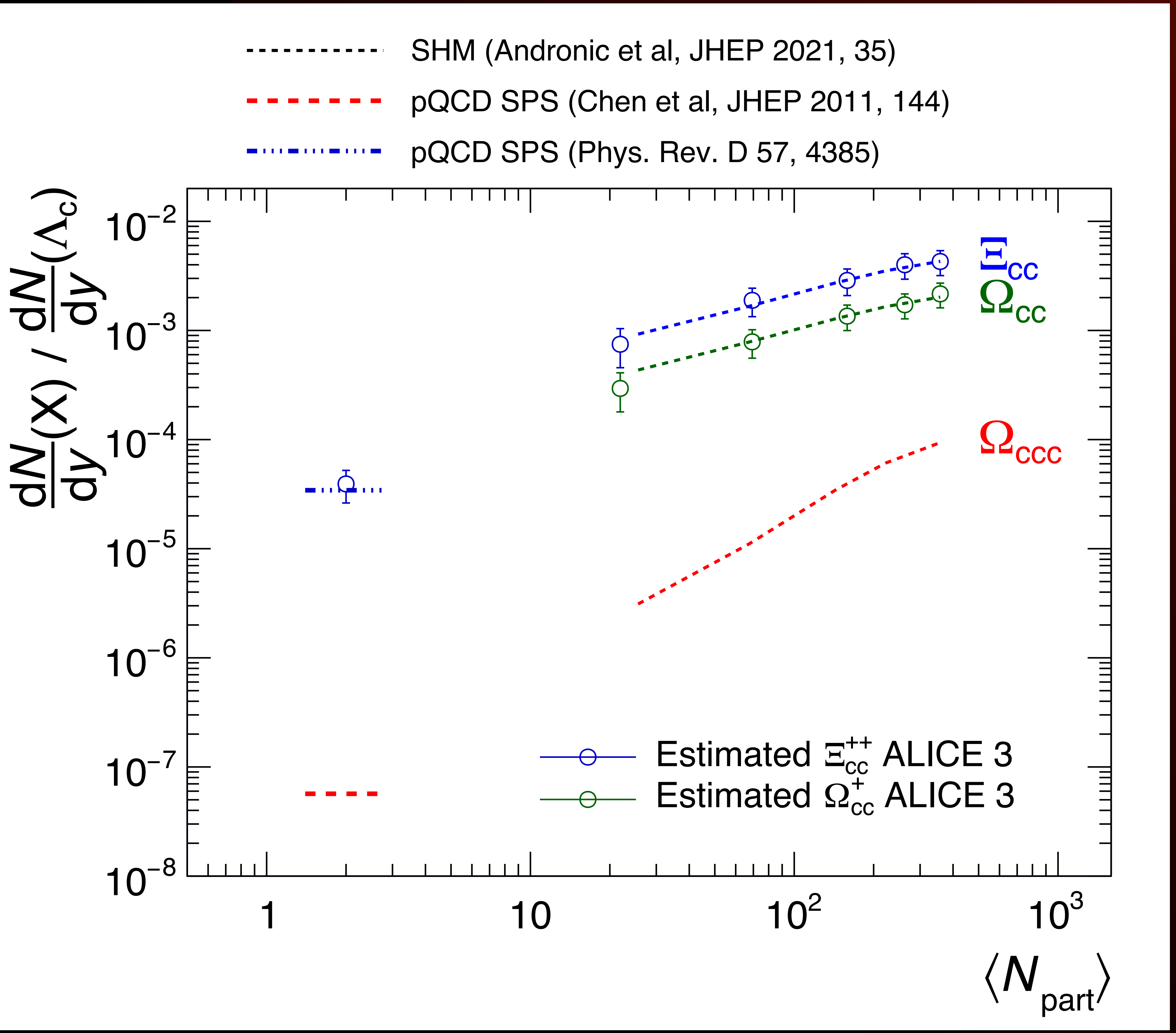

Dielectrons

Use improved pointing resolution to reject HF

➡ Significant reduction of charm contribution and associated uncertainty

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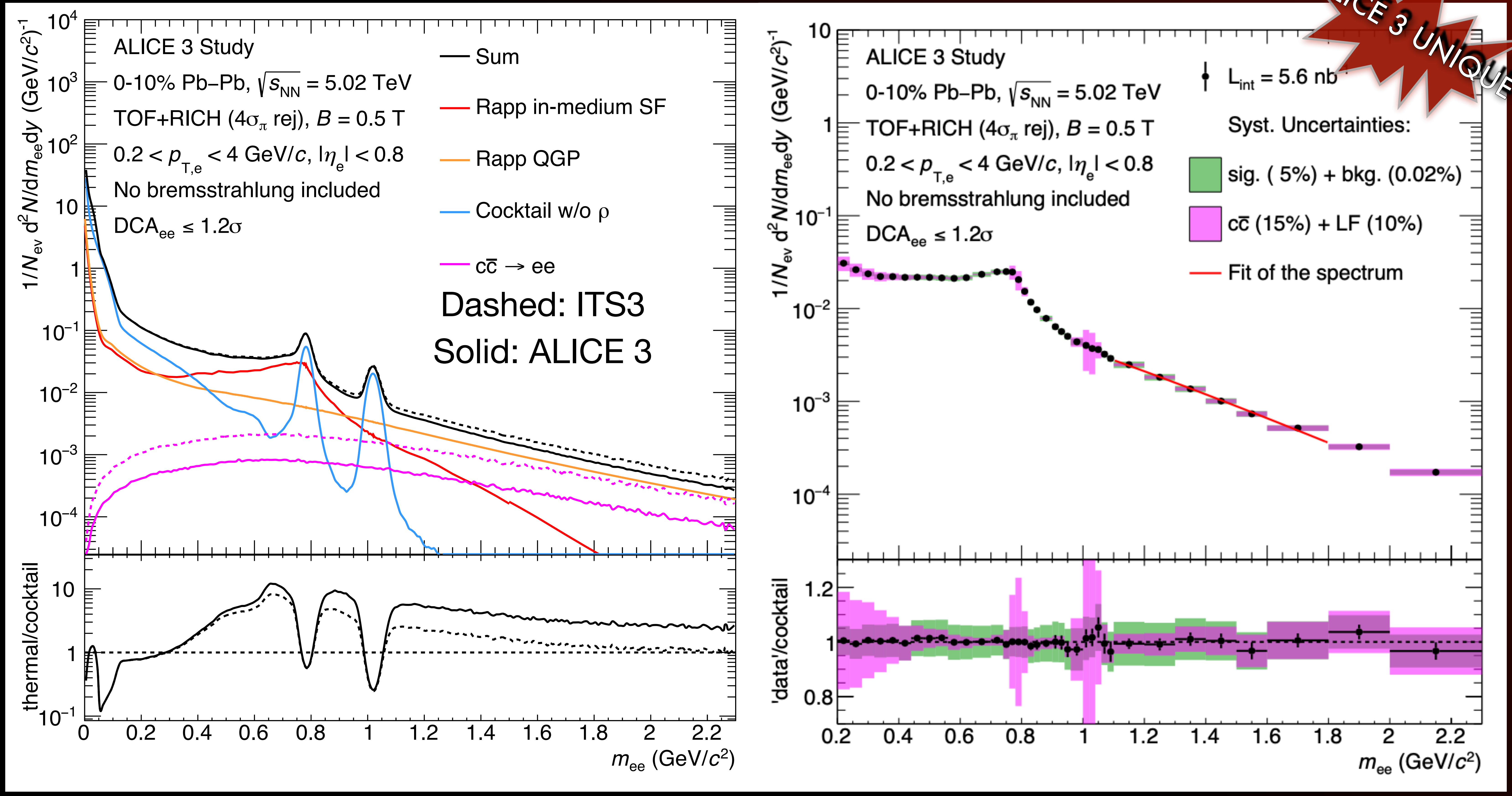
ALICE 3 UNIQUE

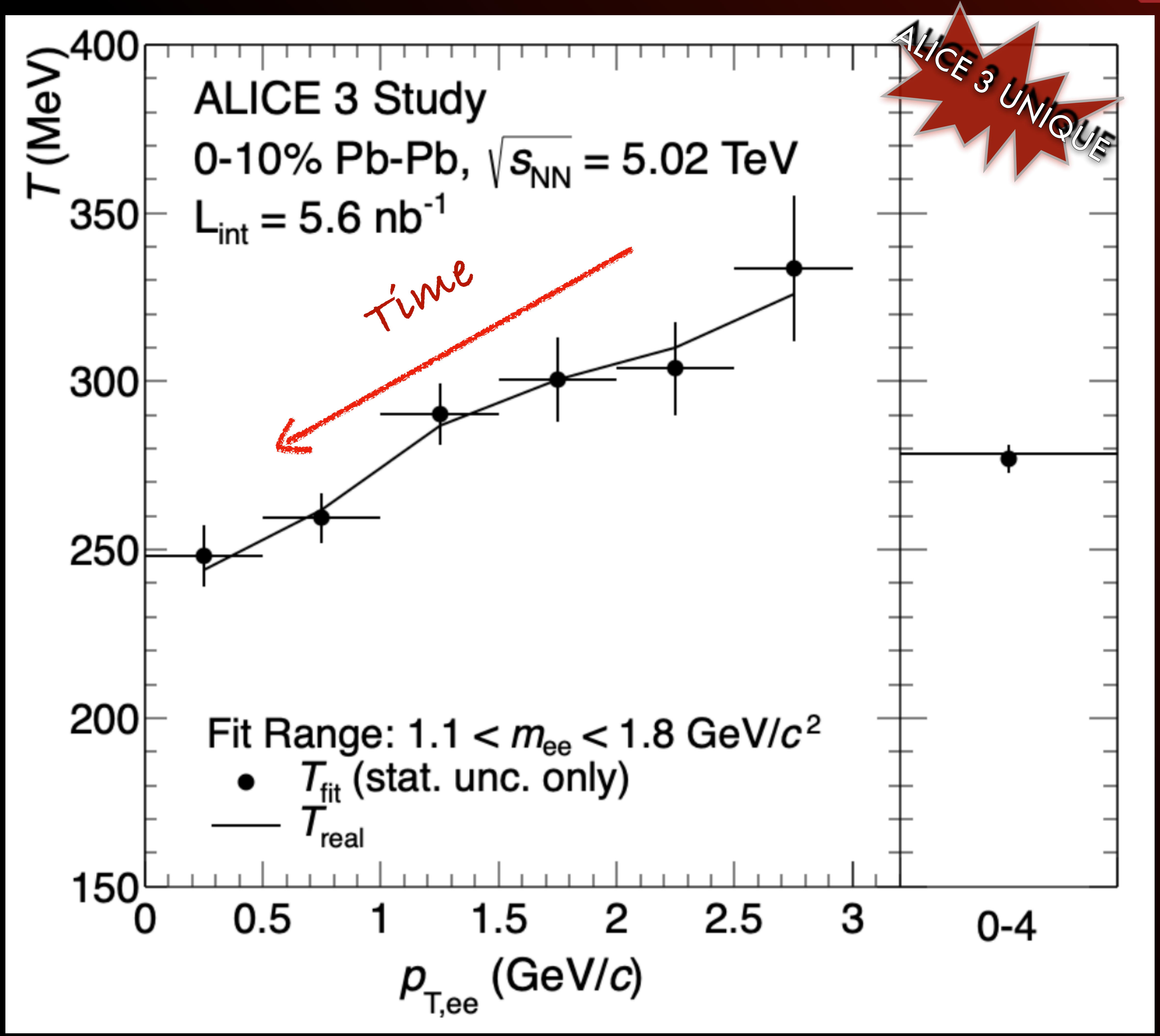


F. Eisenhut – Poster Session T15 1

Dielectrons

Use improved pointing resolution to reject HF

- ➠ Significant reduction of charm contribution and associated uncertainty
- ➠ Possibility for multi-differential dielectron measurements → time dependence of emission



CERN-LHCC-2022-009

Conclusion

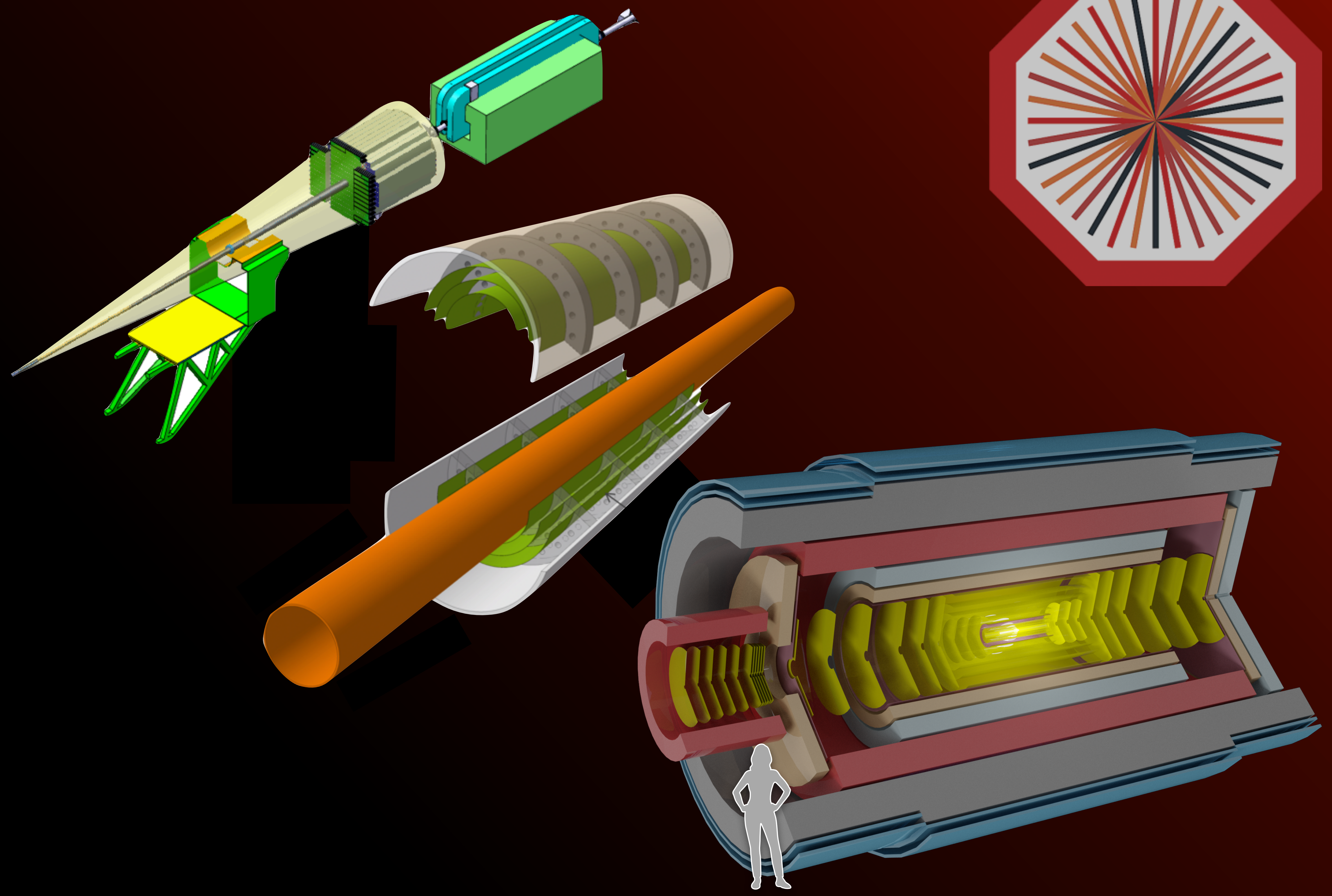
Significant R&D progress with ITS3 and FoCal

Operation of bent silicon sensors in test beams

Demonstration of FoCal concept in test beams, complete prototype under construction

Letter of ALICE 3 reviewed by LHCC: CERN-LHCC-2022-009

Recommendation to proceed with R&D programme



F. Eisenhut – Poster Session T15 1
E. Frajna – Poster Session T15 2
A. Palasciano – Poster Session T11 2
T. Rogoschinski – Poster Session T15 1
J. Seo – Poster Session T15 1
M. Völkl – Poster Session T15 2