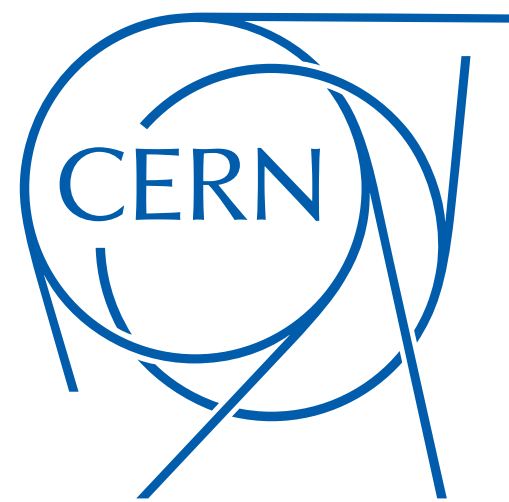


Welcome to Hard Probe 2018

Eckhard Elsen

Director Research and Computing

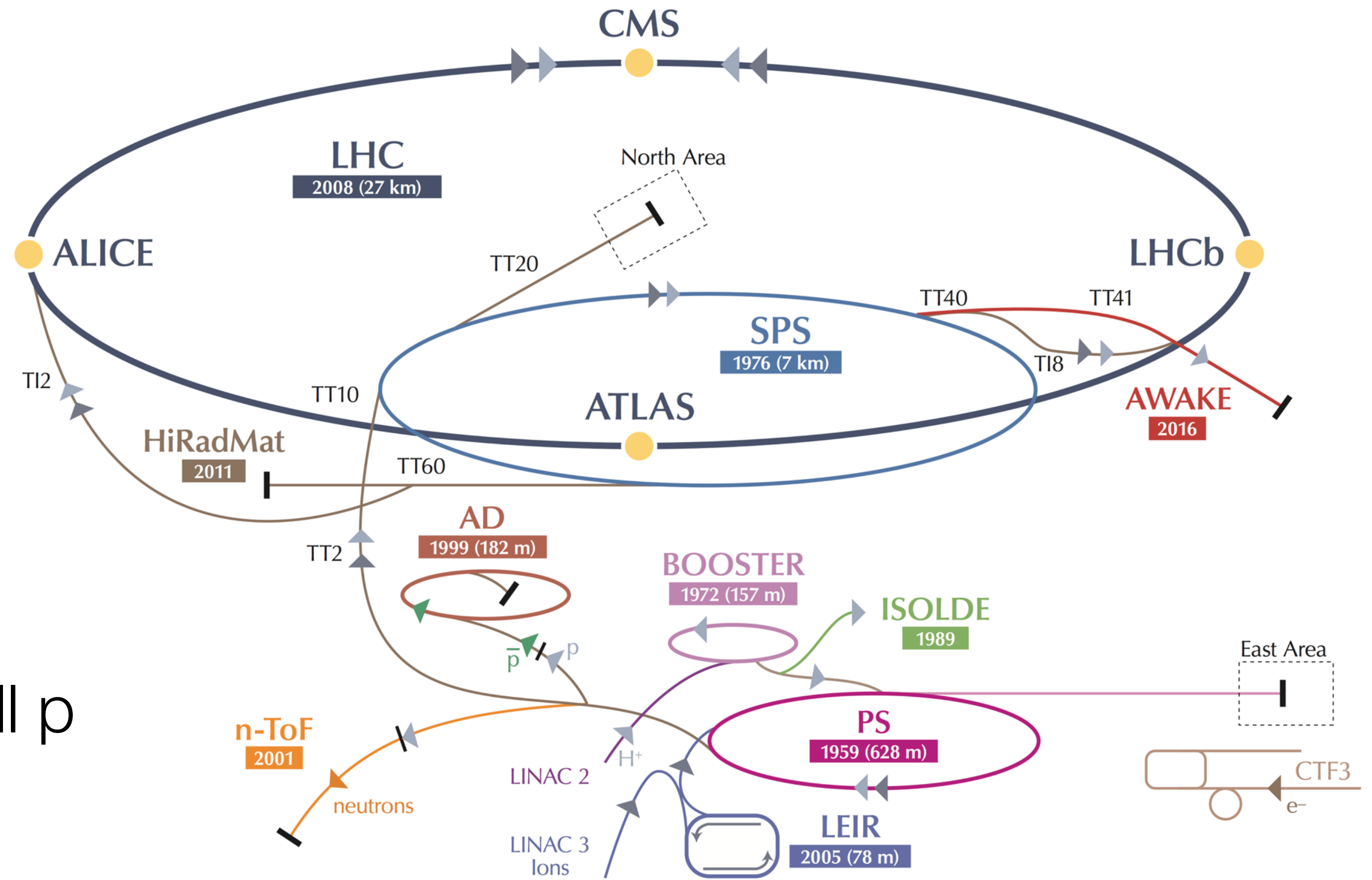


The conference is focused on experimental and theoretical developments on perturbative probes of hot and dense QCD matter as studied in high-energy nucleus-nucleus, proton-nucleus and proton-proton collisions, including: (i) nuclear Parton Distribution Functions and early-time dynamics, (ii) jets and high-pT hadrons, (iii) heavy quarks (charm, bottom, top), and quarkonia, (iv) high-pT photons and electroweak bosons, and (v) future experimental and new theoretical developments in associated topics.



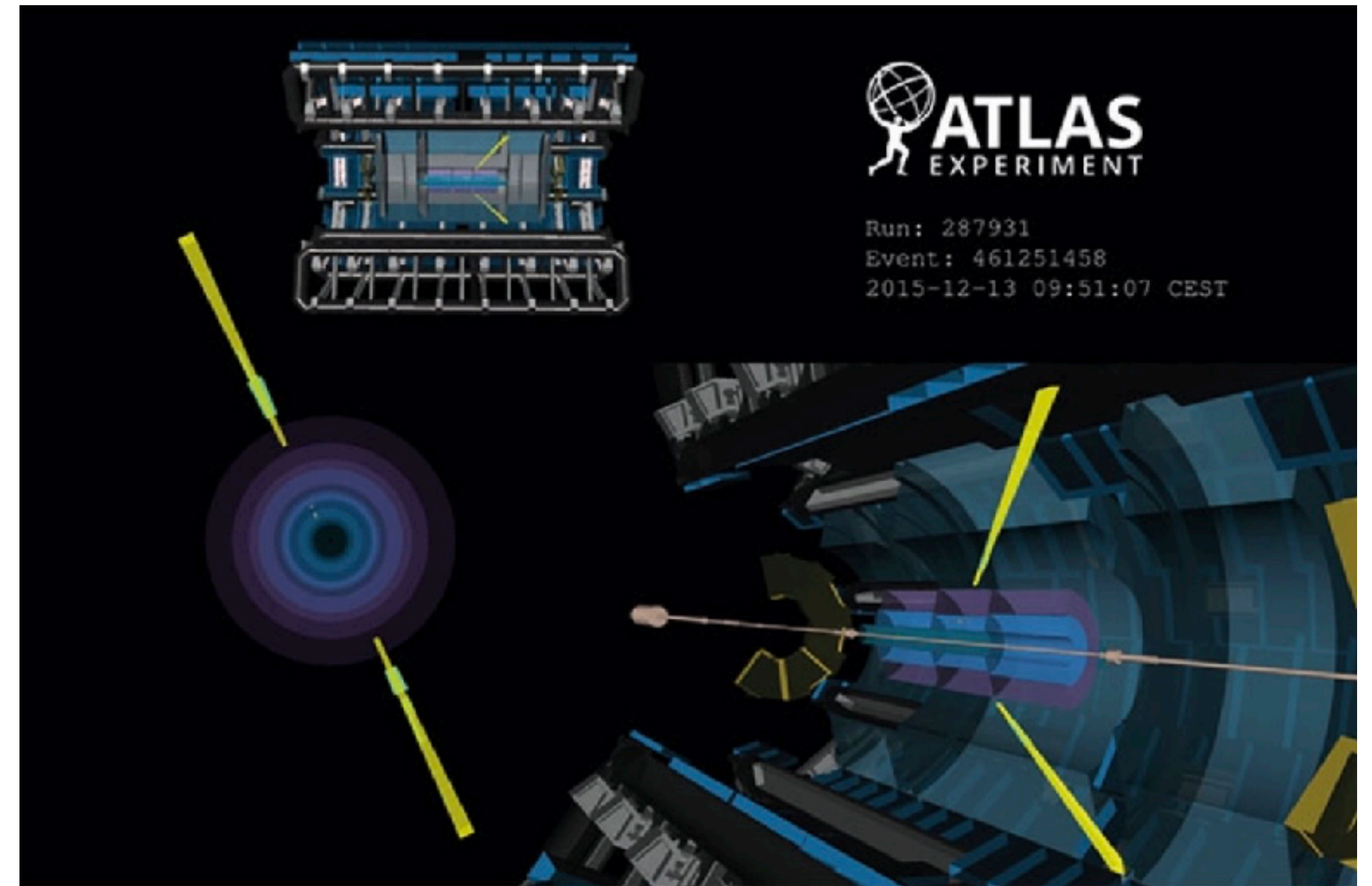
LHC and its injector chain

- LHC
 - ongoing Run 2 @ 13 TeV
- Injectors supporting
 - Fixed target programme
 - ISOLDE (isotopes) } 75% of all p
 - n-ToF
 - AD-programme

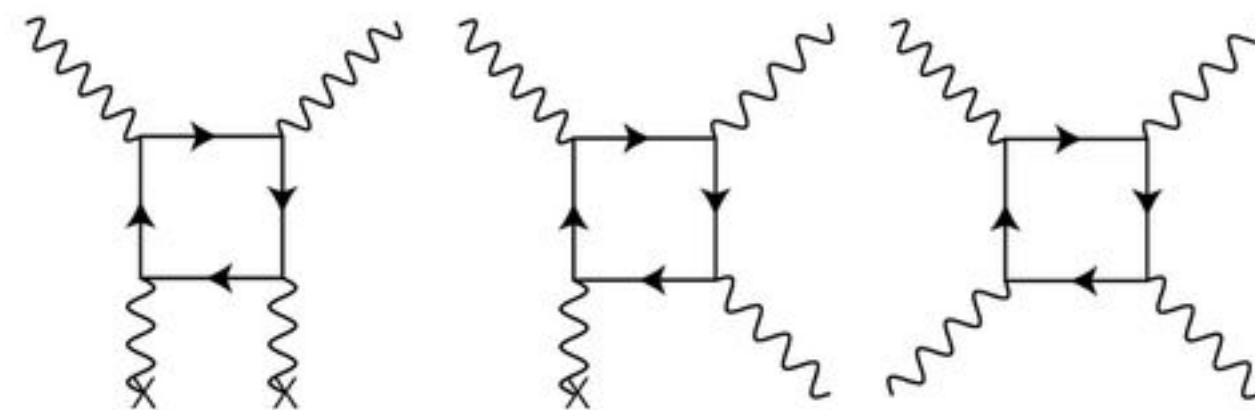


Light by light scattering in Heavy Ion Scattering

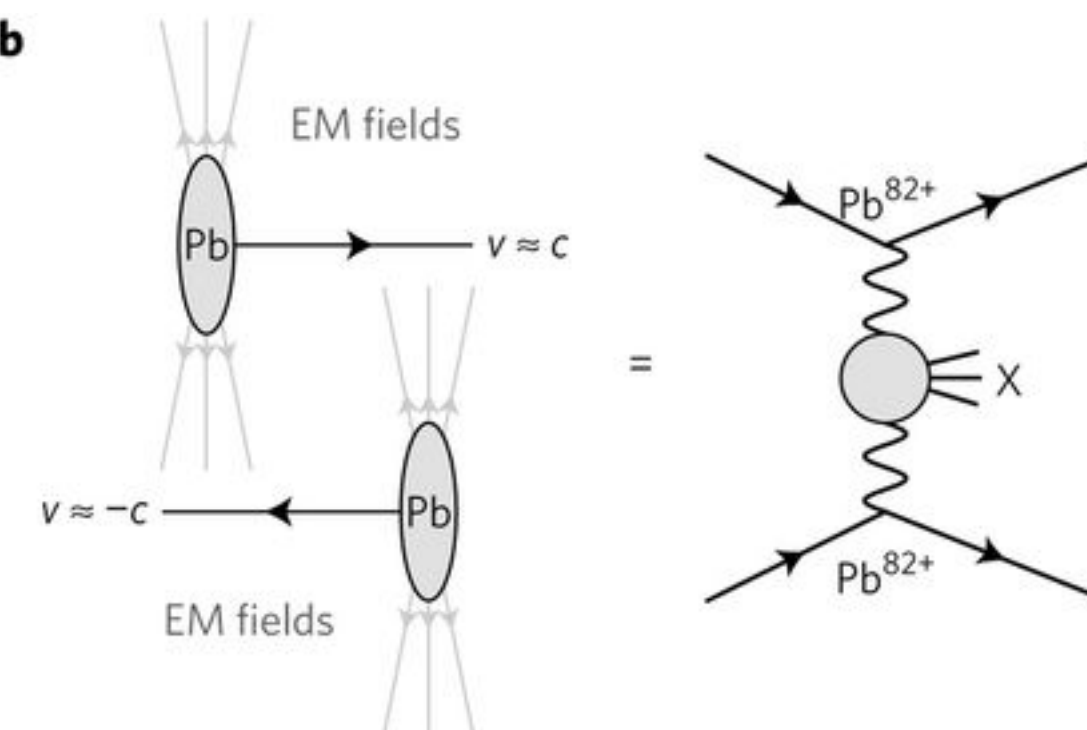
- Heavy Ion acts as a copious source of photons
- ATLAS Collaboration
Nature Physics 13, 852–858
(2017) doi:10.1038/nphys4208



a

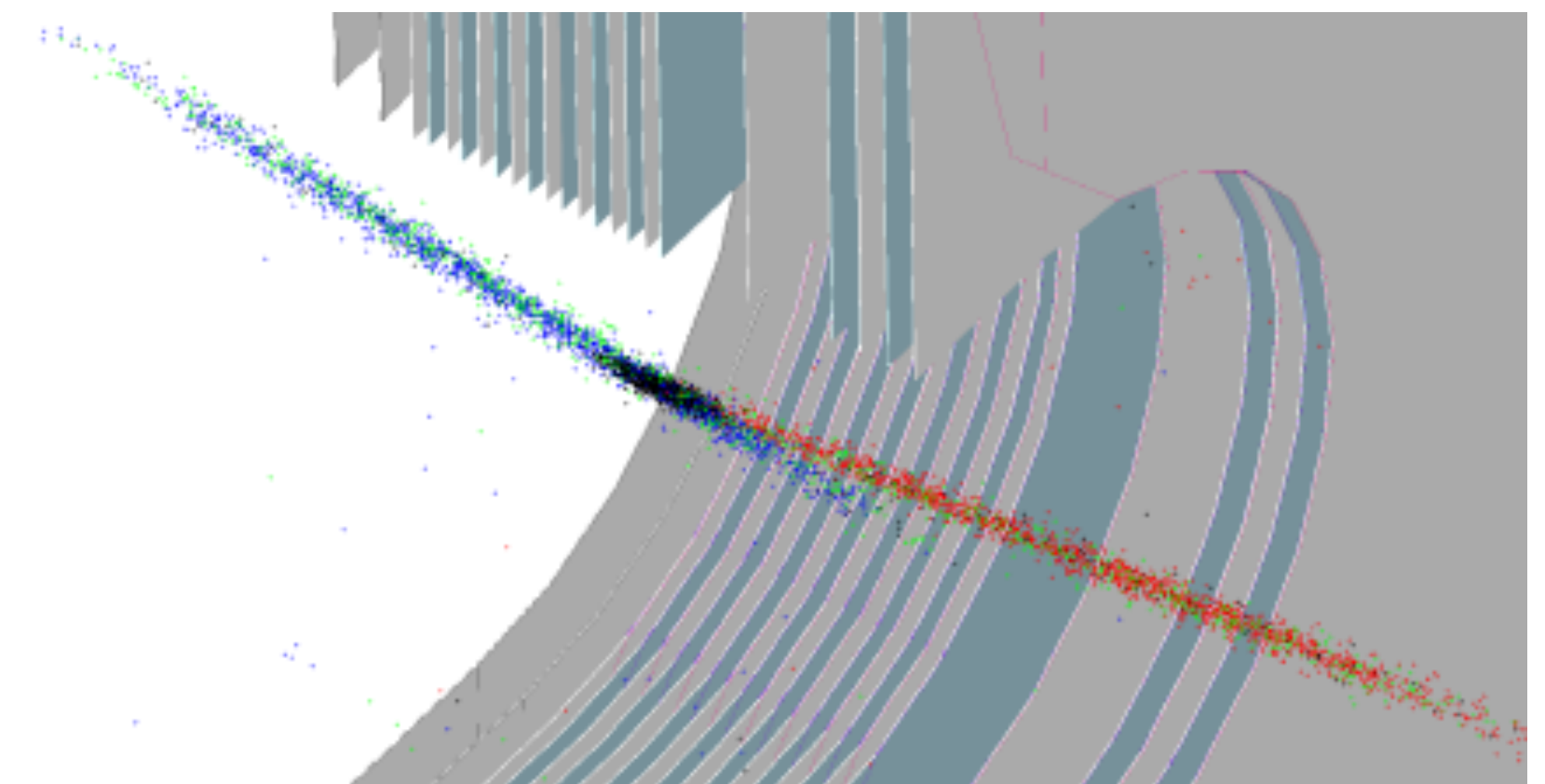
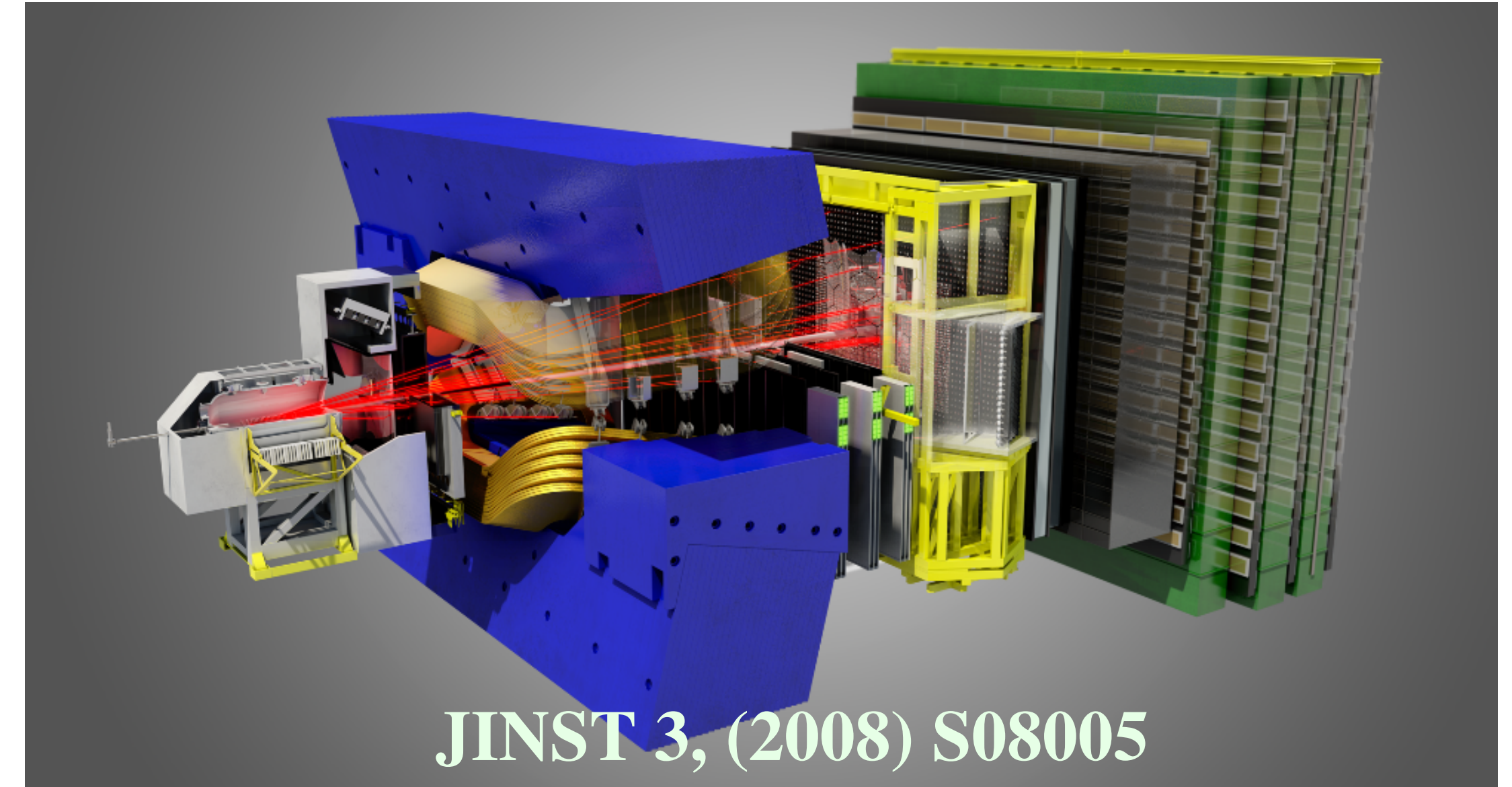


b



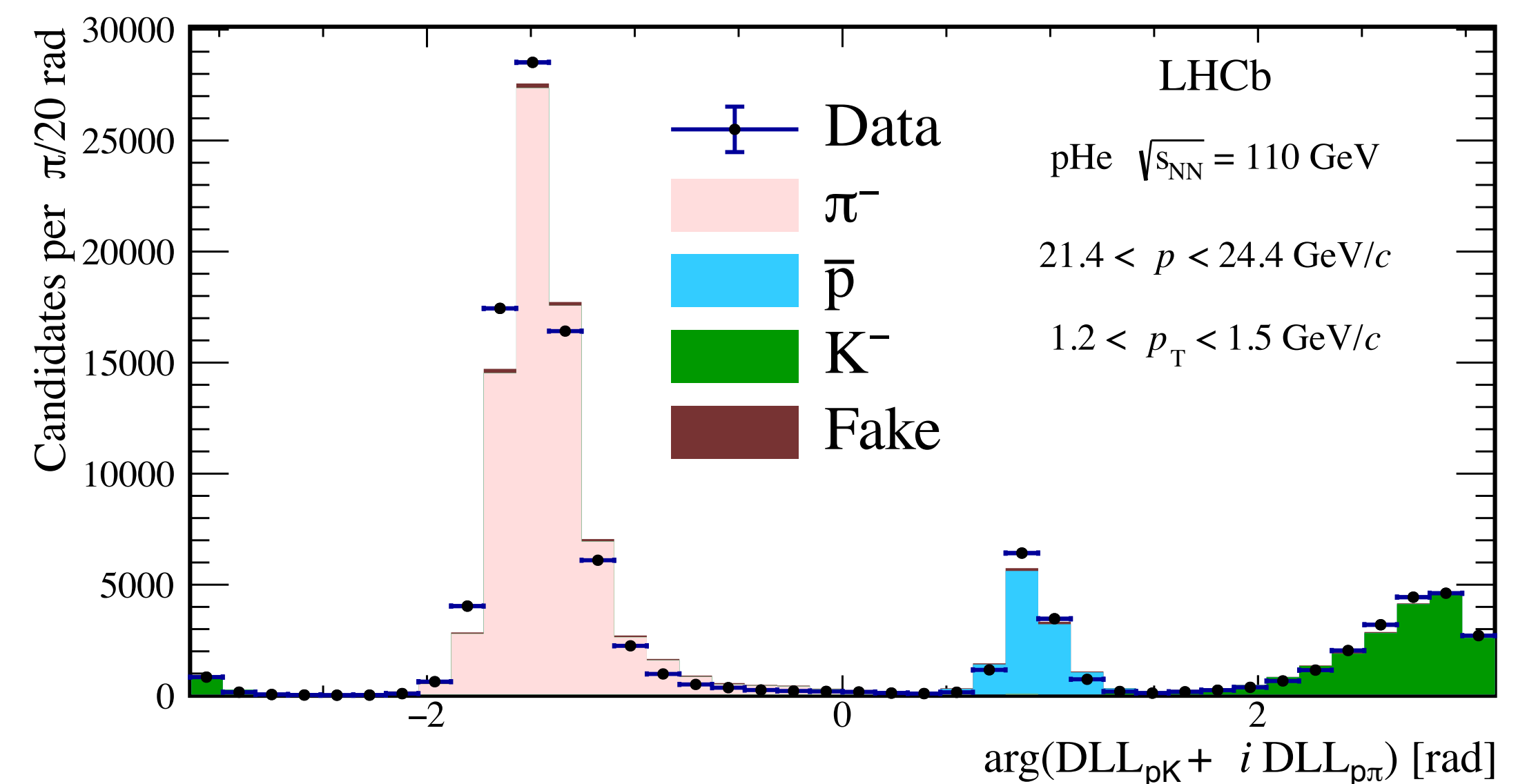
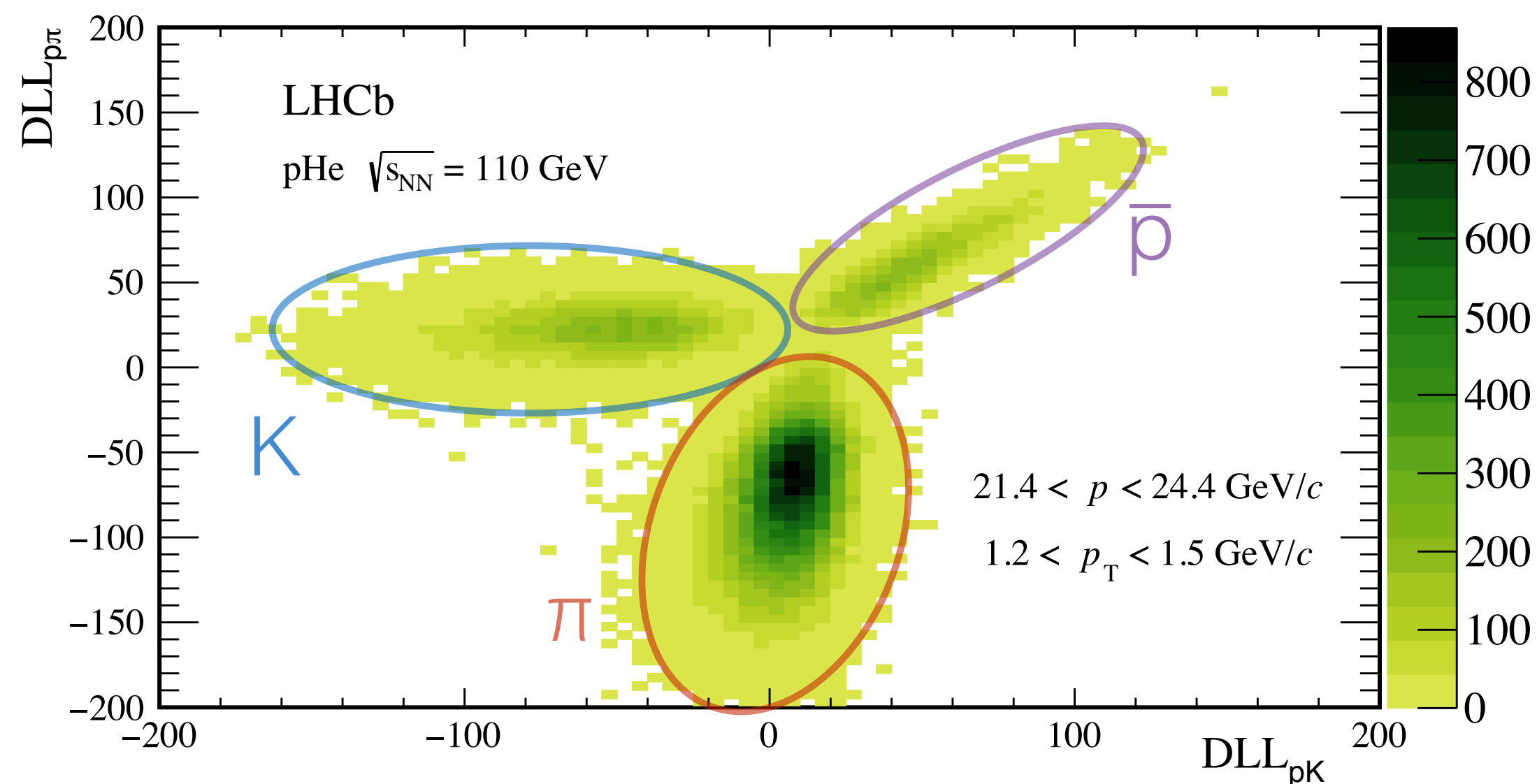
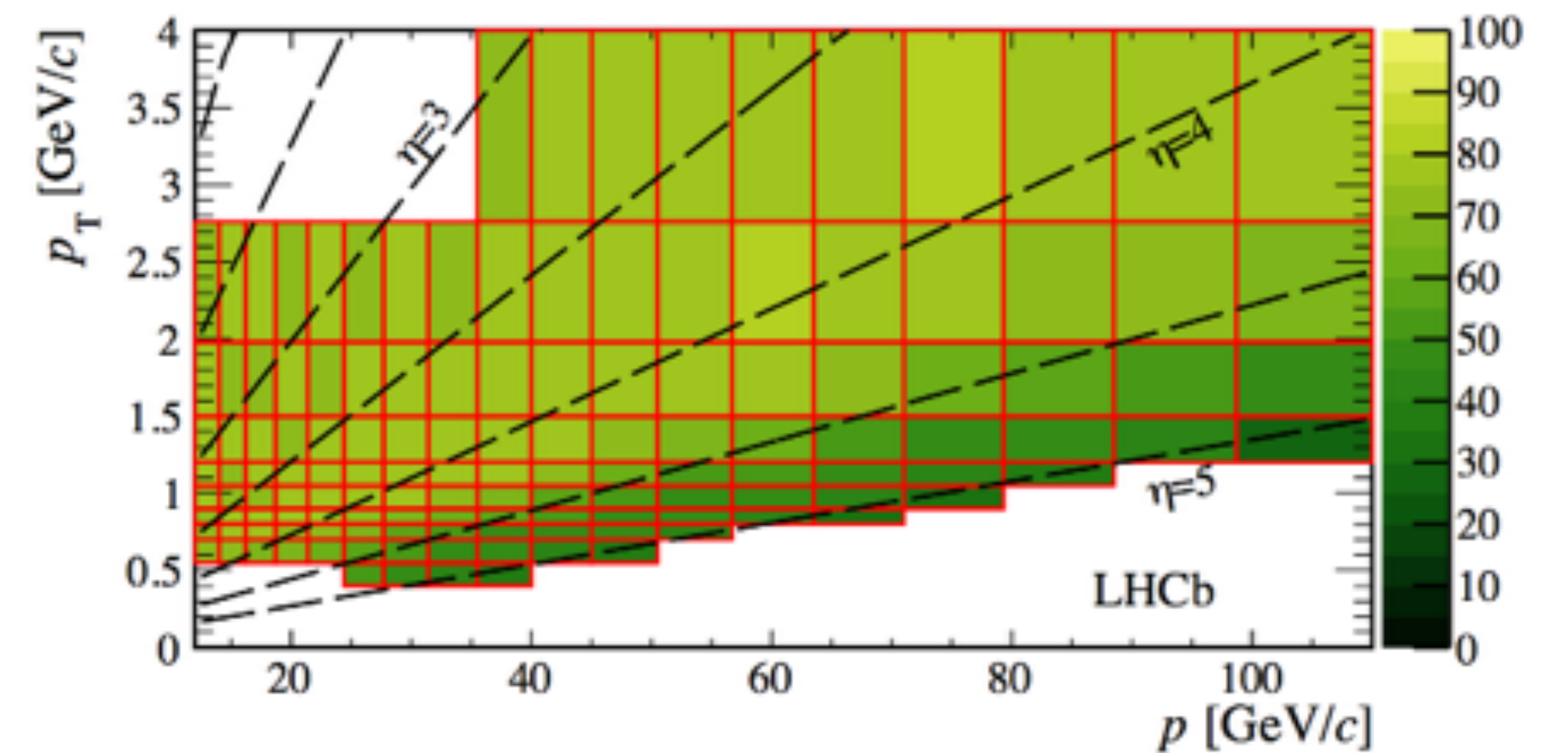
LHCb in Fixed Target mode

- System for Measuring Overlap with Gas (SMOG) allows to inject small amount of noble gas (He, Ne, Ar,...) inside the LHC beam around (± 20 m) the LHCb collision region
- pressure $\sim 2 \times 10^{-7}$ mbar
- In the meantime used for fixed target physics simultaneously with pp-mode.
- Further plans for PBC-study



pHe scattering using gas target

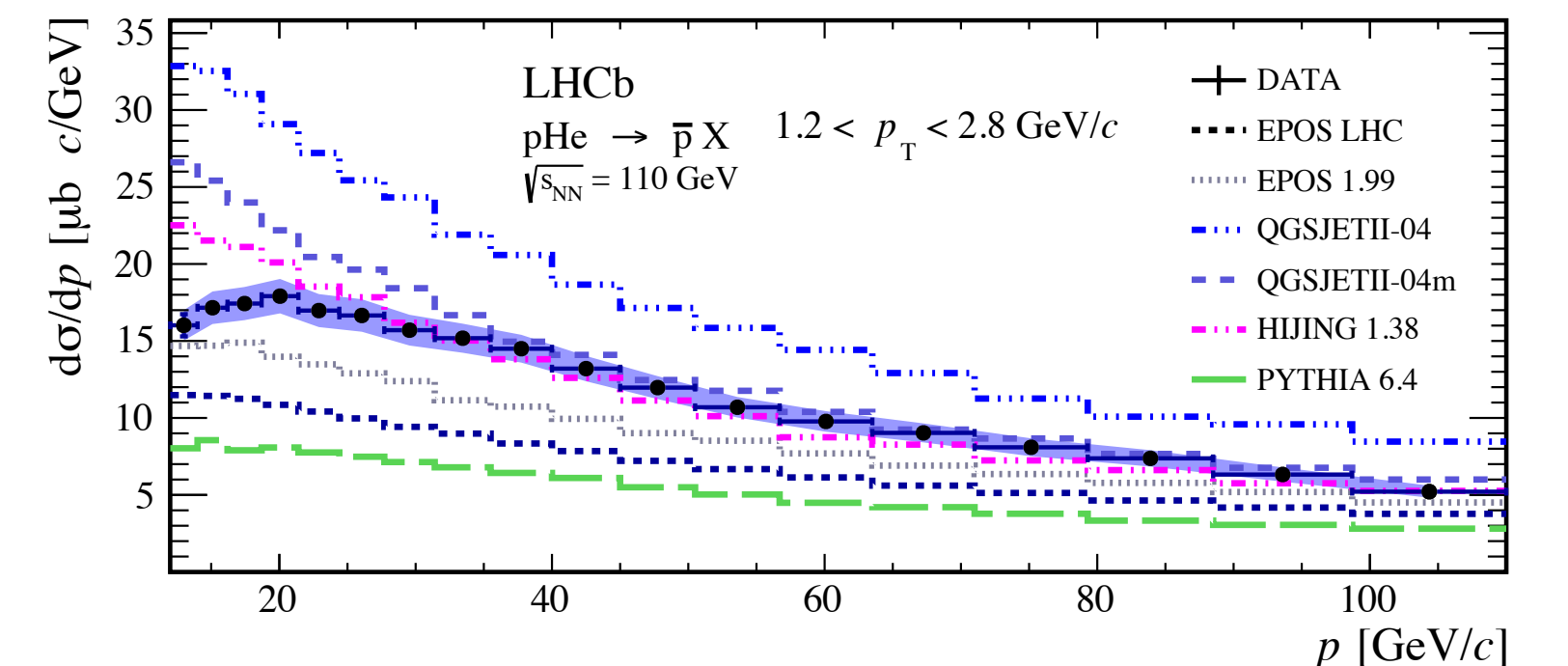
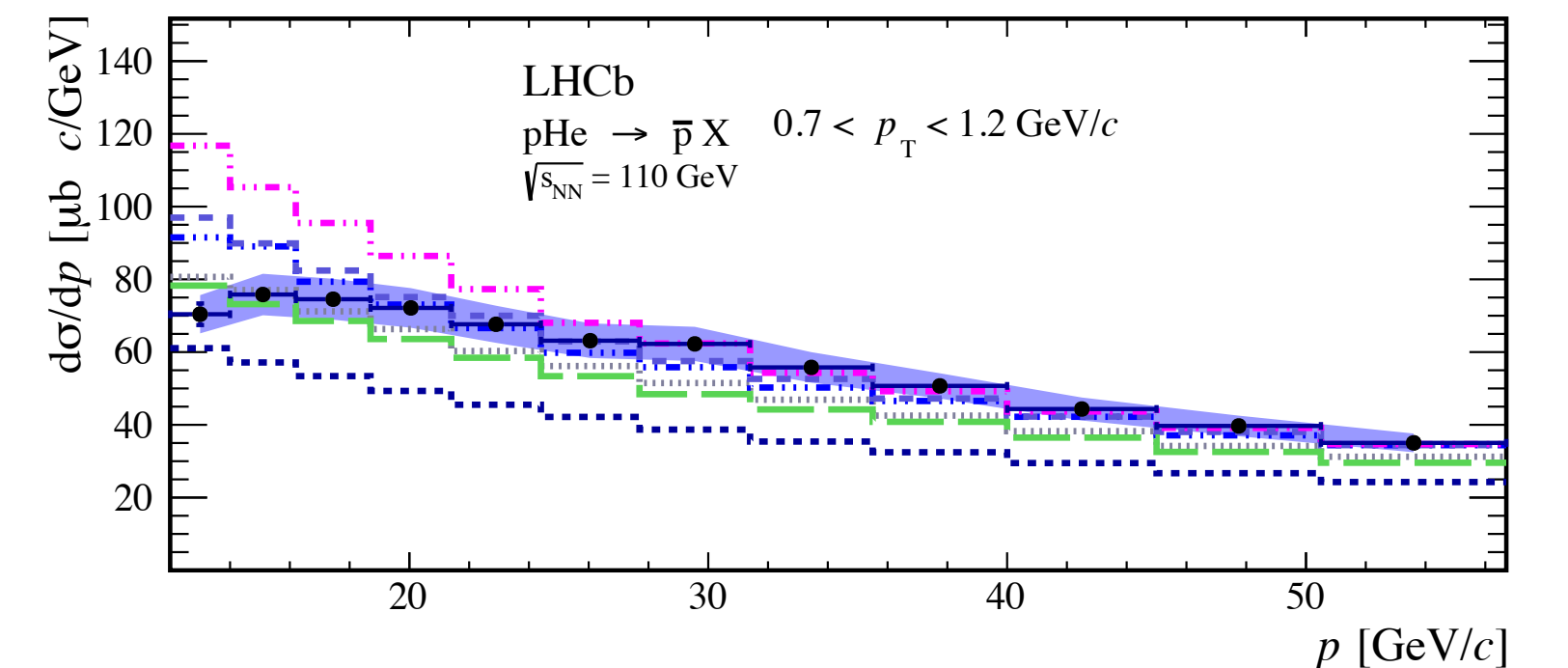
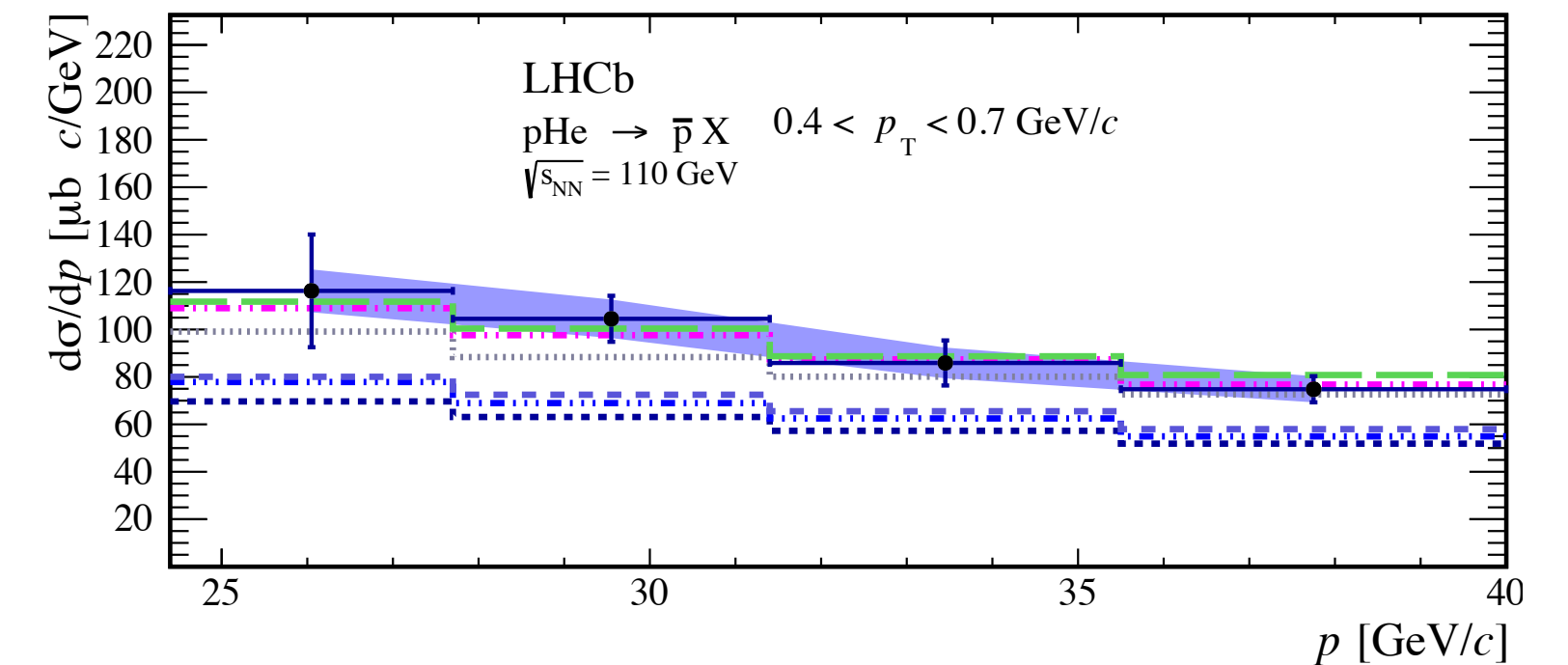
- Measurement of prompt antiproton production in pHe collisions
 - PID from RICH detector response
 - 3 templates built from simulated samples
- 2-d binned extended ML fit and cut-and-count method used to determine antiproton fraction



\bar{p} production in pHe interactions at $\sqrt{s} = 110 \text{ GeV}$

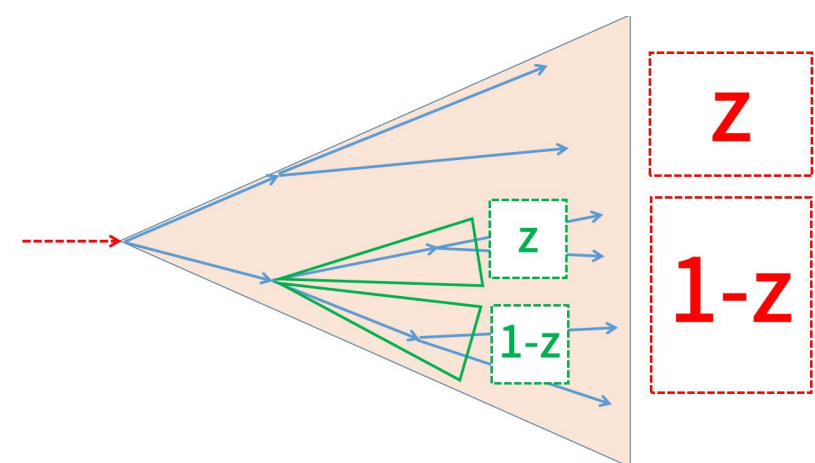
LHCb

- Antiproton production cross section shown (integrated over different kinematic regions)
- Uncertainty lower than 10% for most bins
 - Lower than spread between predictions from various theoretical models
- Improves the precision of secondary antiproton cosmic ray flux predictions



Exploring Jet-Splitting in vacuum and medium

ALICE



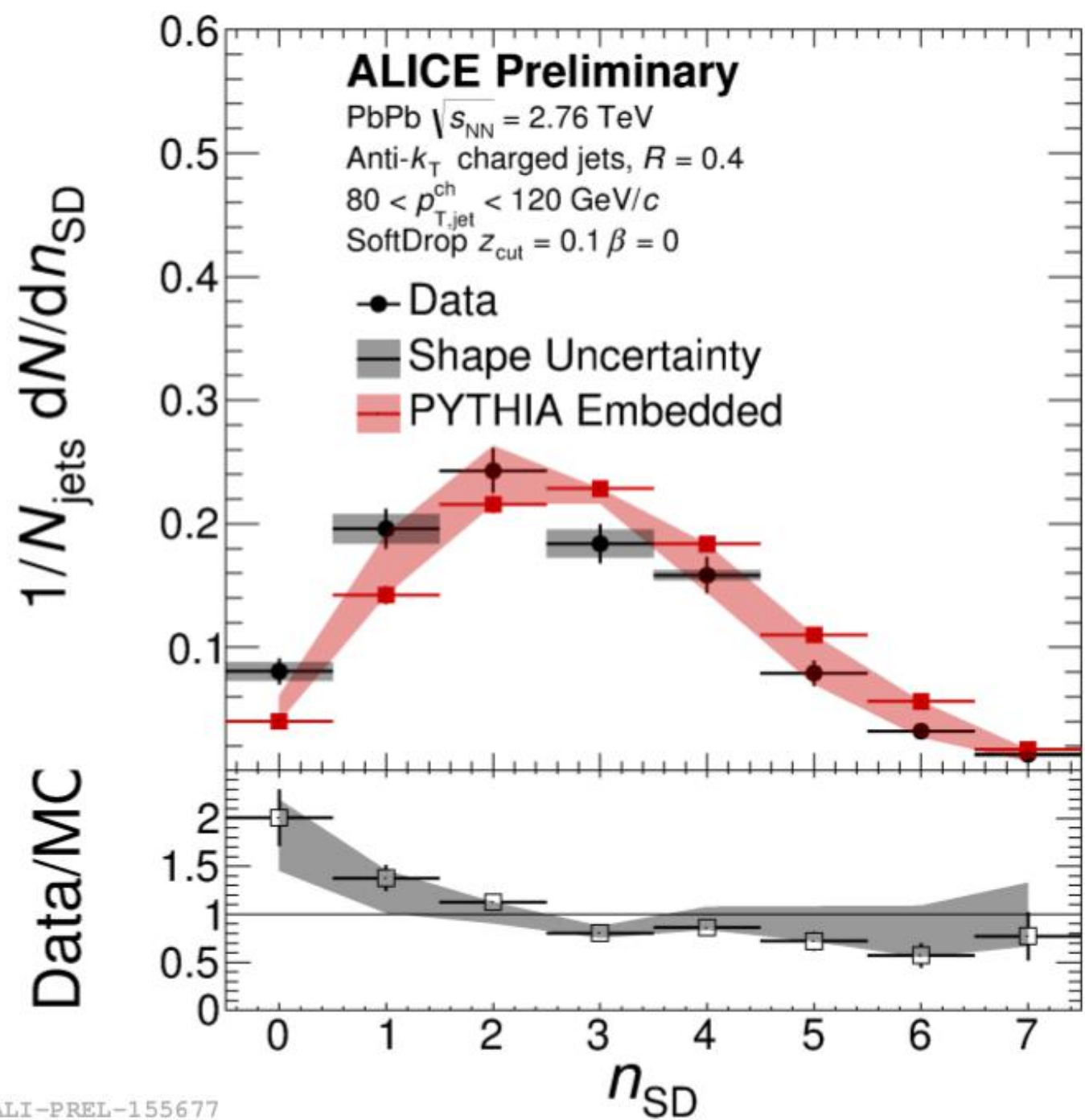
Re-wind last clustering step and evaluate

$$z = \frac{\min(p_{T,1}, p_{T,2})}{p_{T,1} + p_{T,2}}$$

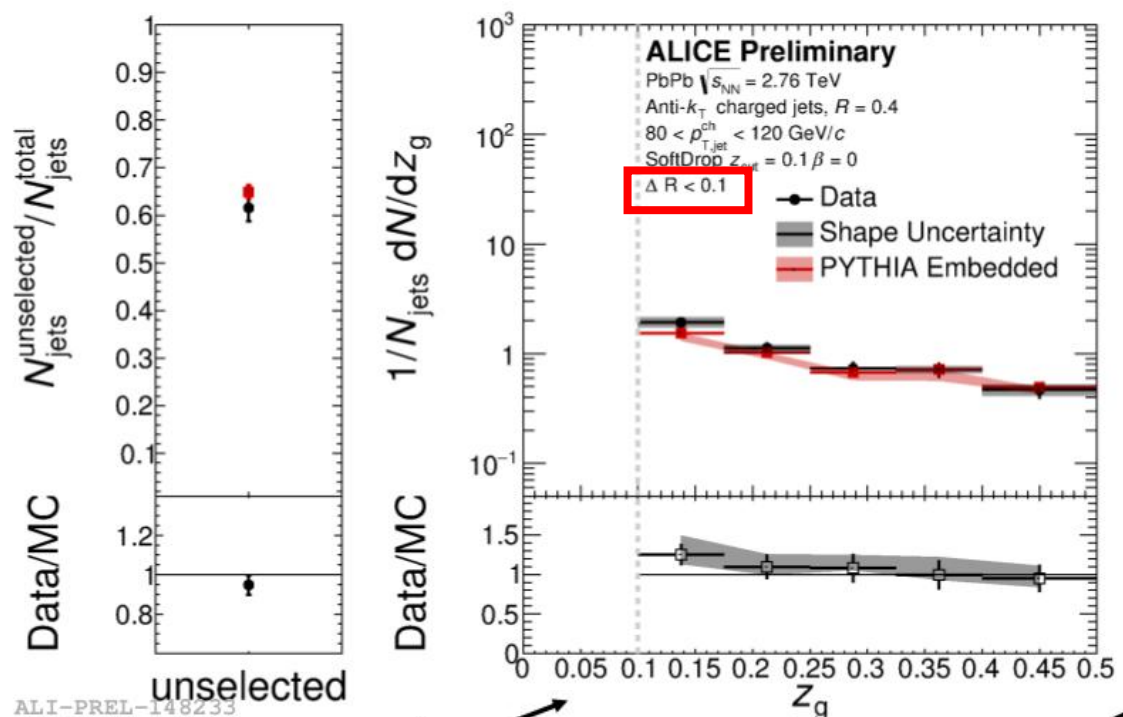
Define hard splitting when

$$z > z_{\text{cut}}$$

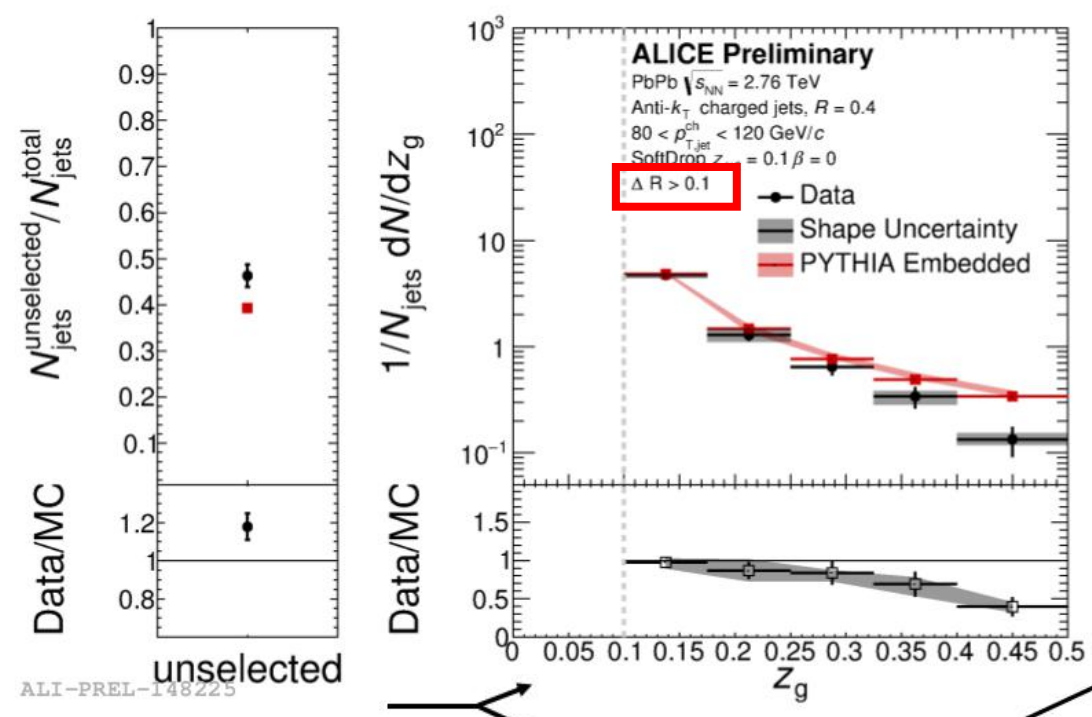
Possible to repeat on hardest prong to find n_{SD} splittings



ALI-PREL-155677



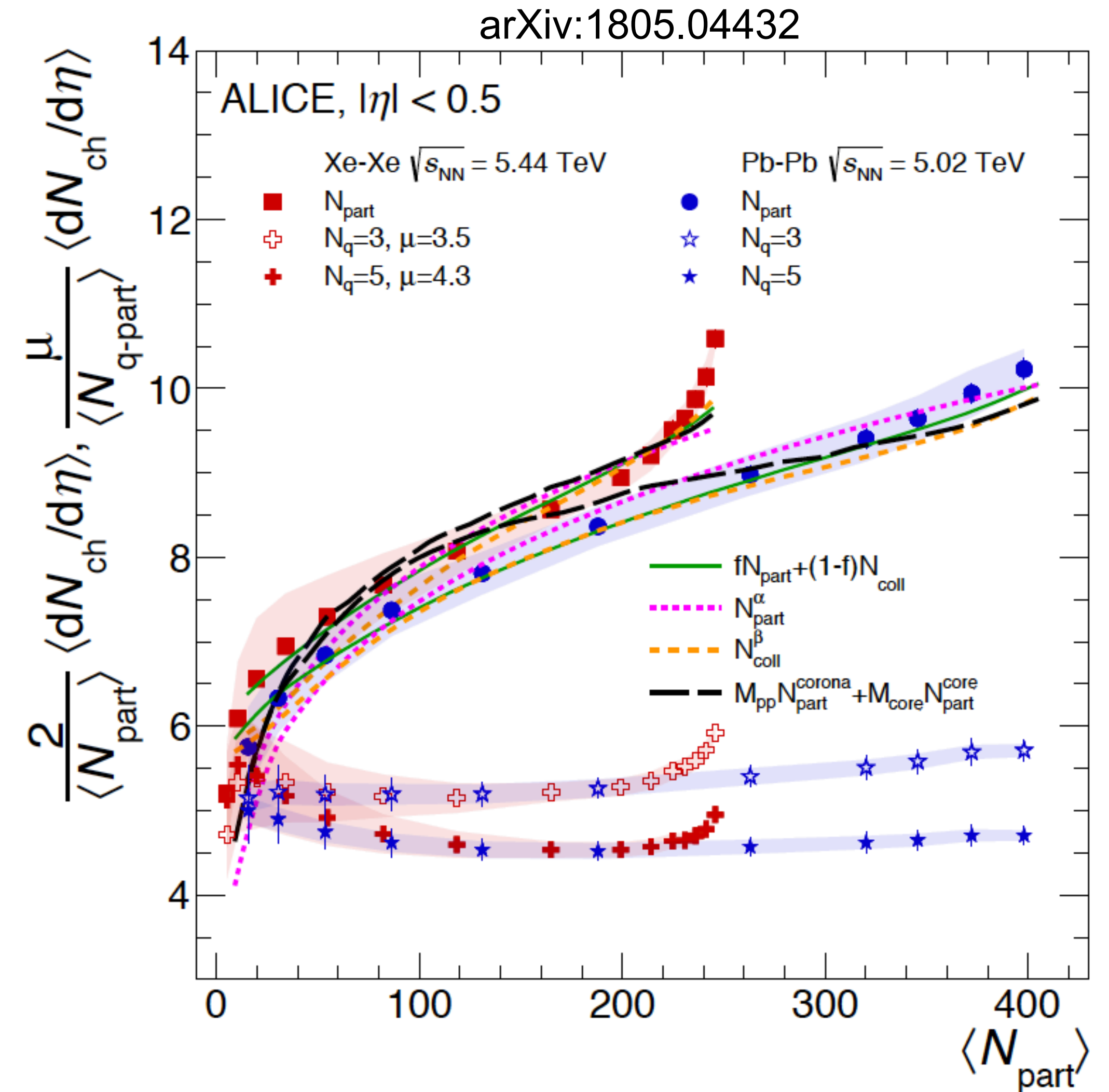
first splitting at **small** angles:
no difference between Pb-Pb jets
and vacuum reference



first splitting at **large** angles:
overall suppression in tagged Pb-Pb
jets, steeper z_g distribution

Charged Multiplicity: XeXe vs PbPb

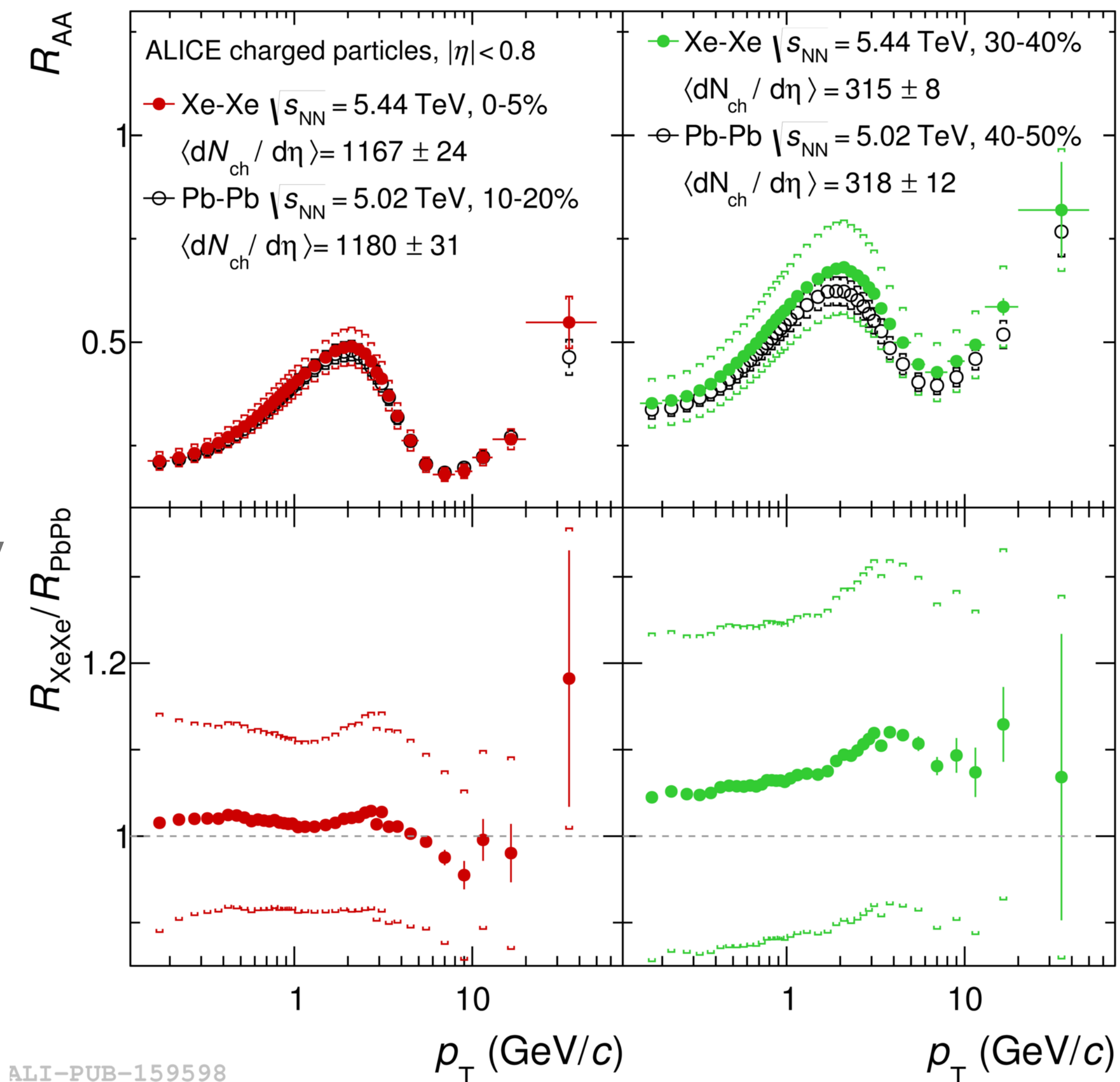
- 6 hours of stable-beam data taking in October 2017
- Normalization by the effective number of participants (nucleons or quarks)
 - Participant quarks describe the Npart scaling violation
- Central collisions of medium-size nuclei produce more particles per Npart than mid-central collisions of large nuclei at the same Npart
 - Not explained



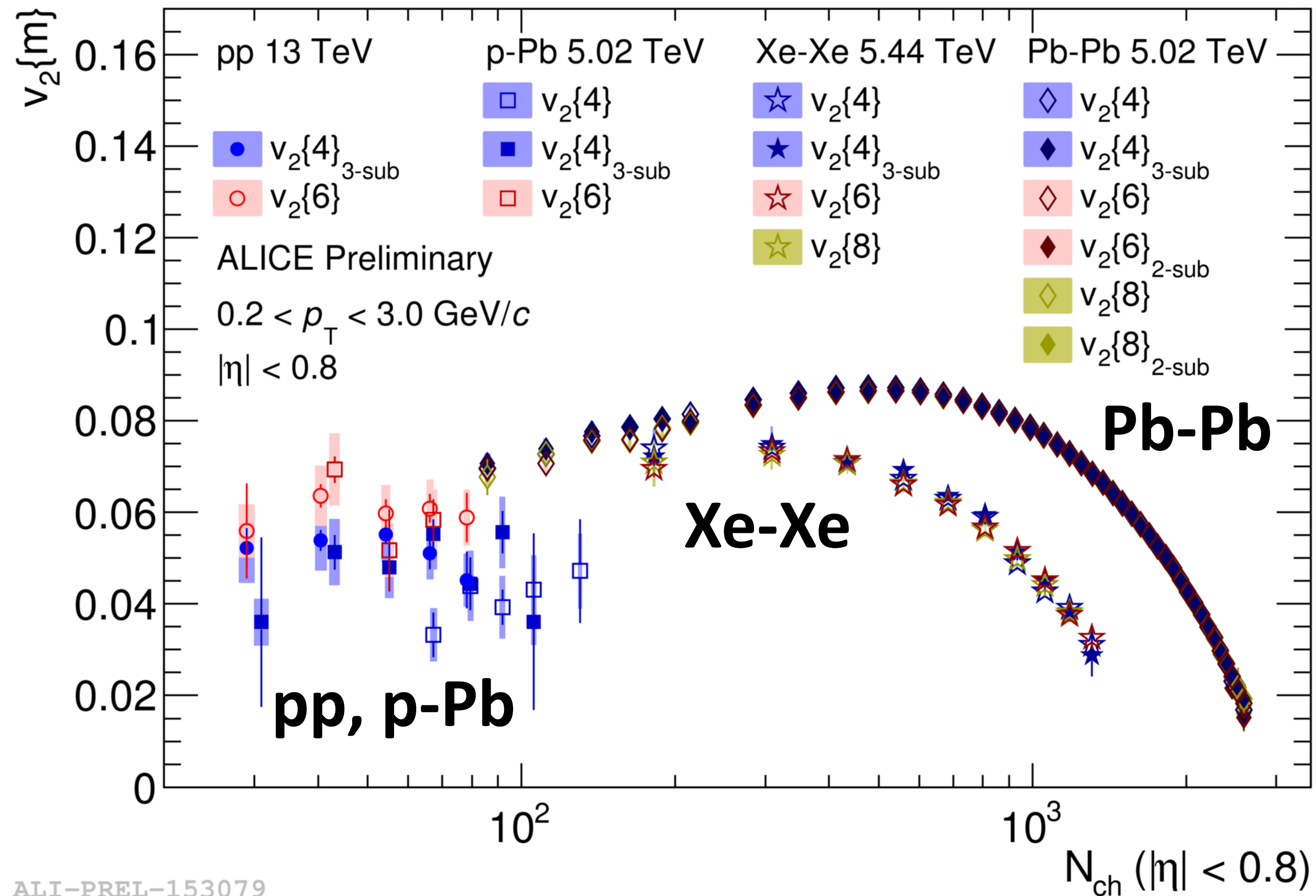
Xe-Xe Scattering: Nuclear Modification Factor

ALICE

- very similar for Xe-Xe and Pb-Pb
- at similar multiplicity
- deviates for peripheral collisions
- different geometry for same multiplicity
- sensitive to geometry \leftrightarrow path length dependence [arXiv:1805.04399]



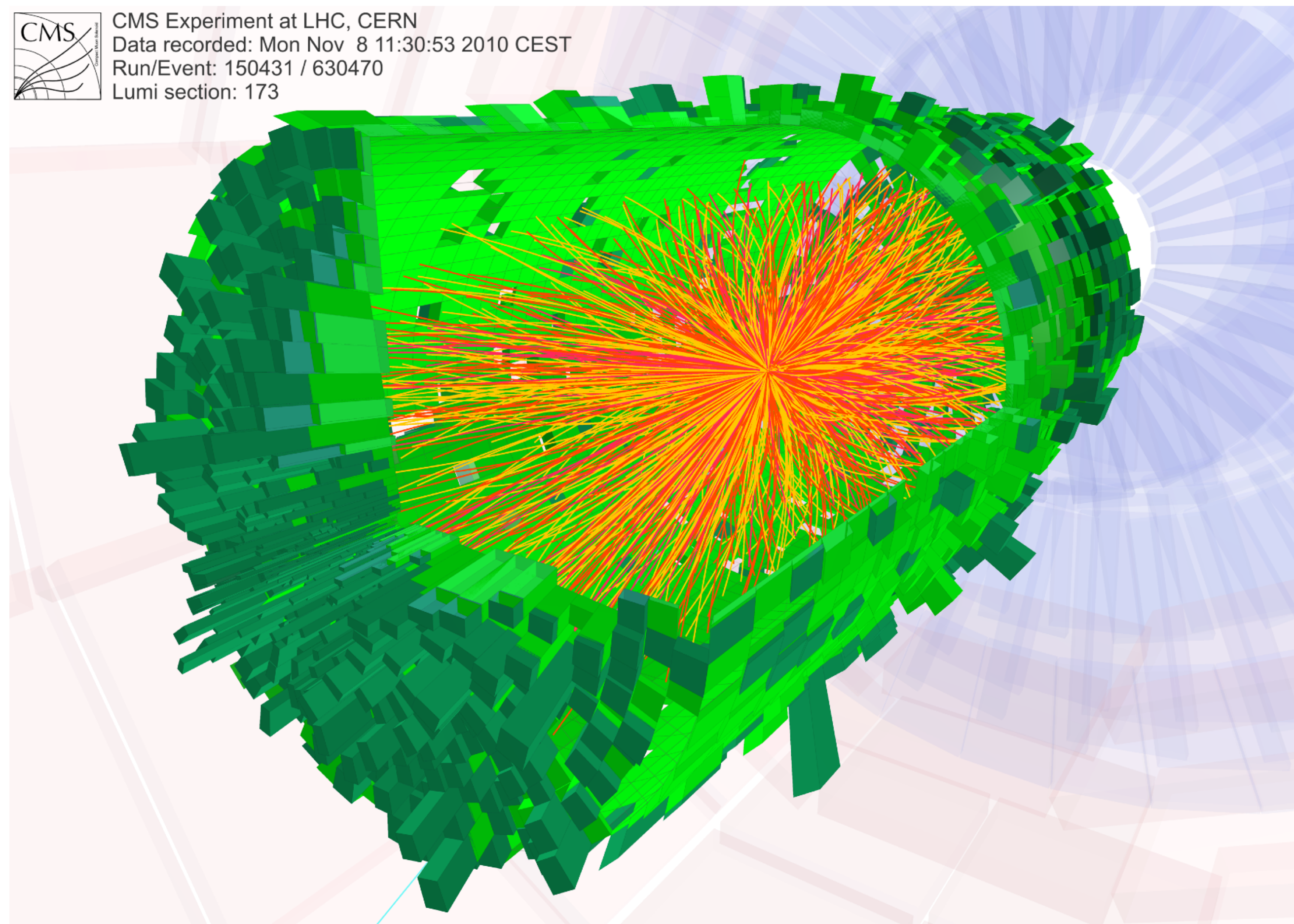
Elliptic Flow in small systems



ALI-PREL-153079

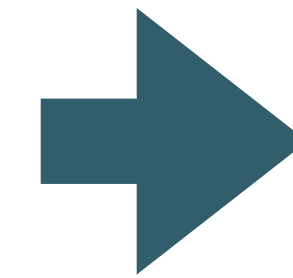
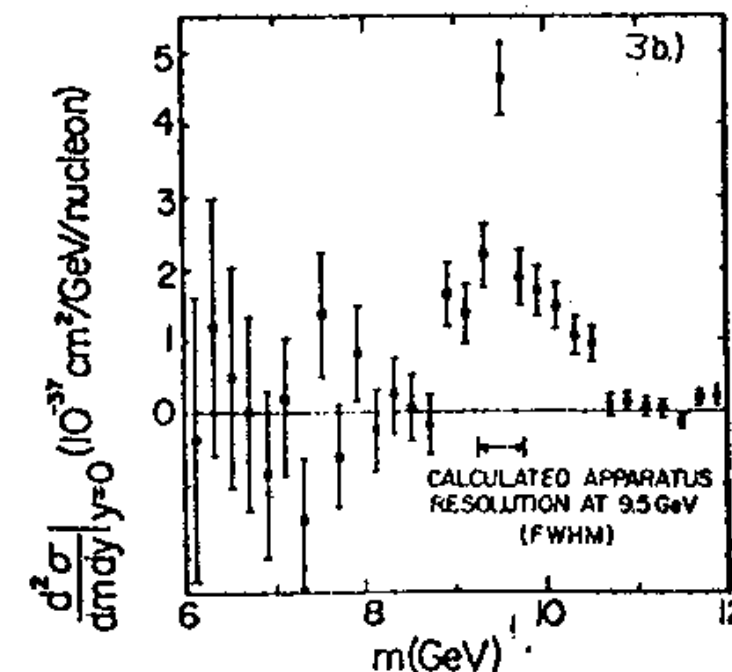
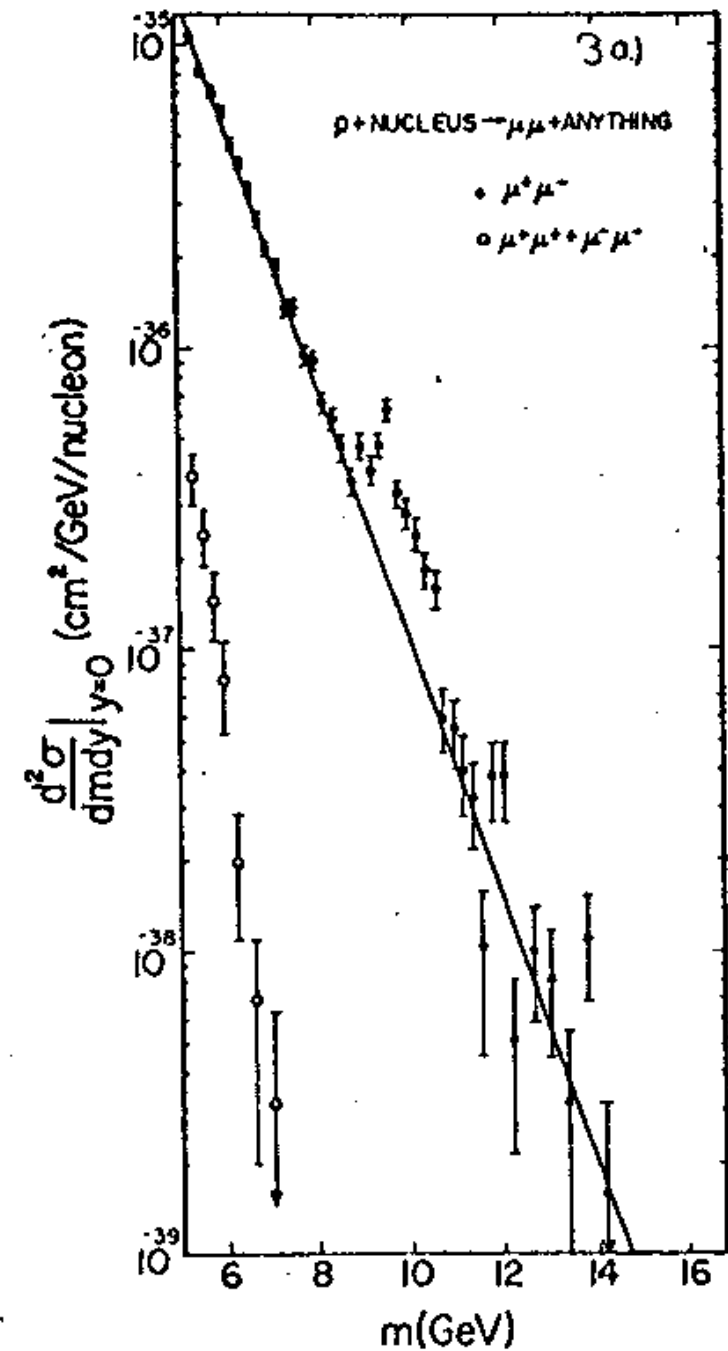
CMS preparing for Heavy Ion Run

- Goal is 1.8 nb^{-1} and large minimum bias sample
- Run with HI-specific firmware for detectors, HI-specific online software, etc.
- Study phase space for energy loss in nuclear medium

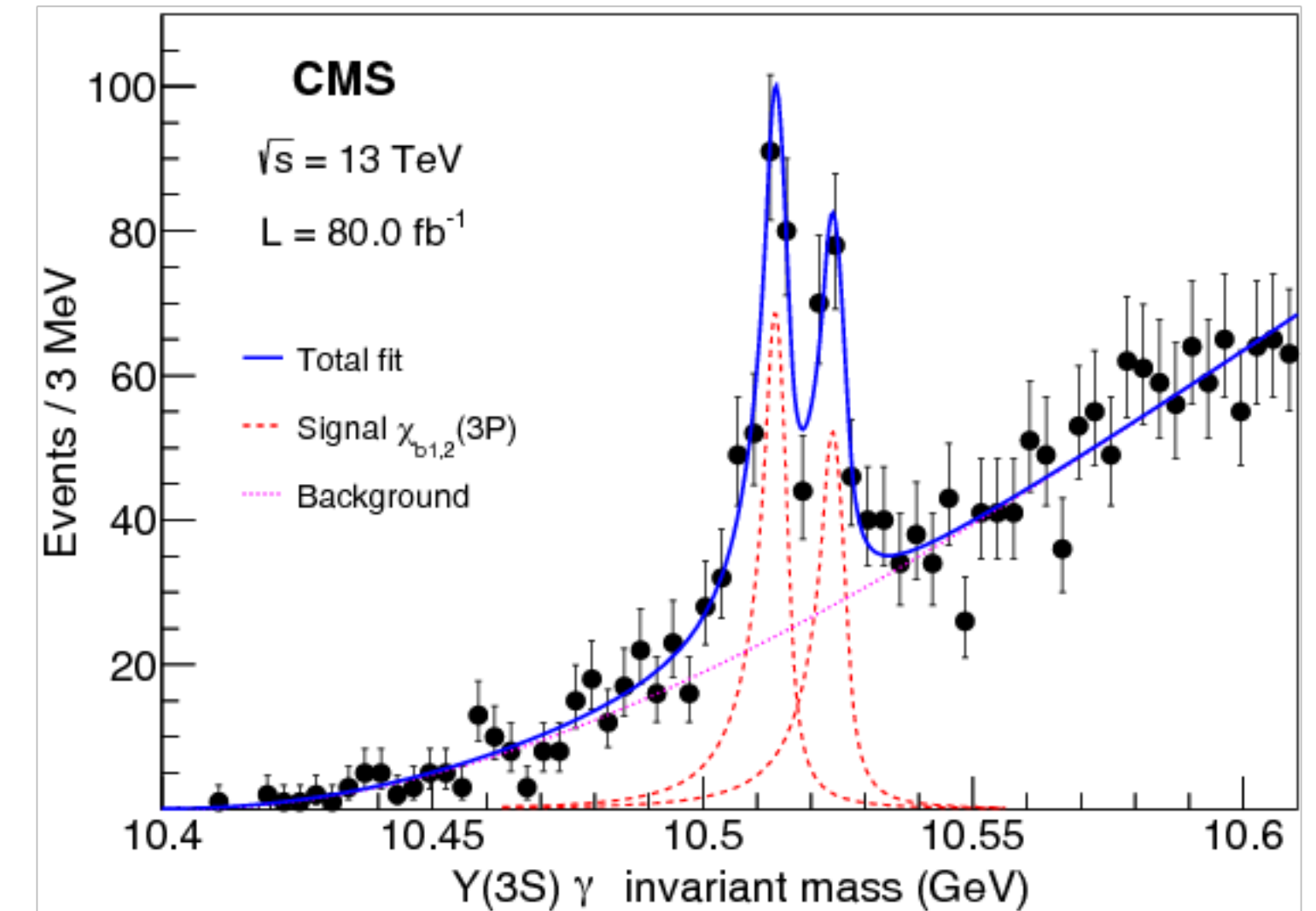


Evolution of Spectroscopy at Hadron Colliders

- Observation of Y-family in Drell-Yan in 1977 (S.Herb et al.)
- 400 GeV proton beam at Fermilab
 $\sqrt{s} = 0.028$ TeV
- since then tremendous improvements in detector resolution



40 years later

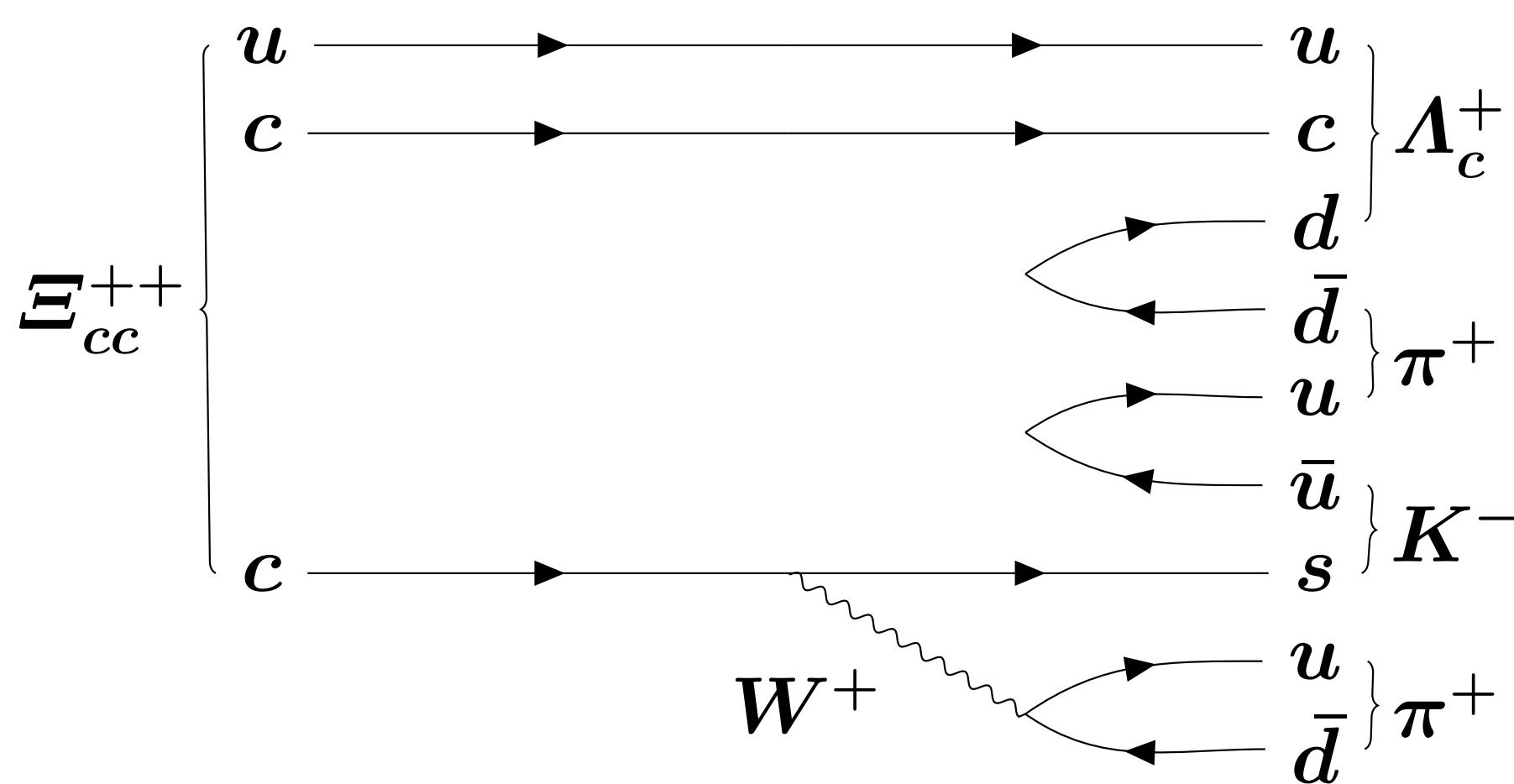


- Observation of Ξ_b -mass splitting in CMS in 2018 at the level of 10 MeV
- $\sqrt{s} = 13$ TeV

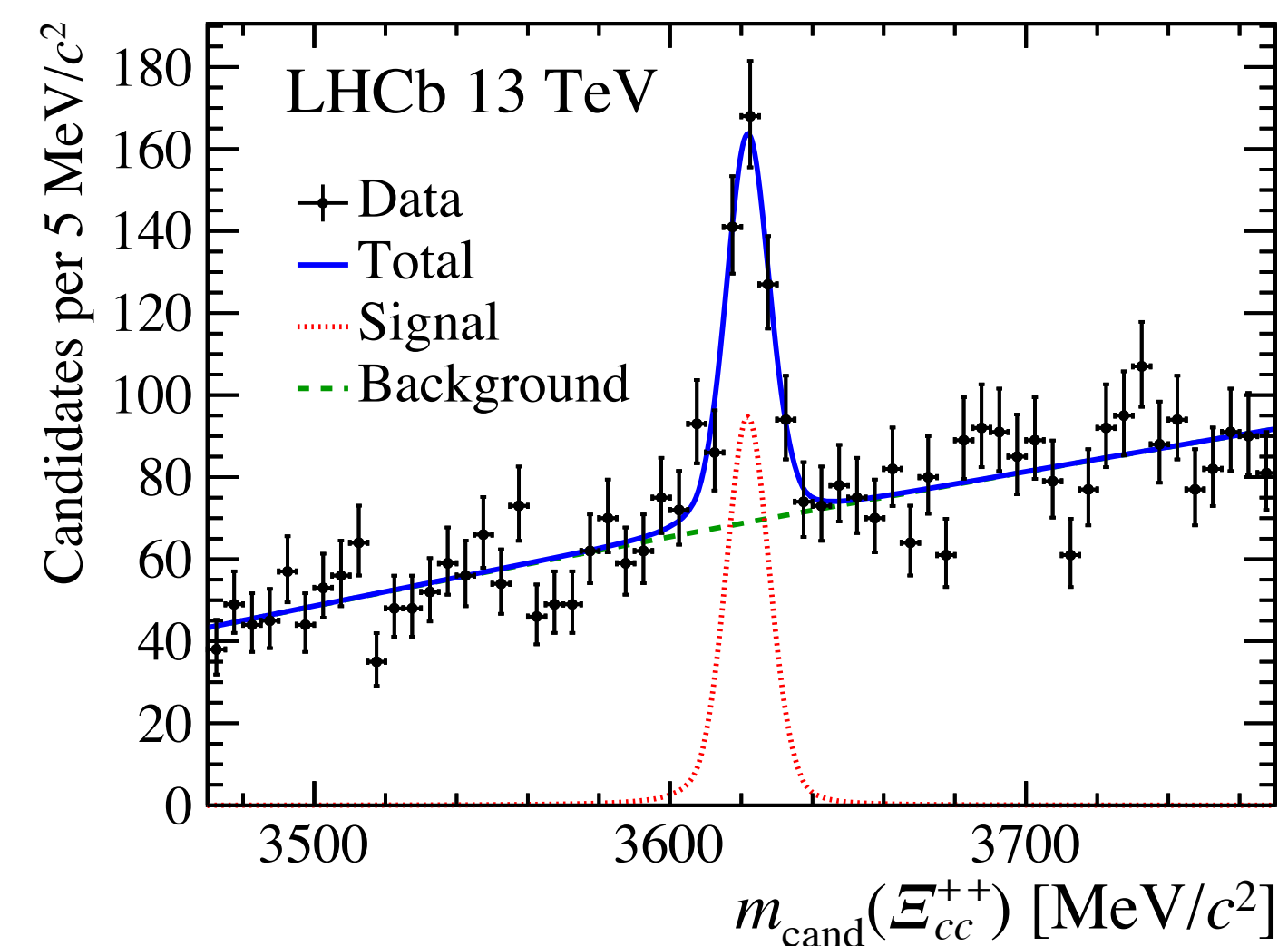
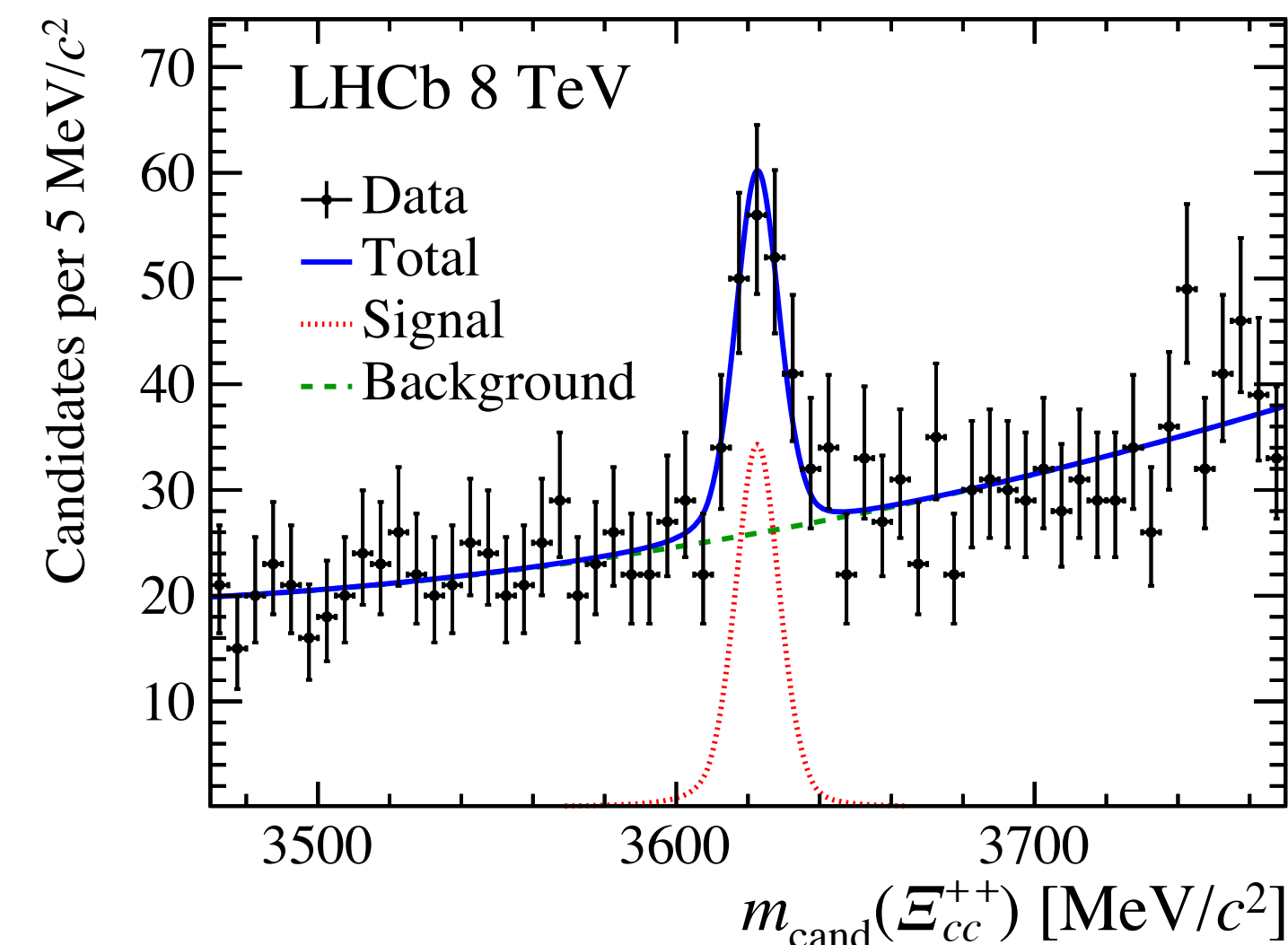
Spectroscopy at LHCb

- Ξ_{cc}^{++}

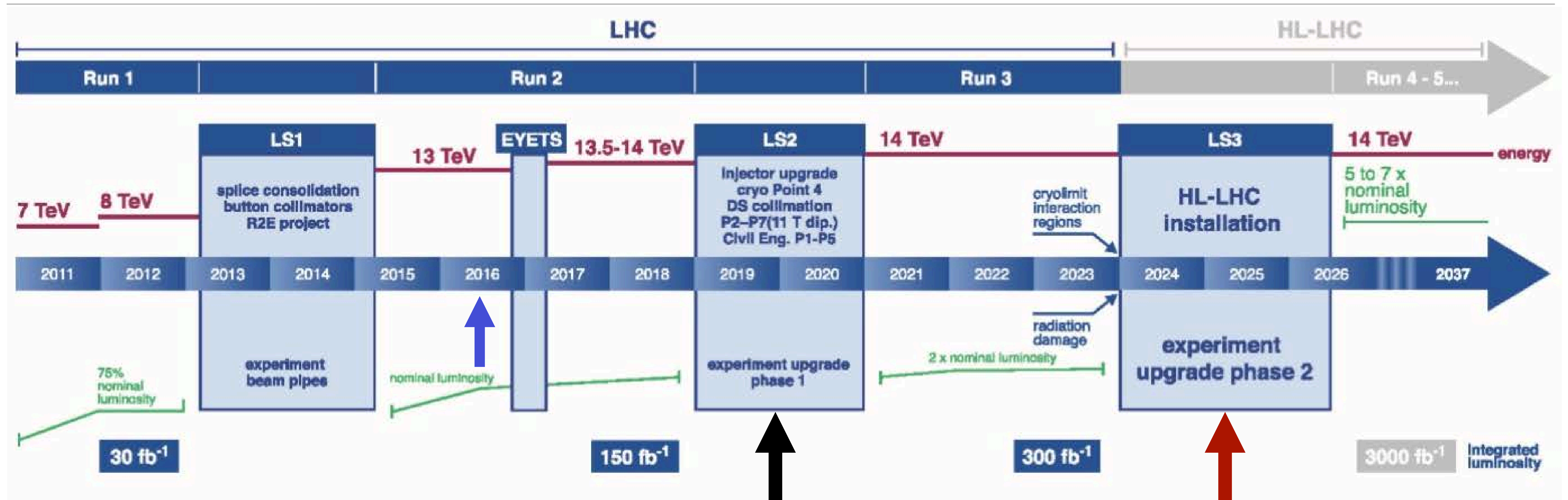
Example diagram



$$m_{\Xi_{cc}^{++}} = 3621.40 \pm 0.72 \text{ (stat)} \pm 0.27 \text{ (syst)} \pm 0.14 \text{ } (\Lambda_c^+) \text{ MeV}/c^2$$



HL-LHC schedule



LS2 (2019-2020):

- ☐ LHC Injectors Upgrade (LIU)
- ☐ Civil engineering for HL-LHC equipment P1,P5
- ☐ First 11 T dipoles P7; cryogenics in P4
- ☐ Phase-1 upgrade of LHC experiments

LS3 (2024-2026):

- ☐ **HL-LHC installation**
- ☐ **Phase-2 upgrade of ATLAS and CMS**

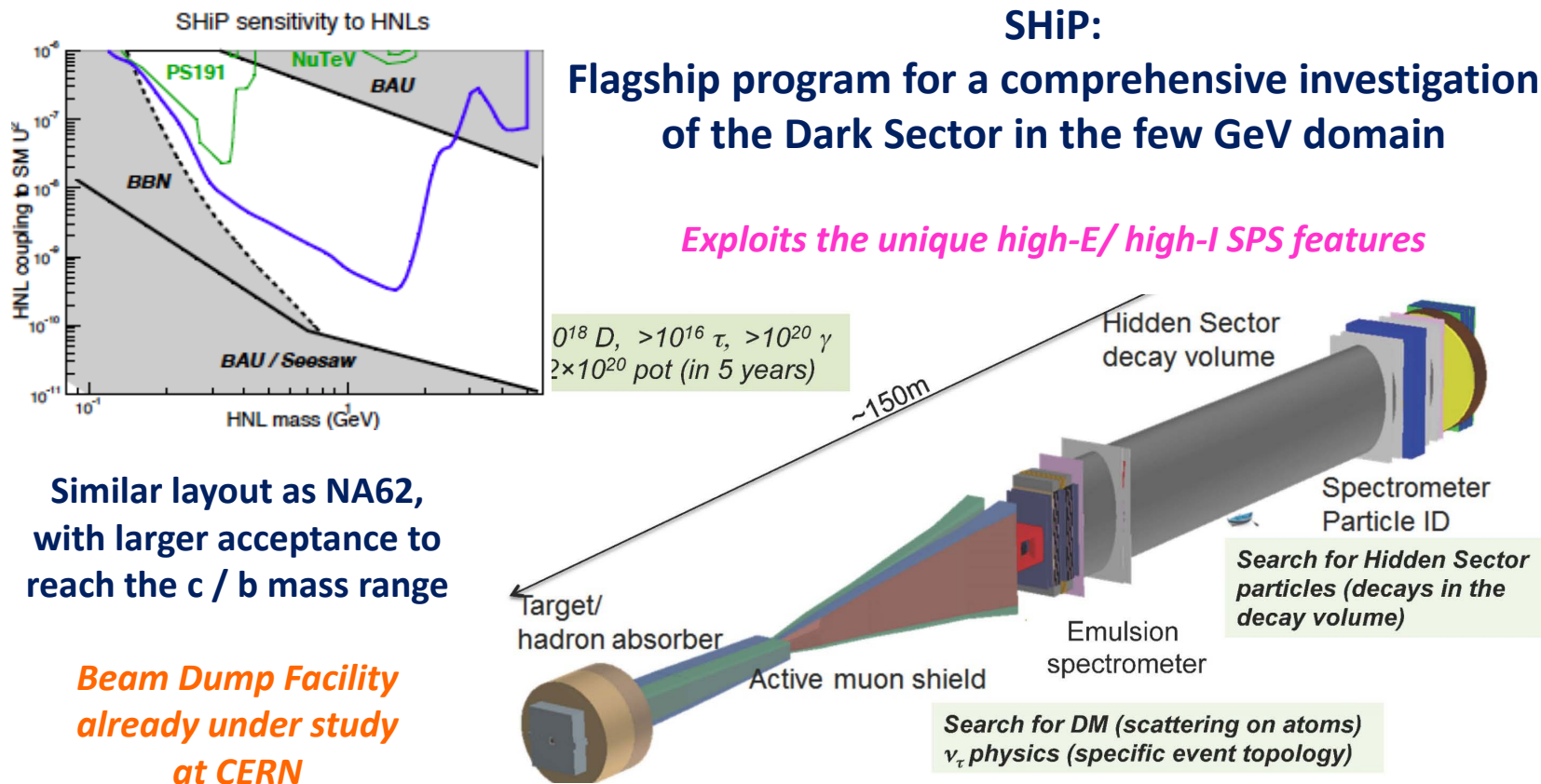
*Schedule driven by radiation damage
to inner triplet (eol: 2023)*

Towards 2020 Update of European Strategy for Particle Physics

Physics Beyond Collider Study



- Kickoff meeting held in September 2016
- Study of fixed target programme
- even with LHC beams

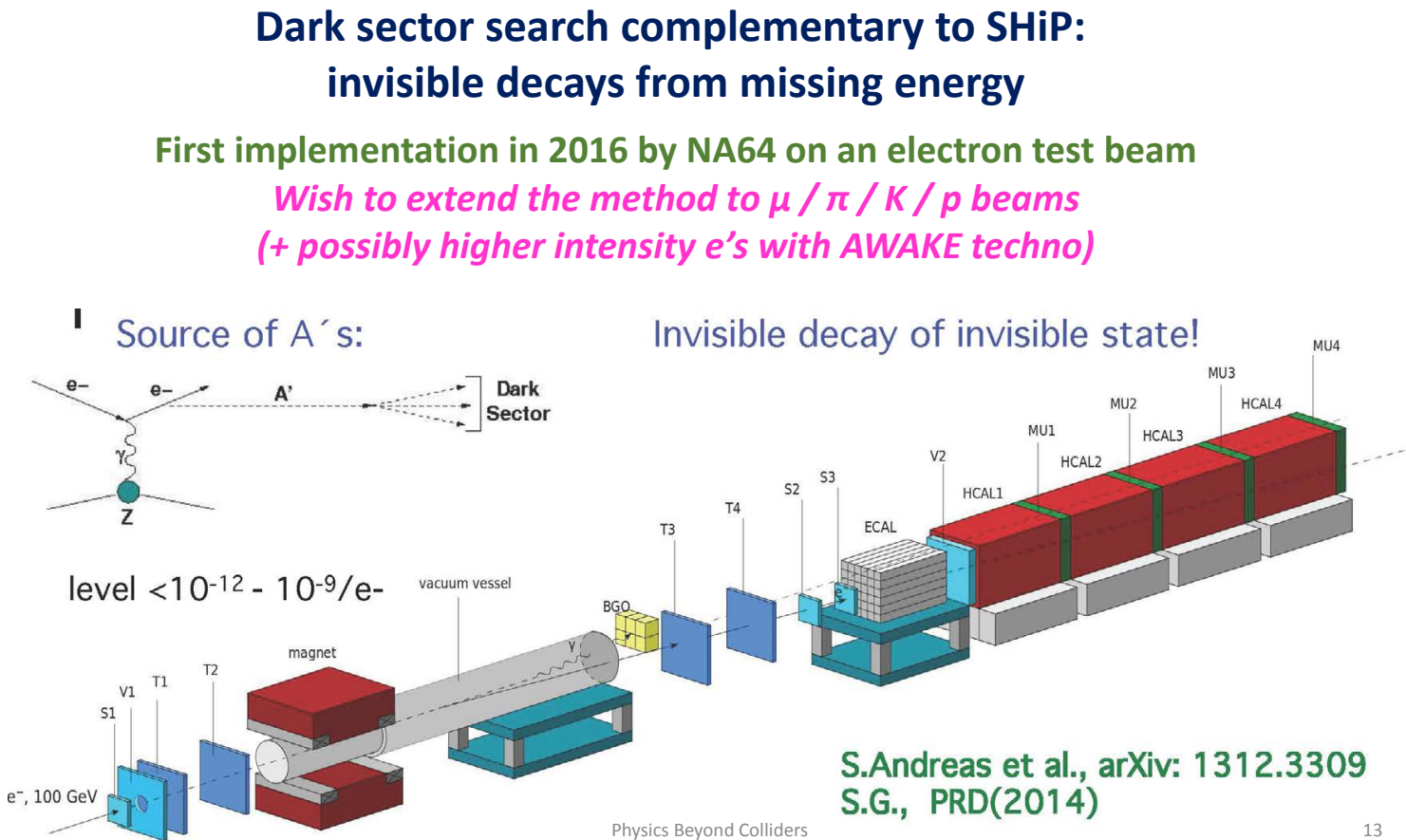
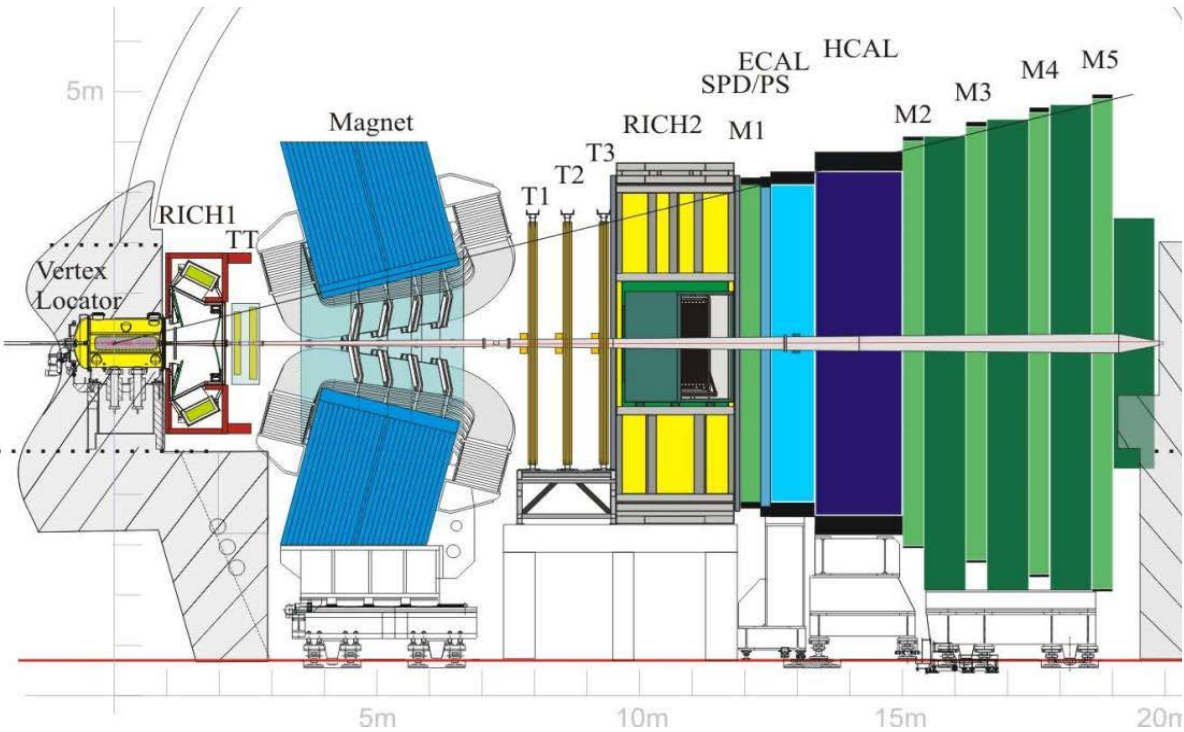


C. Vallée, SPC 299, Sept. 13th 2016

Physics Beyond Colliders

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SMOG



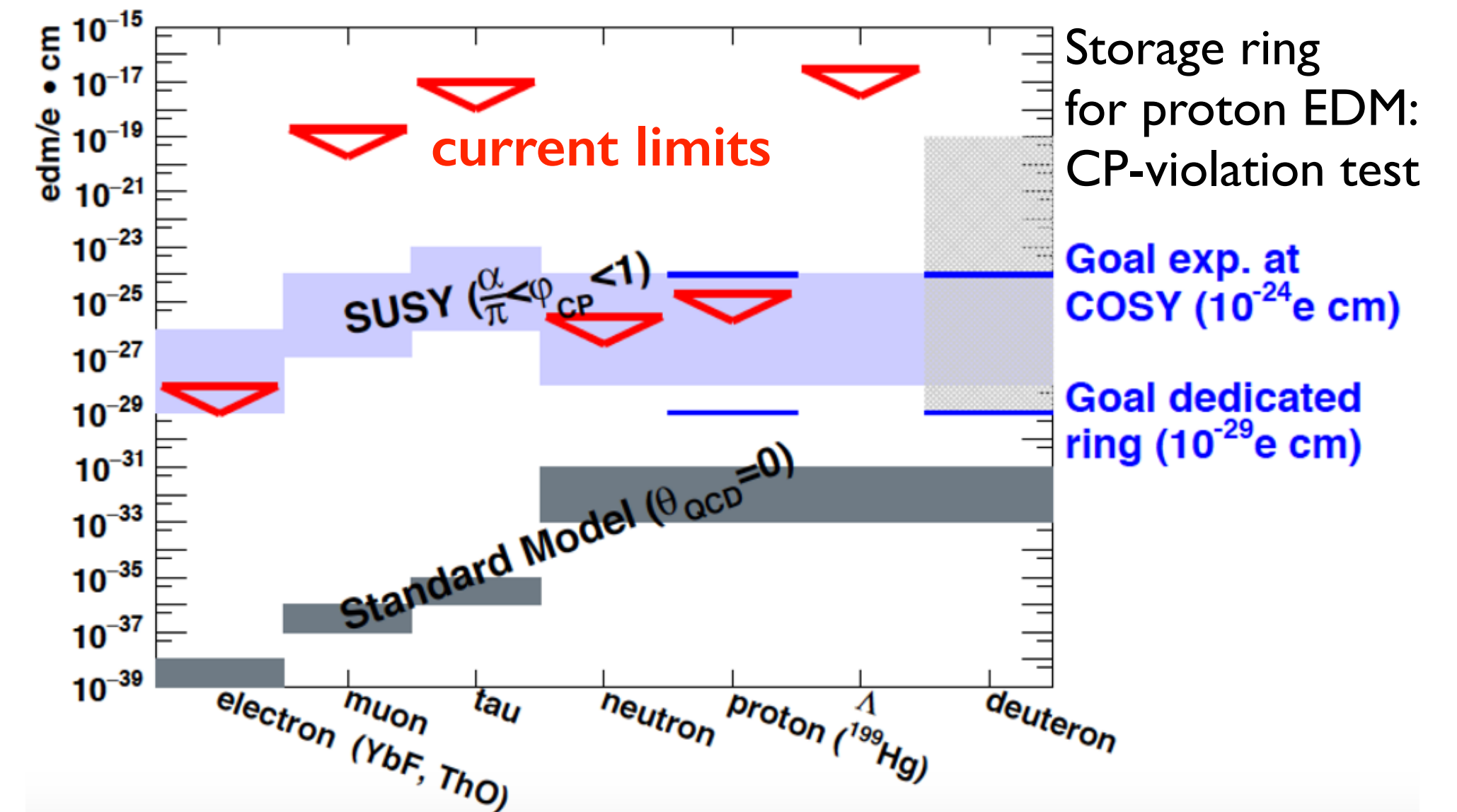
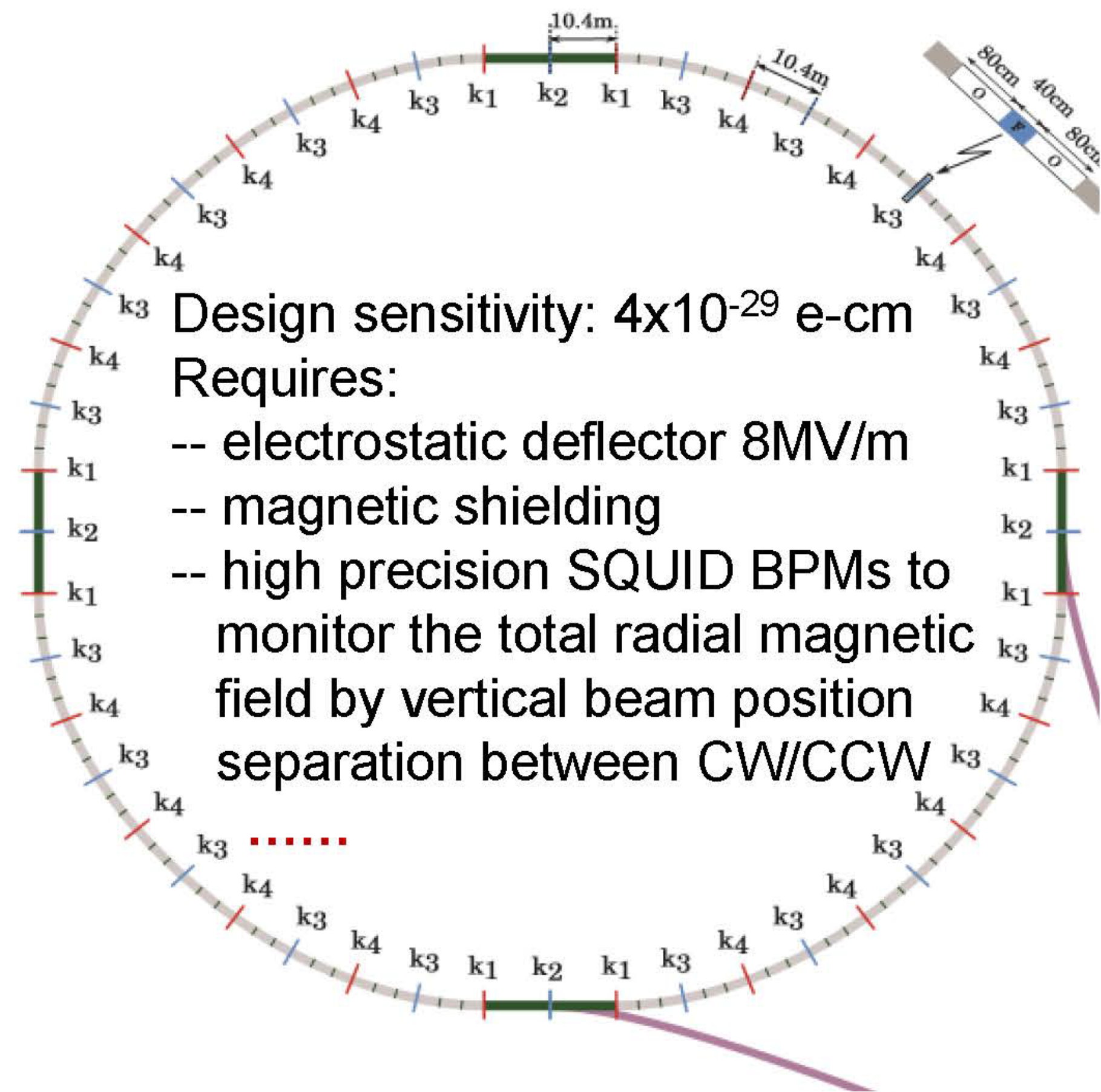
Physics Beyond Colliders

13

Physics Beyond Collider Study cont'd

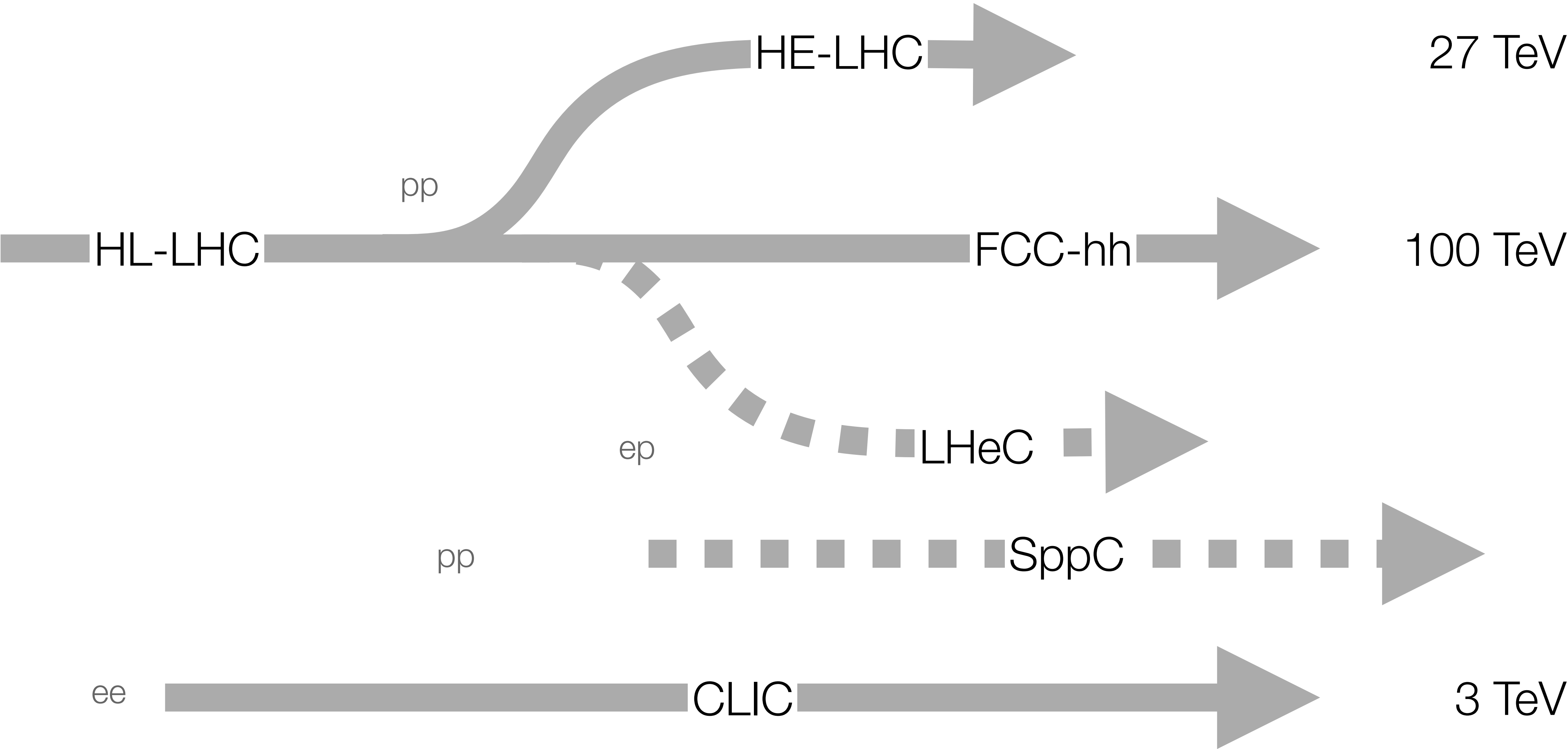


Study of an all-electric storage ring

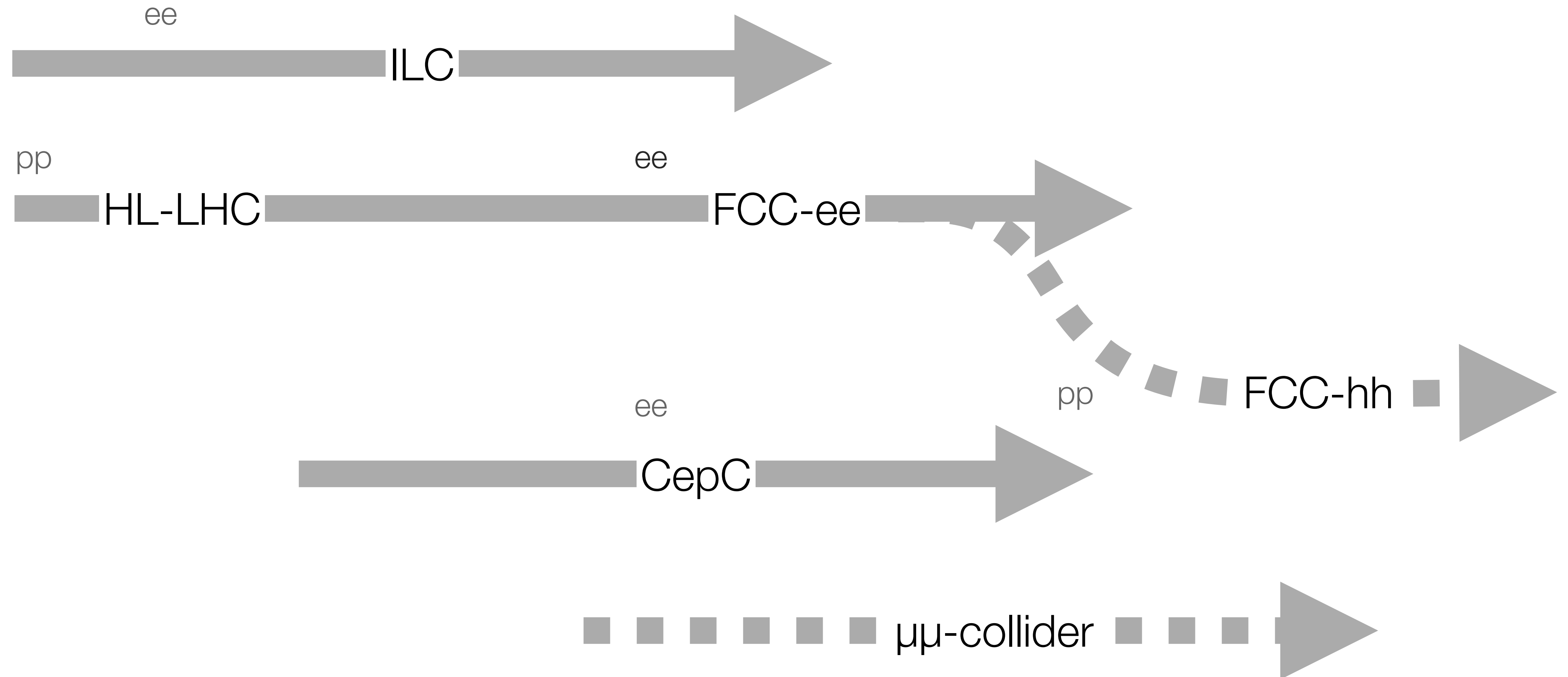


Sensitivity of 10^{-29} e-cm corresponds to 100 TeV for new physics scale

High-Energy Options



Lepton Collider Options for Higgs and beyond...



European Particle Physics Strategy *Update*

