FOCAL in ALICE

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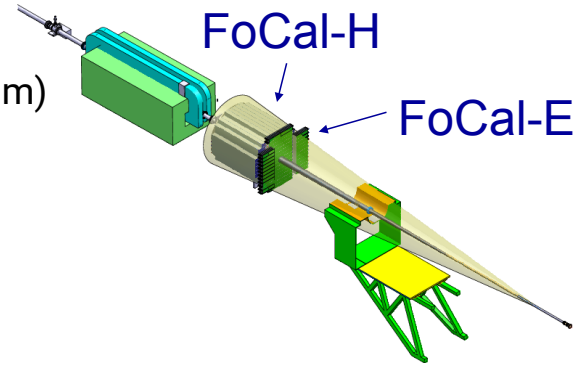
FOCAL proposal

3.4 < η < 5.8
(baseline design @ 7 m)



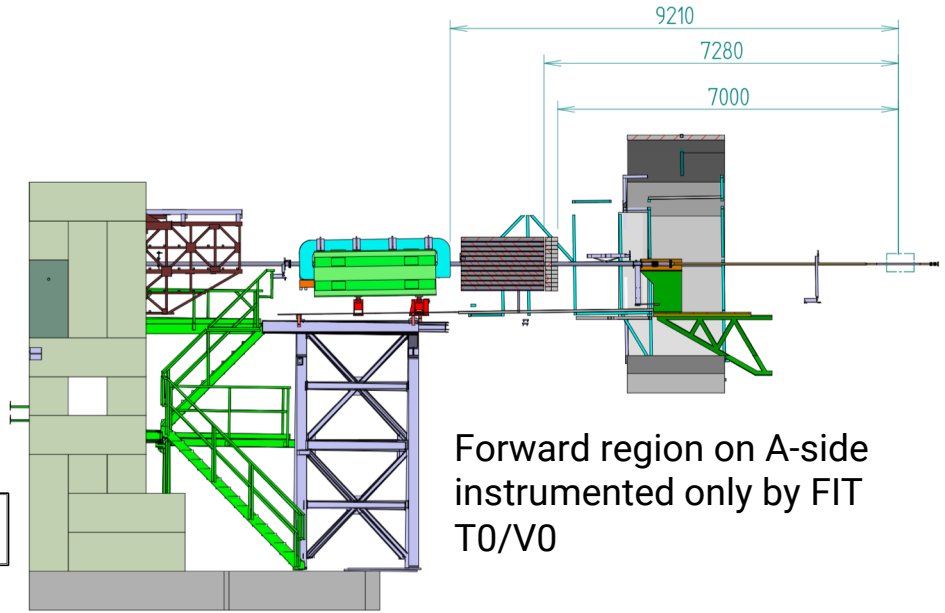
ALICE upgrade for LHC Run 4

- **FoCal-E**: high-granularity Si–W sampling calorimeter for photons and π^0
- **FoCal-H**: conventional Pb–Sc sampling calorimeter for photon isolation and jets

Observables:

- ✓ **π^0 (and other neutral mesons)**
- ✓ **Isolated (direct) photons**
- ✓ Jets (and di-jets)
- ✓ J/ψ (ϒ) in UPC
- ✓ W, Z
- ✓ Event plane and centrality

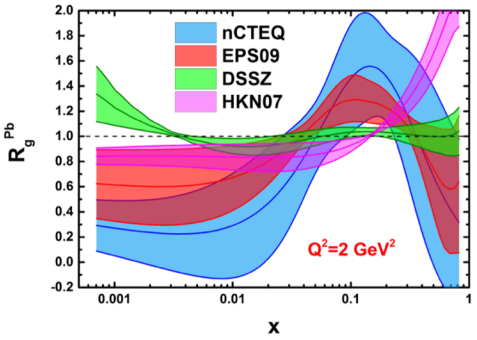
See Letter of Intent: ALICE-PUBLIC-2019-005

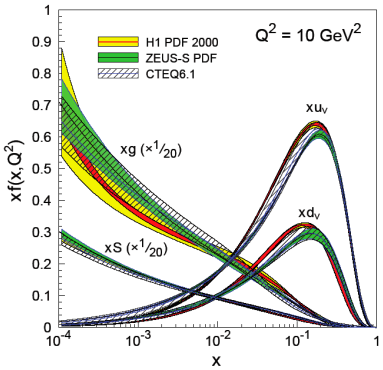


Forward region on A-side instrumented only by FIT T0/V0

Probing the gluon density with isolated photons

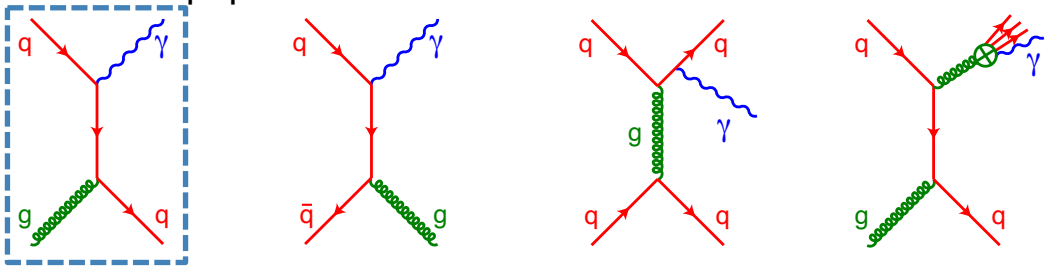
- Prompt photon production (LO) is sensitive to the gluon density inside the colliding hadrons
  - nPDF: very few (DIS) measurements available
    - Probe the gluon density via the (DGLAP) evolution

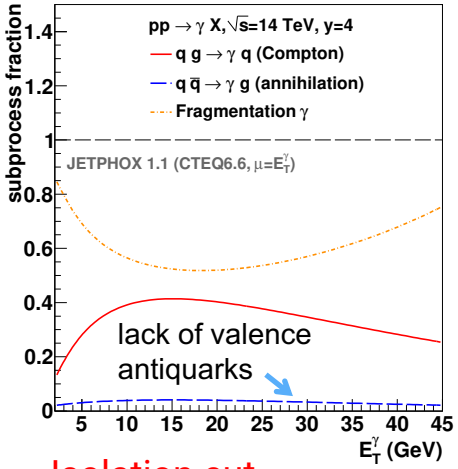


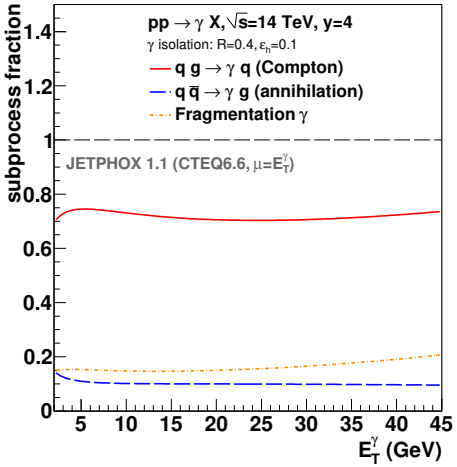


- Large uncertainties on the gluon content of the nucleus at small *x*
- Explore non-linear evolution and saturation at small *x*

Prompt photons





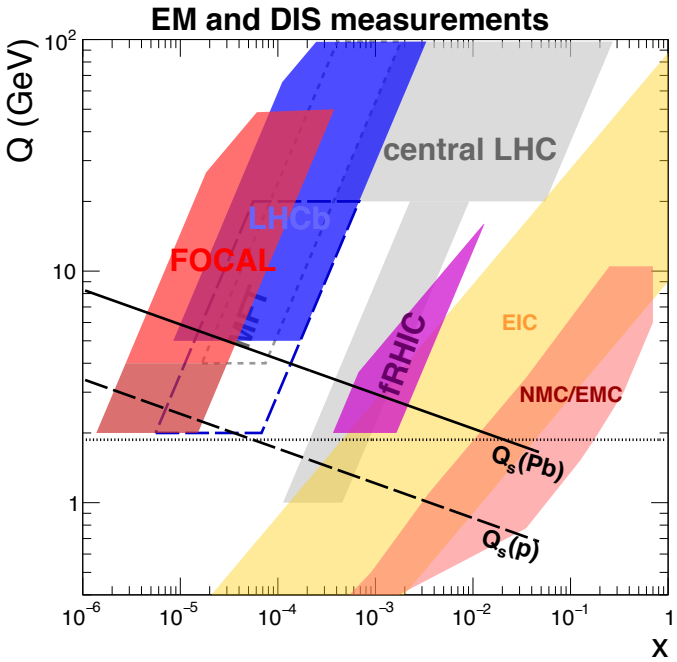


Isolation cut

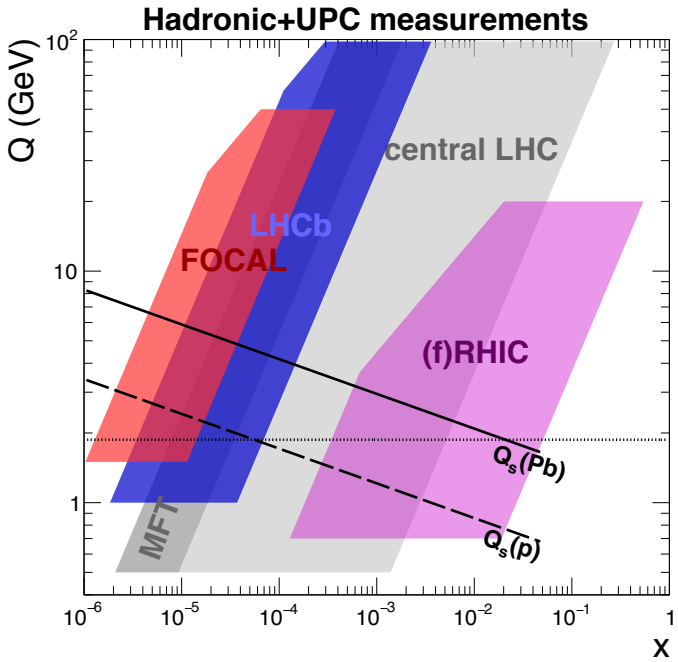
- Significantly suppresses fragmentation and bremsstrahlung
- Reduce the background of decay photons in the measured signal

Kinematic reach

- Coverage of the electromagnetic and hadronic probes by the current and planned measurements at LHC and other colliders

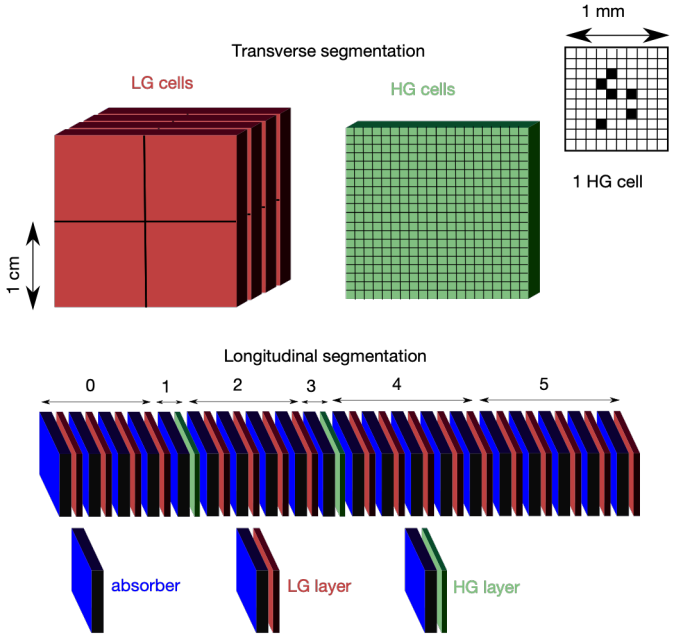


DIS, direct photons, Drell-Yan



Charged hadrons, neutral pions, heavy flavors

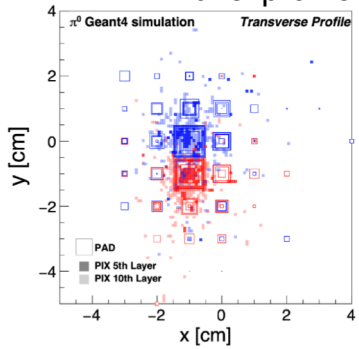
FOCAL-E conceptual design



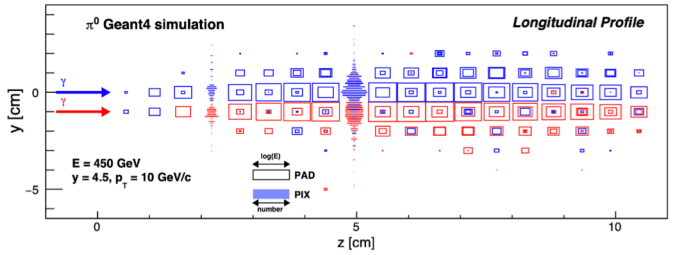
Main challenge: separate γ/π^0 at high energy

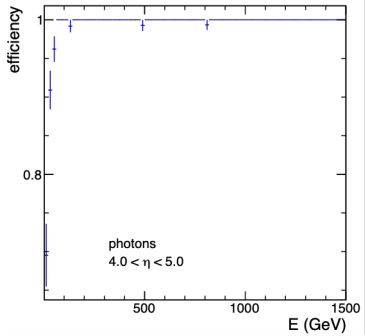
- Two photon separation from π^0 decay (p_T = 10 GeV, η = 4.5) ~5 mm
- Requires small Molière radius and high granularity readout
- Si–W calorimeter with effective granularity ≈ 1 mm^2

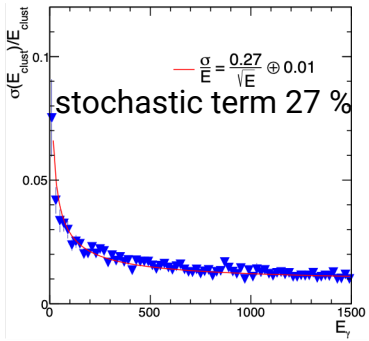
Trans. profile



Longitudinal profile (2γ showers)







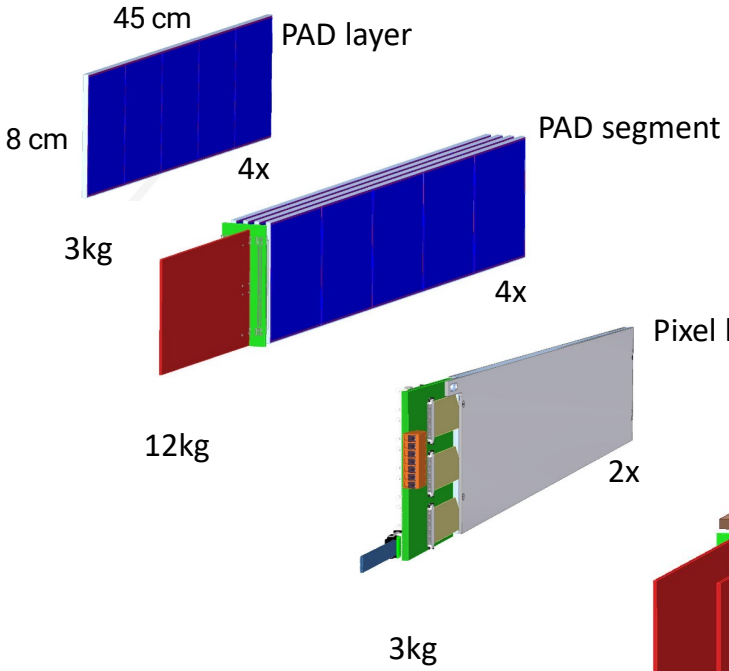
Studied in simulations 20 layers: W(3.5 mm ≈ 1X_0) + silicon sensors

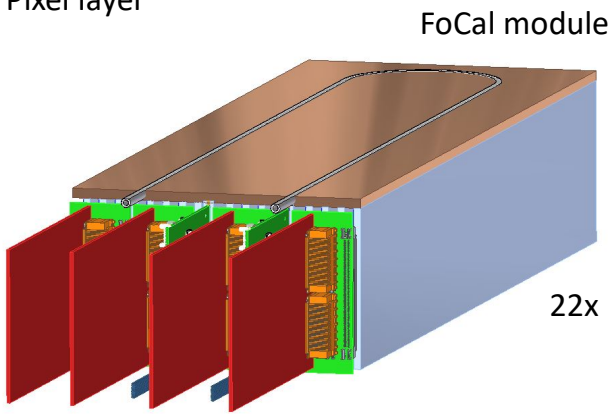
Two types: Pads (LG) and Pixels (HG)

- Pad layers provide shower profile and total energy
- Pixel layers (ALPIDE) provide position resolution to resolve overlapping showers

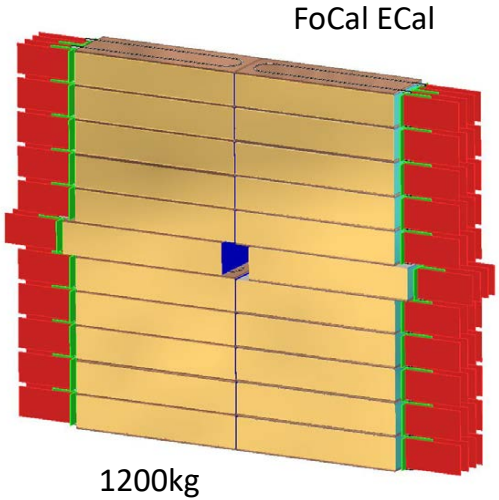
Further optimization left for TDR: location of pixel layers, number of pad layers, sensitive area at front for CPV/eID

FOCAL-E layout



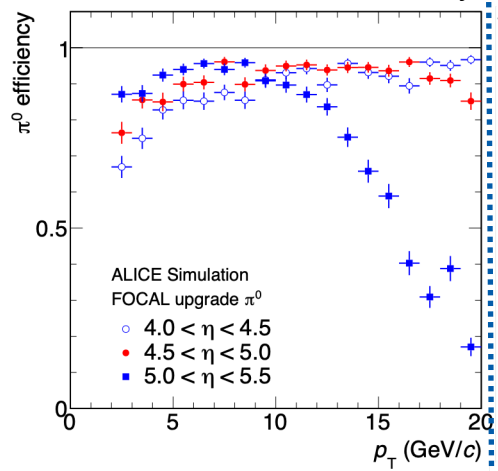


Readout, power, cooling
connected on one side

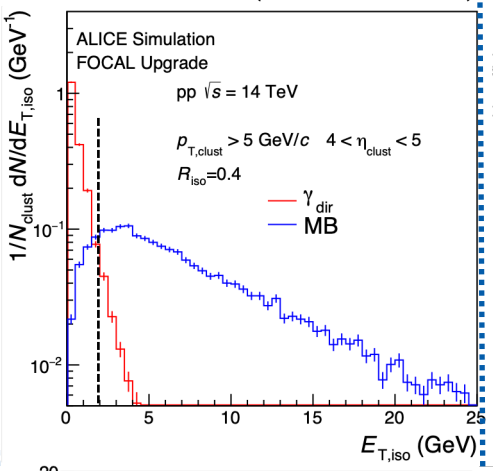


Key ingredients for isolated photon measurement w/ FOCAL

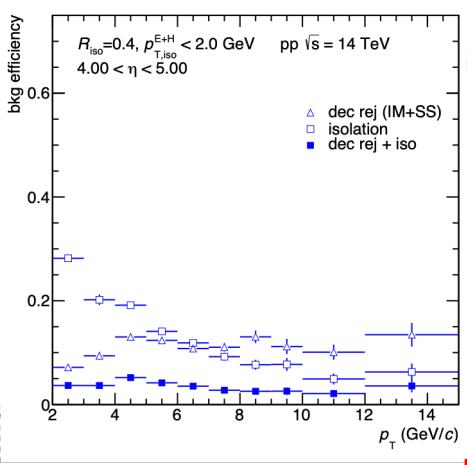
π^0 reconstruction efficiency

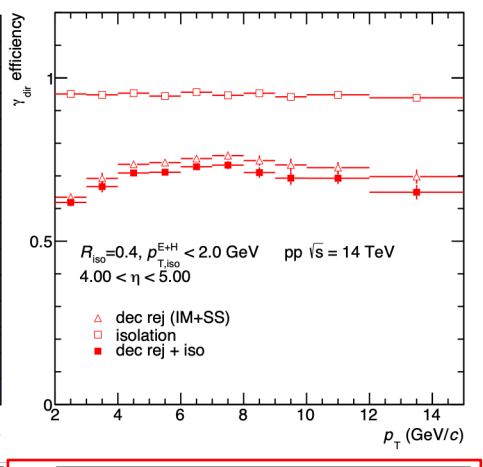


isolation cut (EMCAL+HCAL)

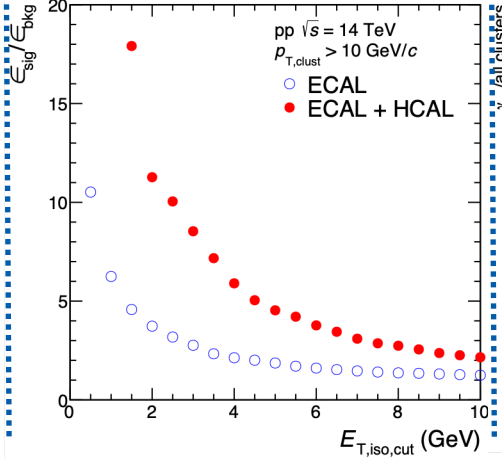


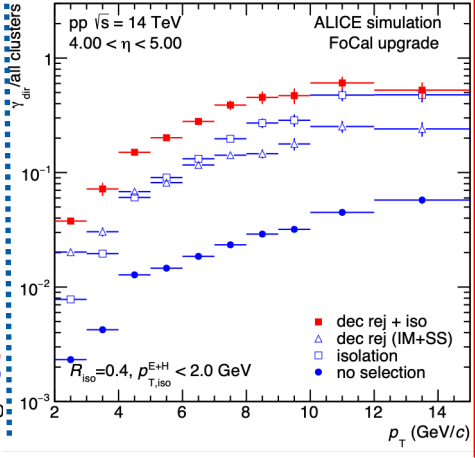
rejection of decay photons: IM+SS

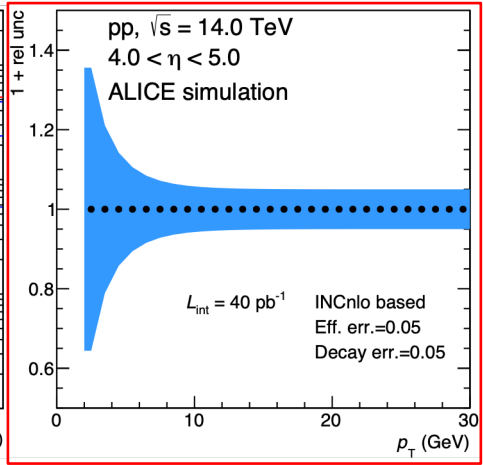




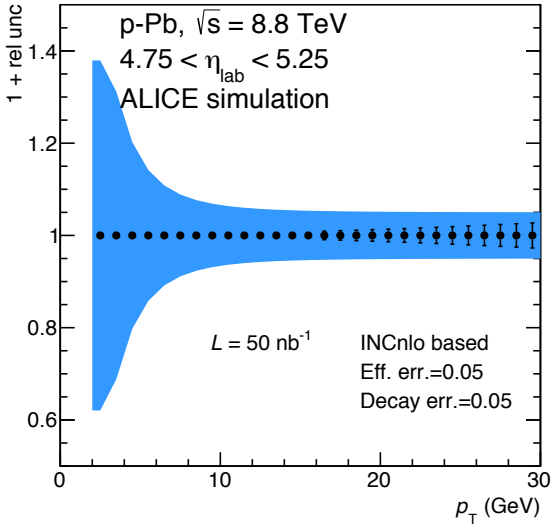
Improvement in signal fraction by factor ~10, from 0.01−0.06 to ~0.1−0.6



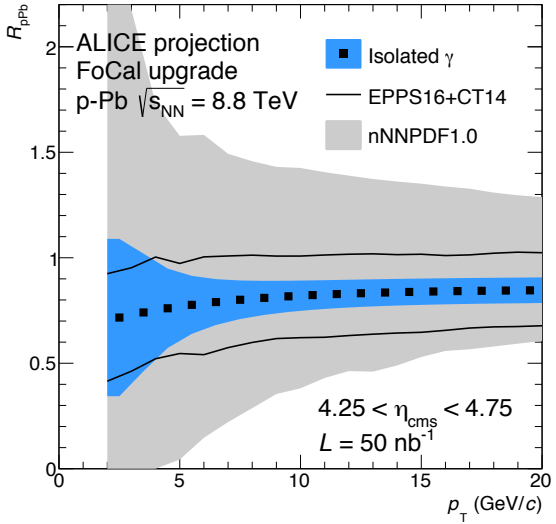




Impact of forward photons on nPDF

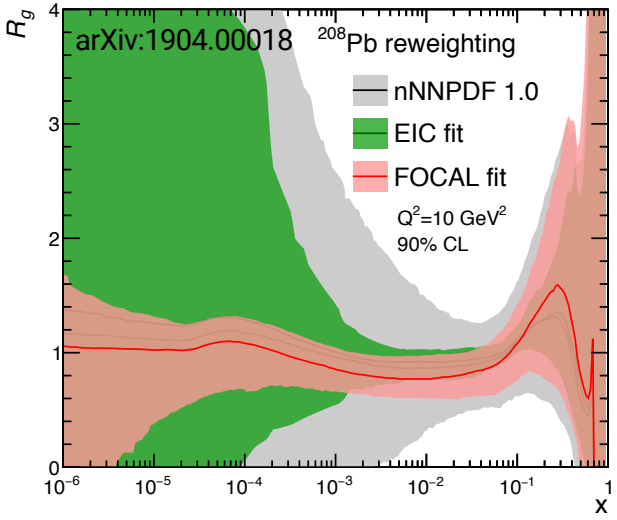


Sys. uncer. added in quadrature



- Sys. uncer. < 15 % above 4 GeV
- Below 6 GeV, uncertainty rises due to background subtraction
- Significant improvement (up to factor 2) on EPPS16 gluon PDF
- Similar improvement as for open charm
  - Test factorization/universality

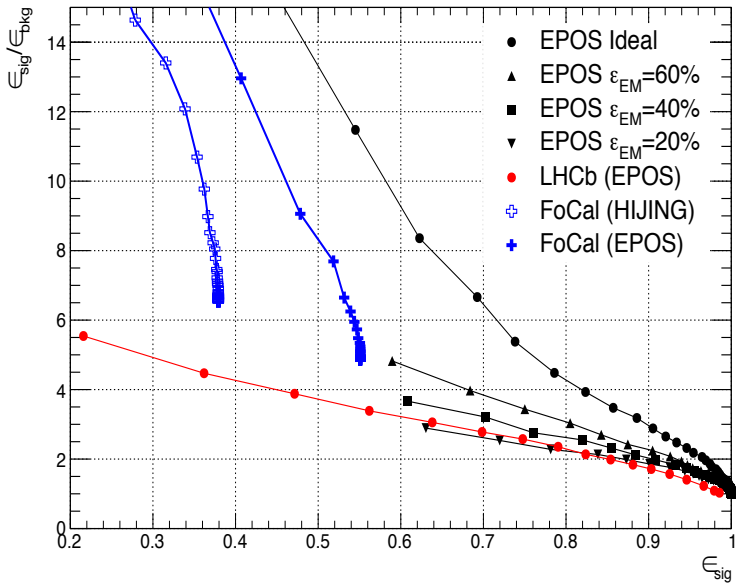
Impact of FOCAL refit on nNNPDF

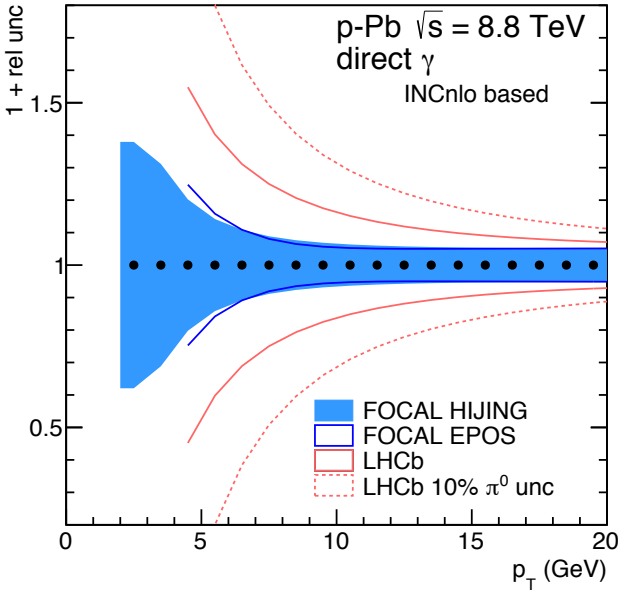


Recent nuclear PDFs: nNNPDF from DIS and theoretical assumptions

- No constraints for x<10^{-2} from DIS
- FOCAL provides significant constraints over a broad range: ~10^{-5}–10^{-2}
- Outperforming the EIC for x<10^{-3}

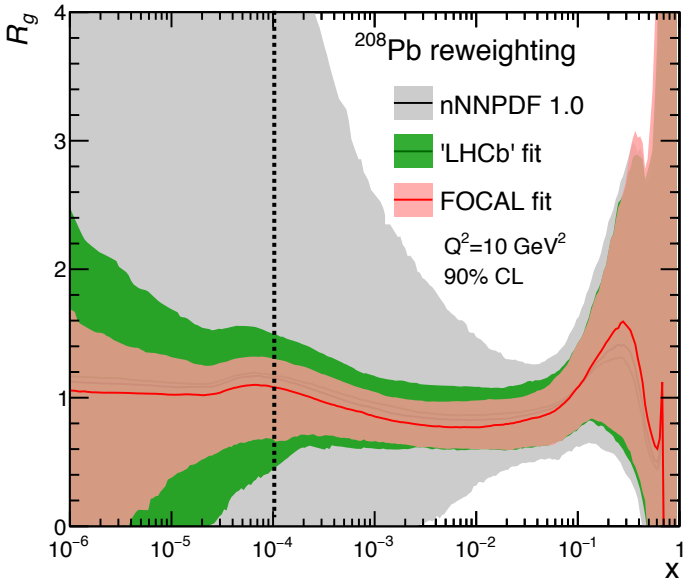
Comparison with LHCb

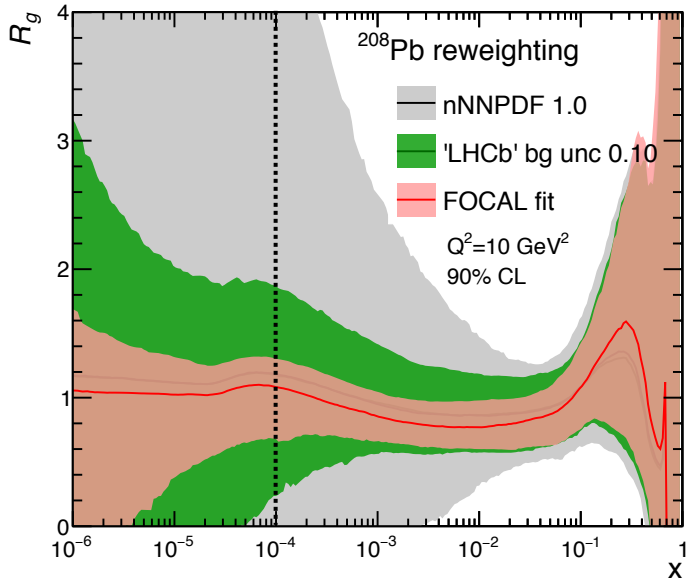




Public note from LHCb with more info LHCb-FIGURE-2020-006

Expected uncertainties on R_g from LHCb





- Main goal of the small-*x* program is to identify or exclude deviations from linear evolution for lower *x* (and *Q*)
  - Benefit from multiple measurements (w/ diff. syst.) over a broad range in *x* and *Q*

FOCAL timeline

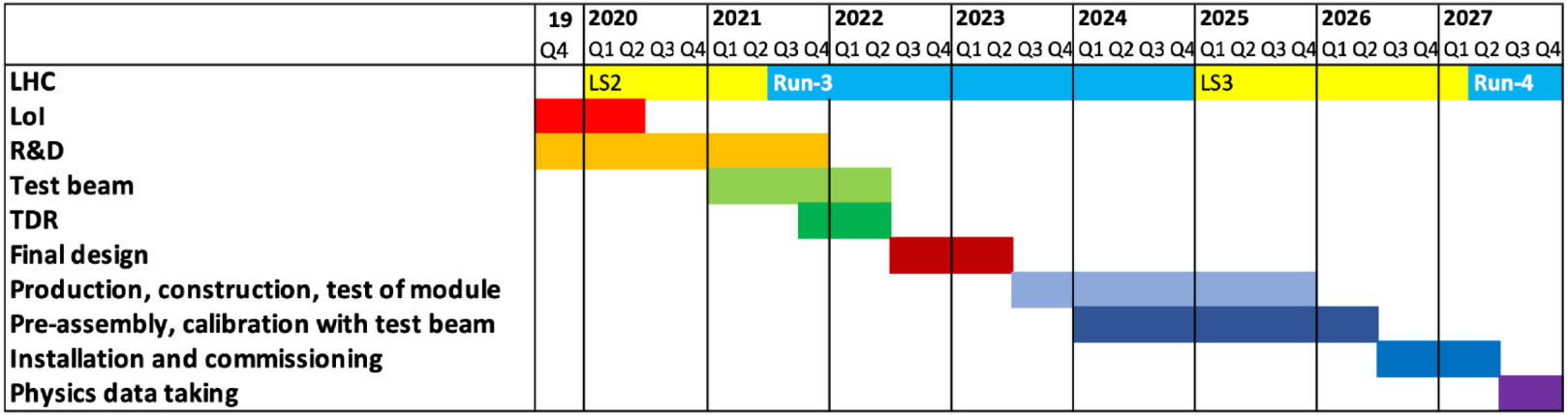


Table 6: Project timeline

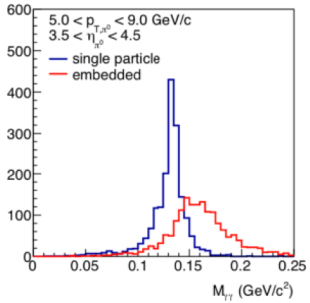
Year	Activity
2016–2021	**R&D**
2020	Letter of Intent
2020–2022	**final design**
	Technical Design Report
	design/technical qualifications
2023–2027	**Construction and Installation**
2023–2025	production, construction and test of detector modules
2024–2025	pre-assembly
	calibration with test beam
2026	installation and commissioning
06/2027	Start of Run 4

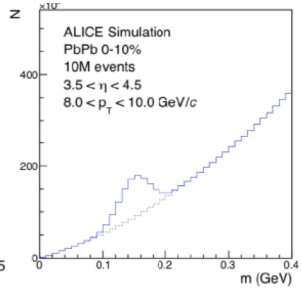
- Next important step: entering the engineering phase towards testbeam(s) 2021/22 and TDR
  - Produce a close-to-final prototype module
    - Pad and pixel layers
    - HCAL prototype
- Production estimated to fit well into 24 months
  - Plus 6 months of contingency

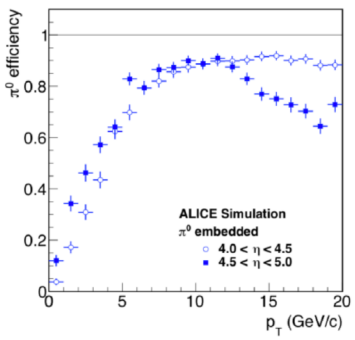
(not adjusted for Covid-19 changes)

And much more…

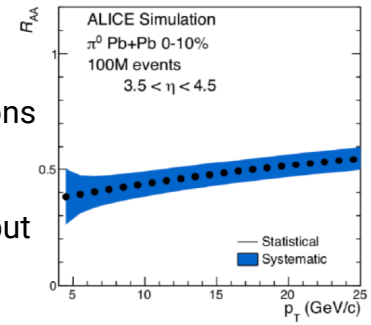
Performance in PbPb



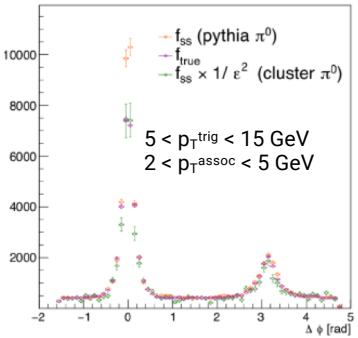




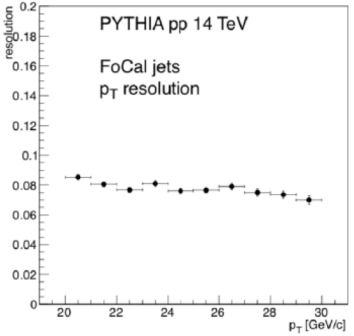
- Performance in PbPb affected by shower overlaps and combinatorial background
- Efficiency for high energy neutral pions nevertheless quite good
- Combinatorial background may prohibit very low p_T reconstruction, but above 5 GeV expect a precise R_{AA} measurement



Other observables

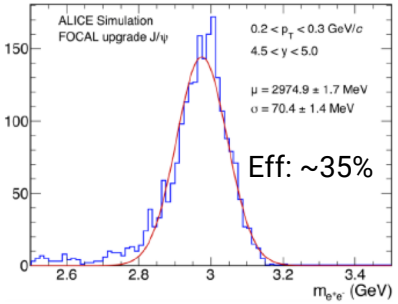


π⁰–π⁰ correlations in pp (for decorrelation studies)



Jet resolution (jet/dijets in pp/pPb/UPC)

- Promising performance for other key observables
- To be studied in more detail for TDR



J/ψ reconstruction (in UPC)

Recent discussion focused on isolated direct photon measurement as the core of the program

- Broader program to be studied for TDR: correlation measurements, UPC, PbPb

+ synergies with RHIC-II and EIC