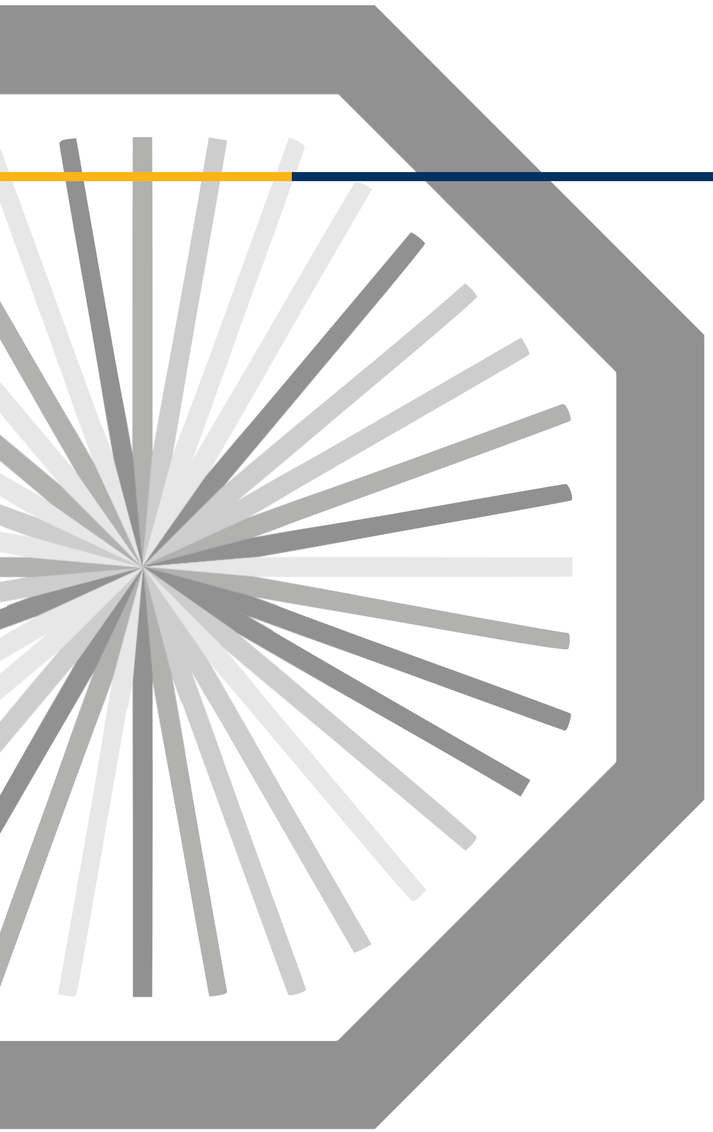

Measuring prompt photon production with the ALICE Forward Calorimeter (FoCal) upgrade

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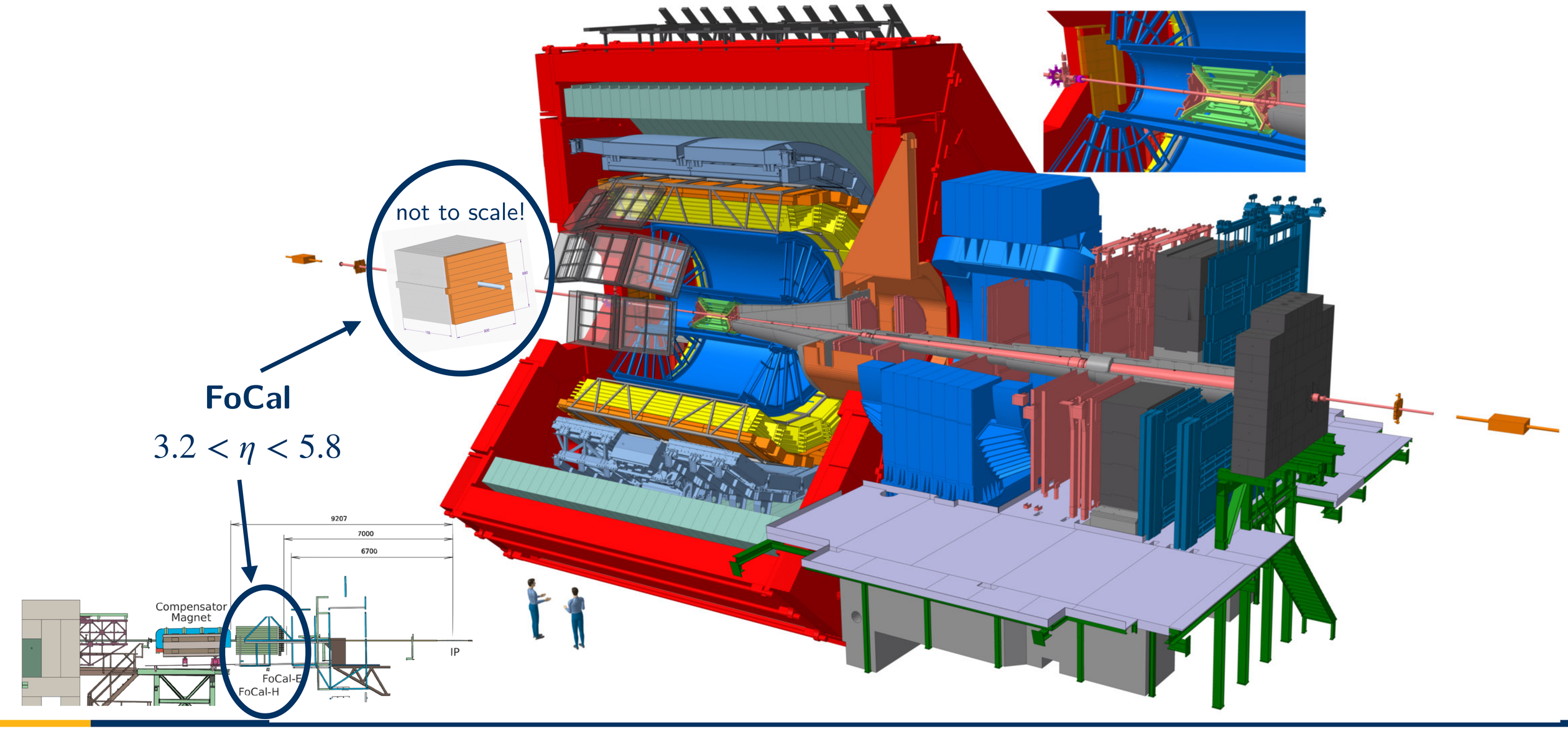
Berkeley
UNIVERSITY OF CALIFORNIA

Lawrence Berkeley
National Laboratory

ALICE

The Forward Calorimeter (FoCal)



The Forward Calorimeter (FoCal)

Acceptance:
$3.2 < \eta < 5.8$

General:

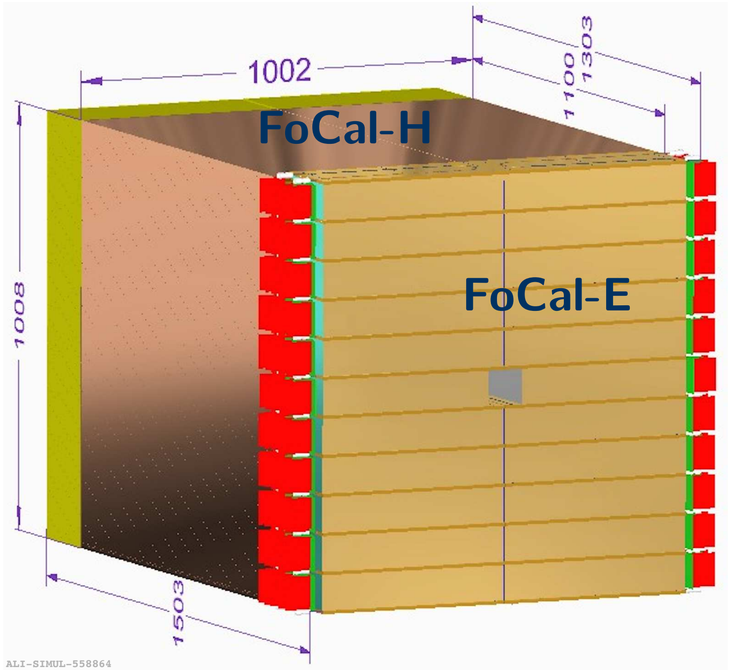
- Very forward calorimeter consisting of two parts (FoCal-E and FoCal-H) located $\approx$ 7m from IP of ALICE

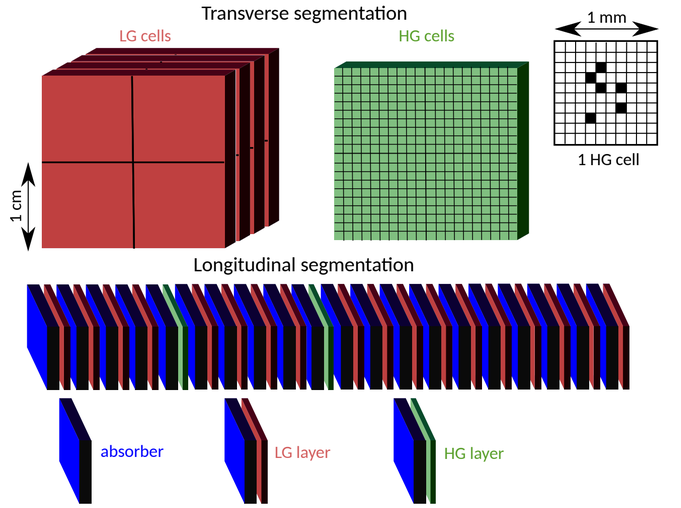
FoCal-E (electromagnetic):

- High-granularity Si-W sampling calorimeter combining two sensor granularities
  - 18 pad layers with silicon pads $(1 \times 1\text{cm}^2)$
  - Two pixel layers with digital readout $(30 \times 30\mu\text{m}^2)$
- Ability to "track" longitudinal component of shower!
- Used to measure photons and π^0 (40μm position rec.)

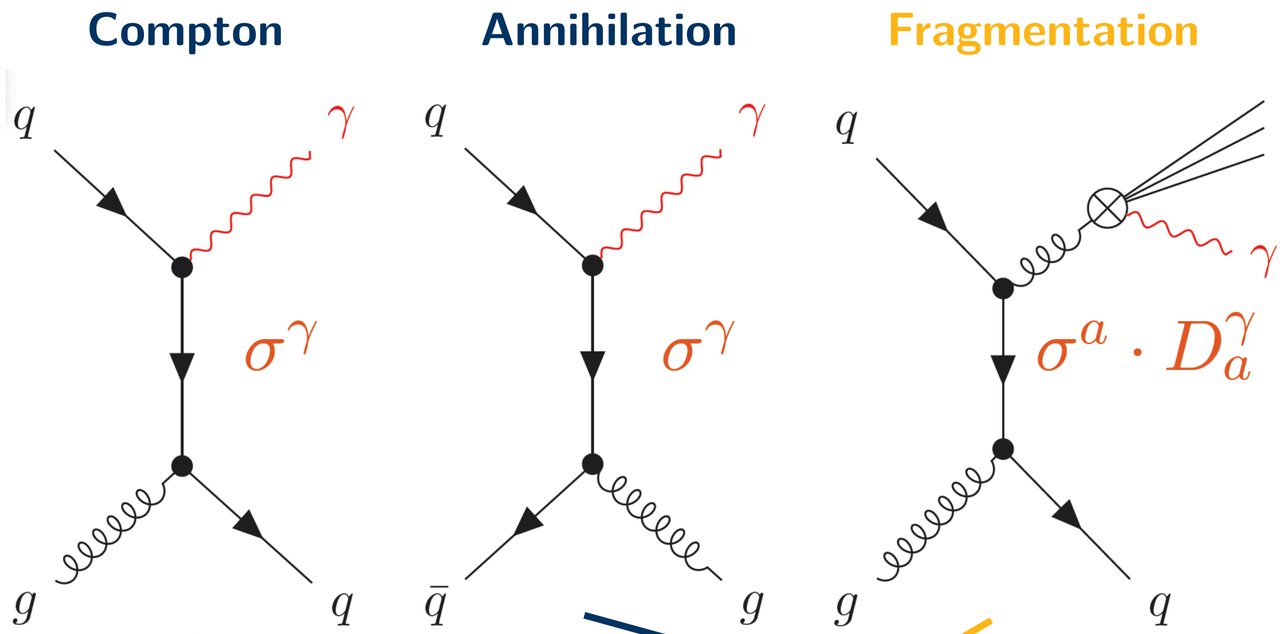
FoCal-H (hadronic):

- Conventional metal-scintillator hadronic calorimeter behind FoCal-E
- Design using scintillating fibres embedded in Cu tubes
- Used to measure photon isolation, jet energy etc.





Prompt photon production



$$\sigma(p_\gamma) = \sum_{a=q,\bar{q},g} \int_0^1 \frac{dz}{z} \hat{\sigma}^a\left(\frac{p_\gamma}{z}; \mu_r, \mu, \mu_f\right) \cdot D_a^\gamma(z; \mu_f) + \hat{\sigma}^\gamma(p_\gamma; \mu_r, \mu, \mu_f)$$

μ_r: renormalisation scale, μ: factorisation scale, μ_f fragmentation scale

- Prompt photons produced in hard scattering via two mechanisms:

(1) **Direct production** (direct access to incoming parton, e.g. gluon)

(2) **Fragmentation** of outgoing parton (requires inclusion of non-perturbutive objects)

- Prompt photons sensitive to gluon (n)PDF
- No strong interaction in final state
- Exploration of low-x gluons especially interesting
  - Shadowing?
  - Non-linear QCD effects (saturation)
- Validity of factorization?

⇒ key observable for the FoCal physics program and exploration of the saturation regime!

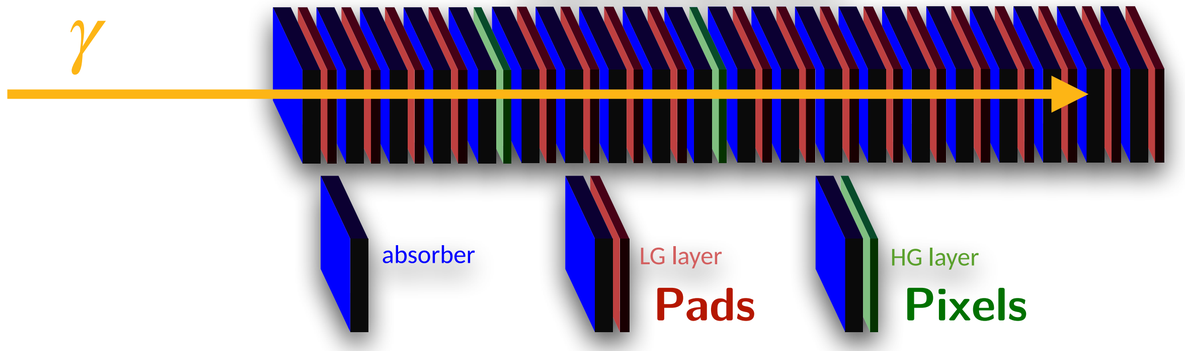
Photon reconstruction with the FoCal-E

Simulated single γ + GEANT3

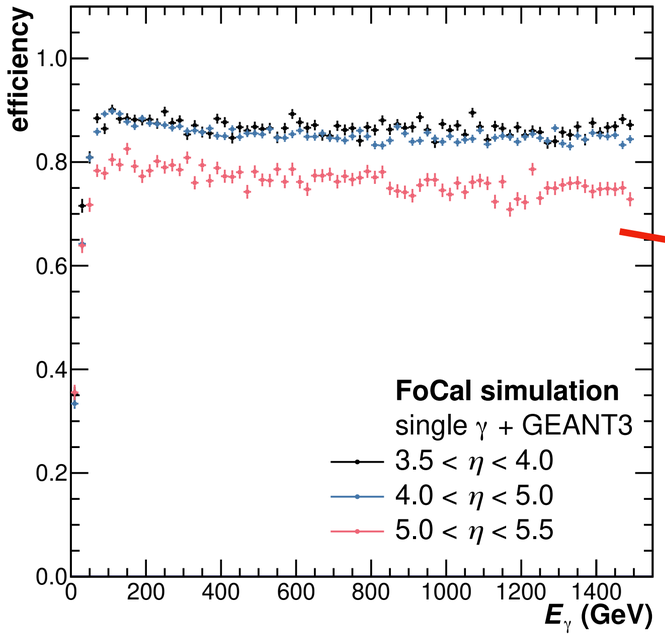
- Detector response to single photons estimated using full description of FoCal-E and FoCal-H in GEANT3
- High photon reconstruction efficiency of about 90%; reduction to about 80% for $\eta \gtrsim 5.3$ due to reduced azimuthal coverage
- High precision measurements with energy resolution of less than 5% for photons up to high energies of 1.5 TeV

FoCal-E module

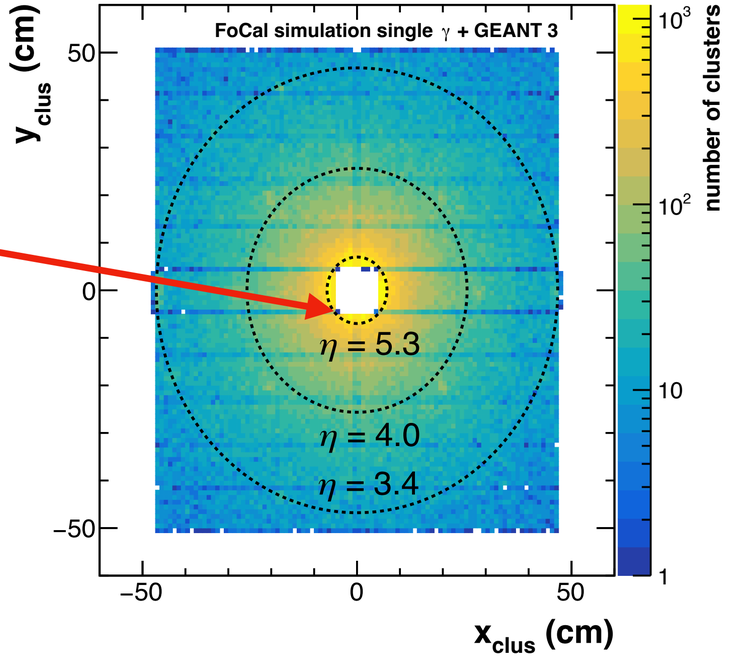
Longitudinal segmentation



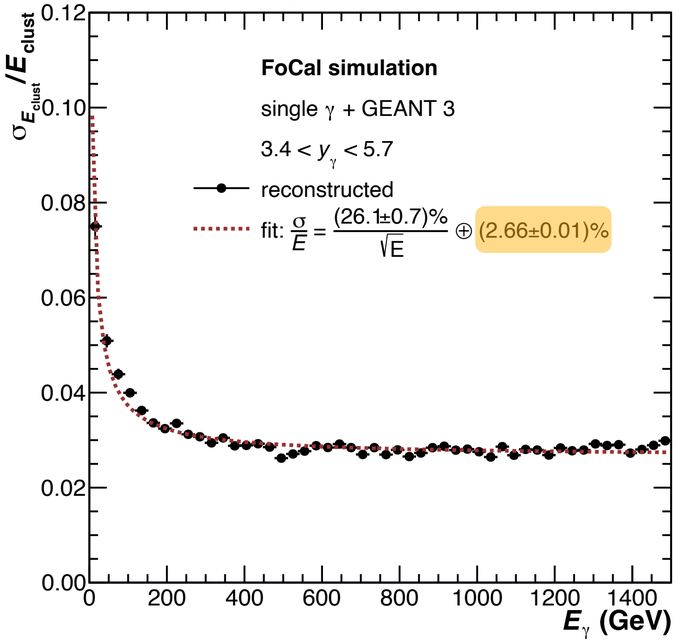
Reconstruction efficiency:



Cluster x-y position:



Energy resolution



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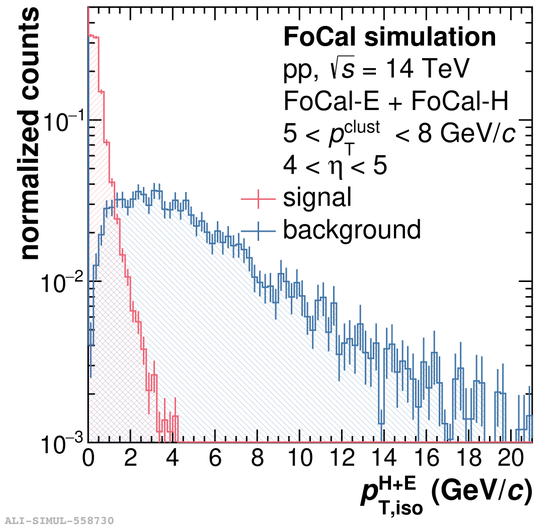
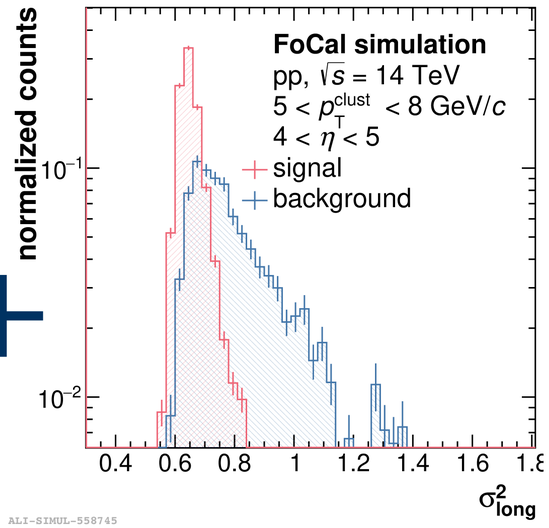
Prompt photon identification

PYTHIA8 pp at $\sqrt{s} = 14$ TeV + GEANT3

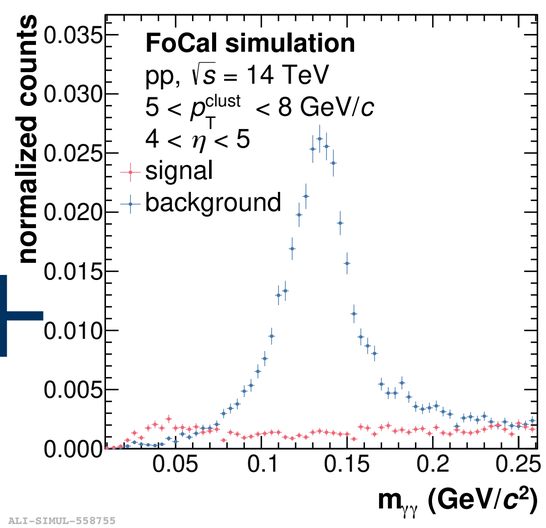
Isolation



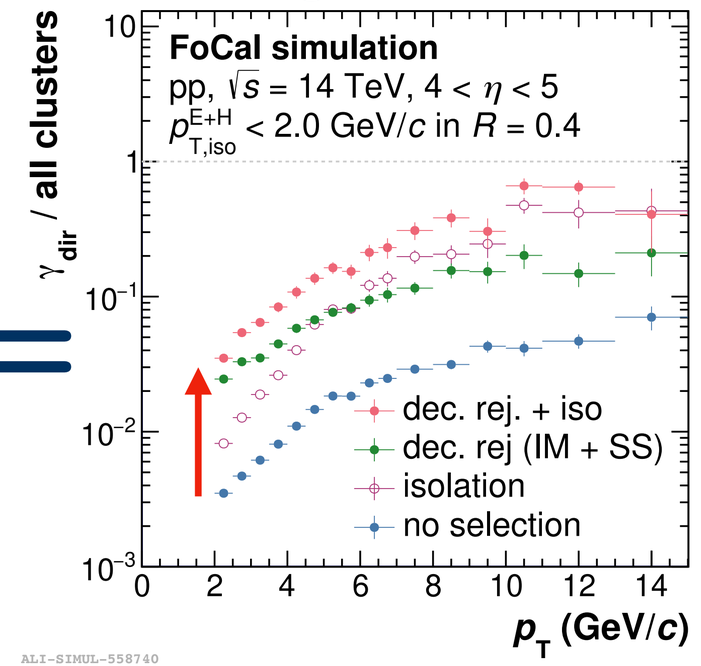
Shower shape

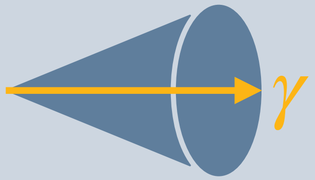


Invariant mass tagging:

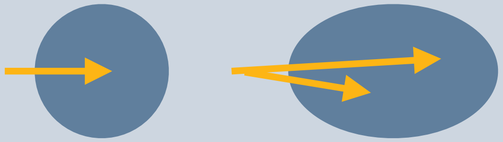


Signal fraction:





E_T sum within cone with $R = 0.4$ allows to discriminate sig. and bck.



Decay photons may produce elongated showers in pad layers due to shower overlaps

Highly granular pixel layers enable large π^0 reconstruction efficiency

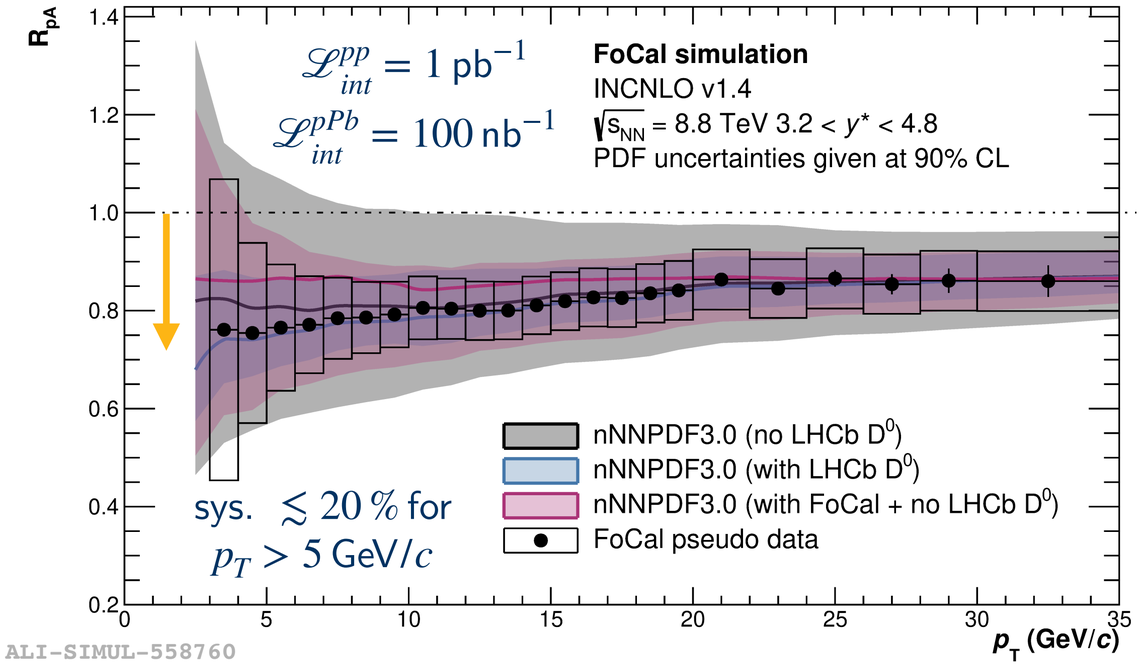
→ tag decay photons according to inv. mass of clust. pairs

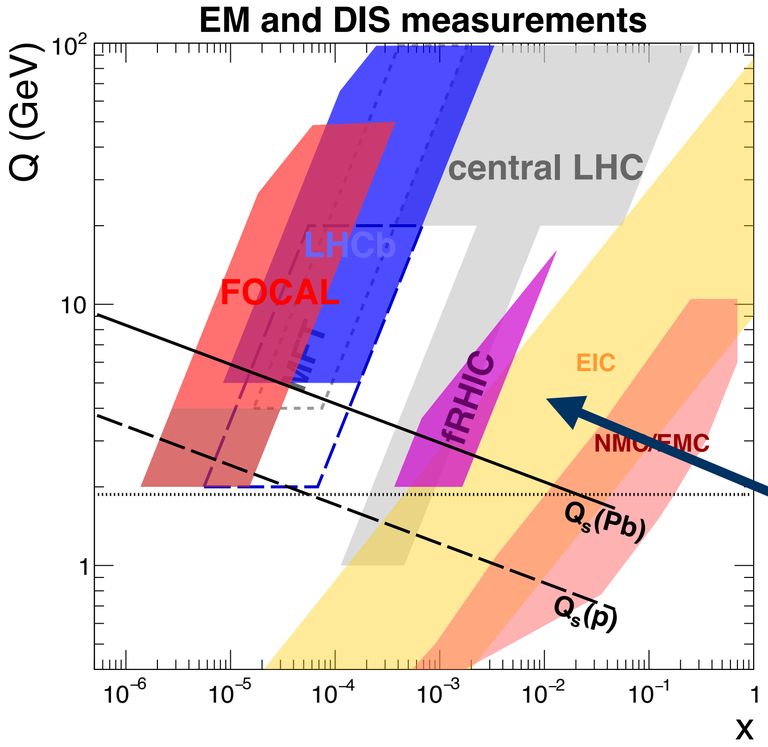
Employed selections increase signal fraction by a factor 11!

Comparable performance in p-Pb collisions at $\sqrt{s_{NN}} = 8.8$ TeV

Physics impact

- **FoCal pseudo-data** of nuclear modification factor R_{pA} contructed using input from NLO+nPDF and assumptions on stat. and sys. uncertainties from perf. studies
- **Bayesian re-weighting of nNNPDF30** prediction showcases **significant reduction of nPDF uncertainties** when including FoCal data; comparable to D meson measurement by LHCb





- Isolated prompt photon measurements in pp and p-Pb collisions with FoCal allow to low Bjorken-x $\sim 10^{-6}$ in a regime where gluon saturation is expected
- **Interesting synergies with future measurements at the EIC!**

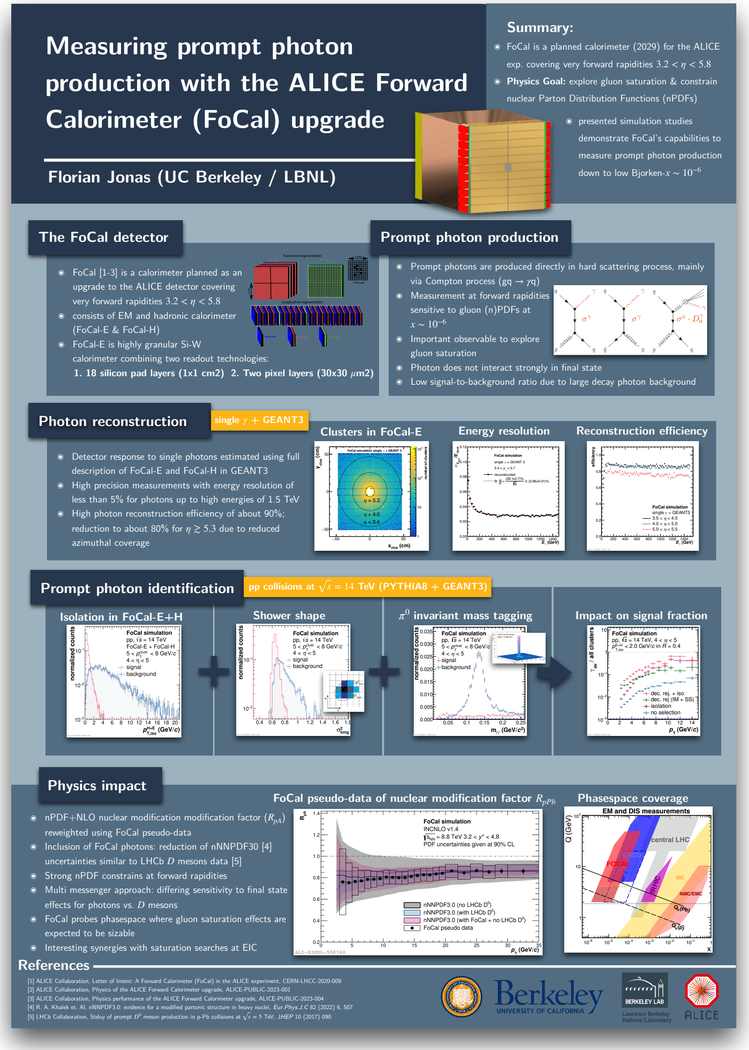
	Inclusive DIS	SIDIS	DIS dijet	Inclusive in p+A	γ+jet in p+A	dijet in p+A
xG_{WW}	−	−	+	−	−	+
xG_{DP}	+	+	−	+	+	+

Summary

- **The Forward Calorimeter (FoCal)** is a future calorimeter upgrade for the ALICE detector planned to be operational in **Run 4 (2029)** of LHC operation
- Acceptance of $3.2 < \eta < 5.8$ allows to access low $x \sim 10^{-6}$
- Measurement of **isolated prompt photon production** in pp and p-Pb collisions is a key measurement for **FoCal's physics goal** of **exploring gluon saturation & constrains for (n)PDFs**
- The shown simulation studies **showcase FoCal's capability to identify and measure this observable with high precision!**

Come and meet me at my poster!

I am happy to discuss :-)



Stay tuned for our upcoming TDR!

Recent publications:

ALICE Coll., *Letter of Intent: A Forward Calorimeter (FoCal) in the ALICE experiment*, CERN-LHCC-2020-009

ALICE Coll., *Physics of the ALICE Forward Calorimeter upgrade*, ALICE-PUBLIC-2023-001

ALICE Coll., *Physics performance of the ALICE Forward Calorimeter upgrade*, ALICE-PUBLIC-2023-004