ALICE – Physics highlights

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JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

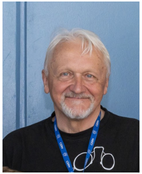
CoE QM

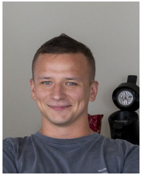
HELSINKI INSTITUTE OF PHYSICS

Outline

ALICE group in Jyväskylä

MT, May 2022

Currently 14 members

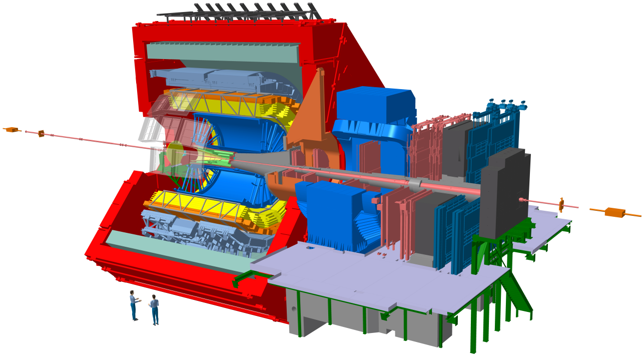
- 3 senior scientists
- 4 post-doctorates
- 6 PhD students
- 1 Master student

A Large Ion Collider Experiment

Dedicated heavy-ion experiment at the LHC

- Study of QGP in A–A collisions
- QCD fundamentals in pp and pA collisions
- Inputs for astrophysics

⟶ Run 1/2 results summarized in ALICE review paper, arXiv:2211.04384 (09.11.2022)



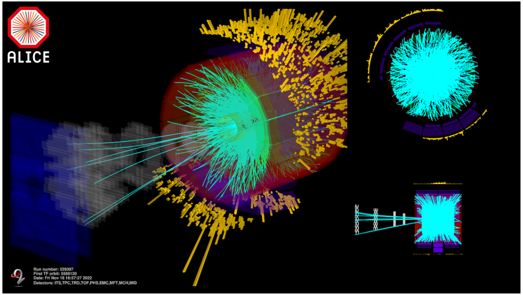
ALICE in Run 3

Run 3 in few numbers

- 05.07.2022: start of Run 3
- 17-18.11.2022: Pb-Pb pilot run
- Target interaction rates
  - pp: up to 1 MHz (with 500 kHz for 2022)
  - Pb–Pb: up to 50 kHz

$766 \cdot 10^9$ events already taken (Run 2: about $2.6 \cdot 10^9$ events)

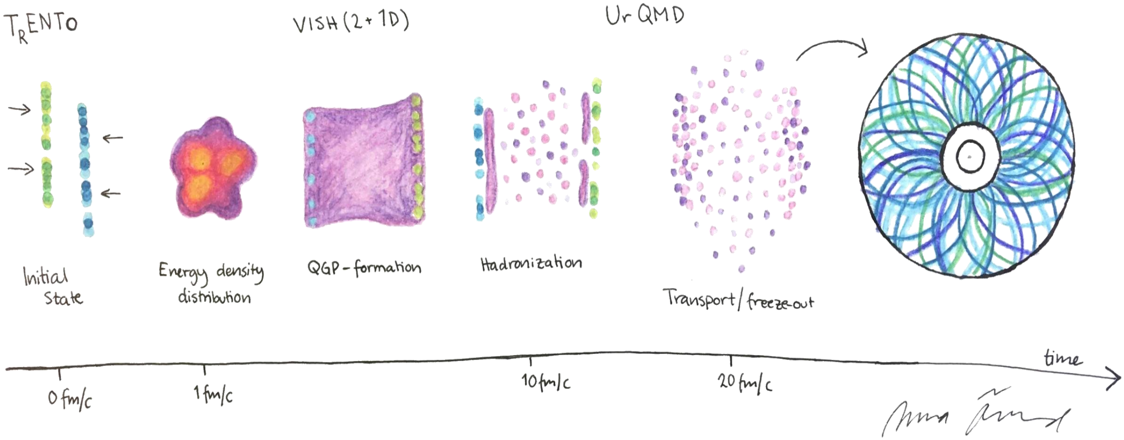
→ See talk by Yury this afternoon



Outline

Evolution of a heavy-ion collision

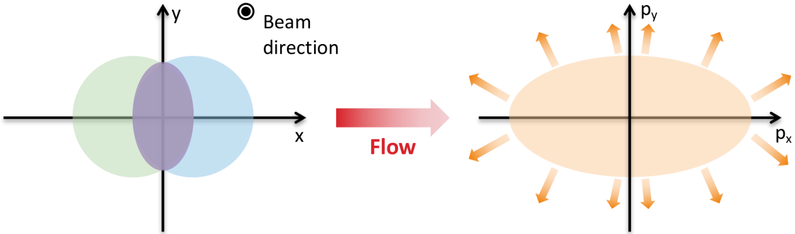
IP-Glasma, EKRT, 3D-Glauber MUSIC SMASH



Credits to A. Önnerstad

Distribution of detected final state particles ⟶ QGP transport properties?

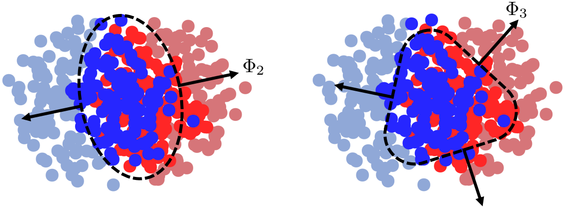
Anisotropic flow in brief



$\longrightarrow$ Anisotropic flow = medium response to the initial geometry

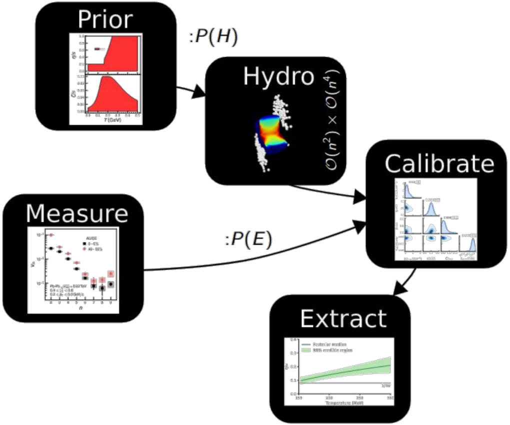
$$V_n \equiv v_n e^{in\Psi_n}$$

$$f(\varphi) = \frac{1}{2\pi}\left(1 + 2\sum_{n=1}^{\infty} v_n \cos(n(\varphi - \Psi_n))\right)$$



A. Poskanzer, S. Voloshin, Z. Phys. C **70**, 665672 (1996)

Credits to M. Lesch



Credits to J.E. Parkkila

Bayes' theorem

$$P(H|E) = \frac{P(E|H)\cdot P(H)}{P(E)}$$

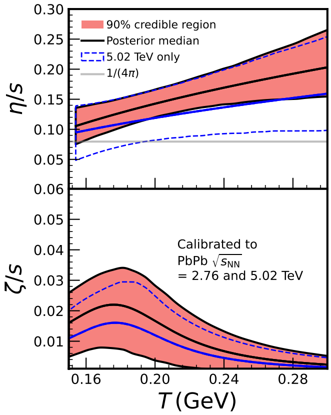
$$P(E) = \sum_{i=1}^{n} P(E|H_i)P(H_i)$$

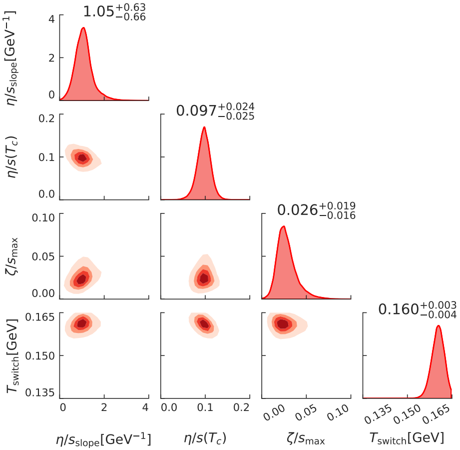
- Find set of model parameters that fit best the experimental data
- Use as input experimental data sensitive to QGP parameters

Two papers published on the topic

- J.E. Parkkila *et al*, PRC **104**, 054904 (2021)
- J.E. Parkkila *et al*, PLB **835**, 137485 (2022) Available online: 06.10.2022

Results from Jyväskylä 2022 – Combined (2.76 + 5.02 TeV) analysis





- Significantly improved uncertainty on $\eta/s(T)$
- Non-zero $\zeta/s(T)$
- Overall better convergence of parameters components

$\longrightarrow$ Two collision energies and additional observables = reduced uncertainties!

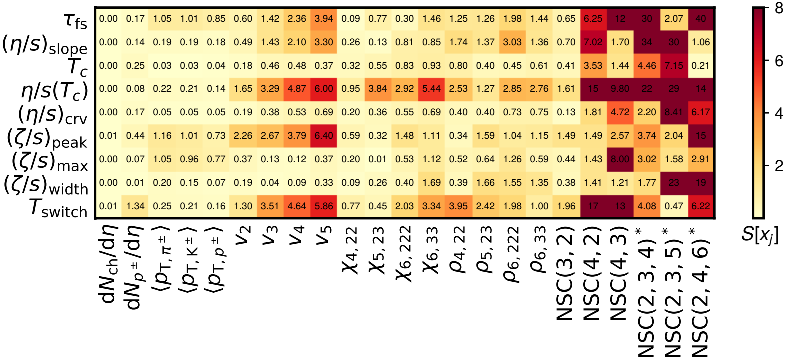
J.E. Parkkila, A. Önnerstad, S.F. Taghavi, CM, A. Bilandzic, D.J. Kim, M. Virta, PLB **835**, 137485 (2022)

Sensitivity study of the input observables

⟶ Higher sensitivity of higher order flow measurements to the QGP parameters!

Ongoing new developments

- Higher order ($n > 5$) symmetric cumulants: Anna
- Asymmetric cumulants: Cindy
- Improved symmetry planes correlations: Maxim



$$S[x_j] = \Delta/\delta, \text{ where } \Delta = \frac{|\hat{O}(\vec{x}') - \hat{O}(\vec{x})|}{|\hat{O}(\vec{x})|}$$

J.E. Parkkila, A. Önnerstad, S.F. Taghavi, CM, A. Bilandzic, D.J. Kim, M. Virta, PLB **835**, 137485 (2022)

Topic 2: Asymmetric cumulants

- Symmetric cumulants (SC):
  $\langle v_m^2 v_n^2 \rangle_c$, $\langle v_k^2 v_l^2 v_m^2 \rangle_c, \ldots$
- General form for two harmonics[1,2]

$$\mathrm{SC}(m,n) = \langle v_m^2 v_n^2 \rangle - \langle v_m^2 \rangle \langle v_n^2 \rangle$$

[1] ALICE Collaboration, PRL **117**, 182301 (2016)

[2] ALICE Collaboration, PRC **97**, 024906 (2018)

- Asymmetric cumulants (AC):
  $\langle v_m^4 v_n^2 \rangle_c$, $\langle v_m^6 v_n^2 \rangle_c, \ldots$
- General form for two harmonics[3]

$$\mathrm{AC}_{a,b}(m,n) \equiv \langle v_m^{2a} v_n^{2b} \rangle_c$$

  - for $a, b = 1$: $\mathrm{AC}_{1,1}(m,n) = \mathrm{SC}(m,n)$

[3] A. Bilandzic, M. Lesch, CM, S.F. Taghavi, PRC **105**, 024912 (2022)

Dependence of SC and AC on the magnitudes of v_m^2 and v_n^2
$\longrightarrow$ Magnitude of the genuine correlations only via normalisation

$$\mathrm{NSC}(m,n) = \frac{\mathrm{SC}(m,n)}{\langle v_m^2 \rangle \langle v_n^2 \rangle}$$

$$\mathrm{NAC}_{a,b}(m,n) = \frac{\mathrm{AC}_{a,b}(m,n)}{\langle v_m^2 \rangle^a \langle v_n^2 \rangle^b}$$

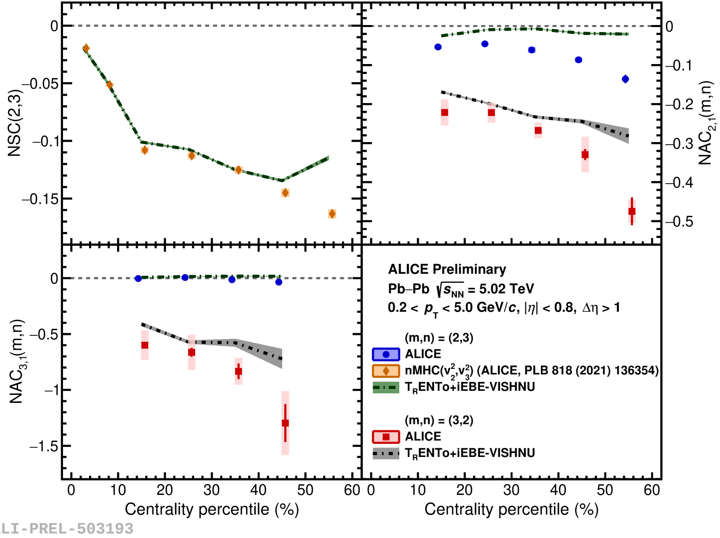
Asymmetric cumulants with ALICE

First measurements in Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV with ALICE

"Good" description of data by model predictions[1] for

- NSC(2, 3)
- $\mathrm{NAC}_{a,1}(3, 2), a = 2, 3$

Tensions between data and model predictions for $\mathrm{NAC}_{2,1}(2, 3)$ and $\mathrm{NAC}_{3,1}(2, 3)$ $\longrightarrow$ Constraints on initial state in central/semicentral events

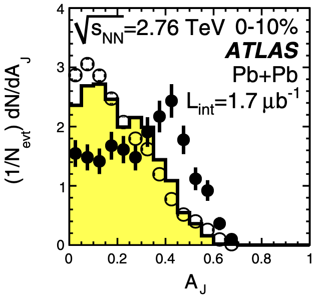


[1] J.E. Bernhard, Nature Phys. **15**, 1113-1117 (2019)

Outline

Di-jet invariant mass

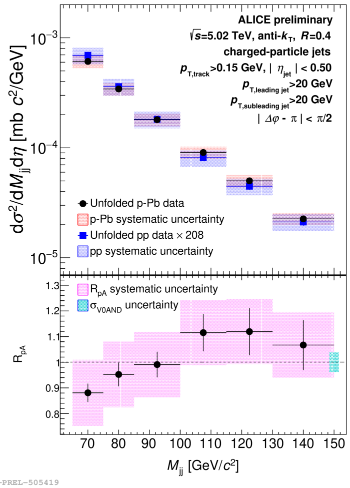
ATLAS PRL 105, 252303 (2010)



$E_{T,lead} > 100\ GeV$
$E_{T,sublead} > 20\ GeV$

- Previous studies (e.g., dijet asymmetry at LHC) indicate that the dijet invariant mass can be sensitive to modifications caused by the QGP medium.
- ALICE capable of measuring low p_T jets.
- $R_{pPb} \approx$ unity $\Rightarrow$ no significant CNM.

Preliminary(Oskari)

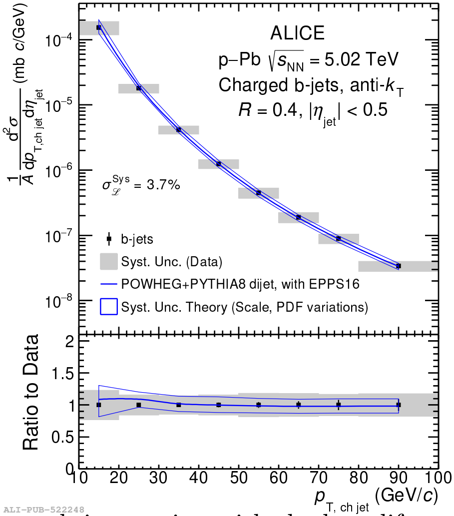


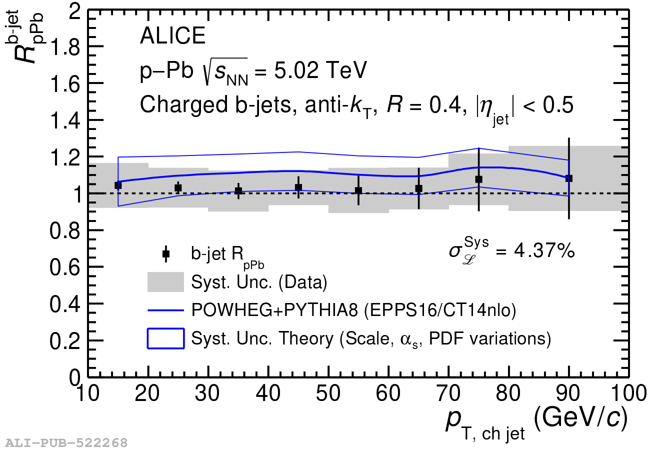
$p_{T,lead} > 20\ GeV$

- Reduced the uncertainties (Oskari) and inputs from the local theory group.
- Centrality dependence in pPb and Pb-Pb.

Measurement of b-jets in pp and p-Pb collisions

ALICE JHEP, 178 (2022)





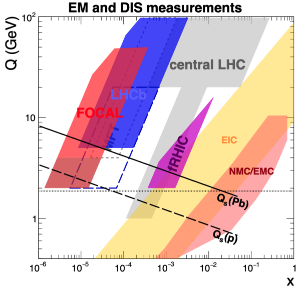
- b-jet tagging with the long life time of b hadrons.
- agree with pQCD with nPDF's.

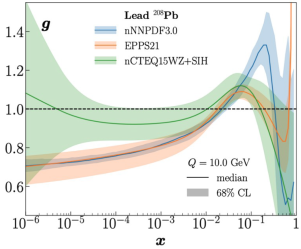
- $R_{pPb} \approx 1 \Rightarrow$ no significant cold nuclear matter effects(CNM) on b-jet production.
- Improve the precision with Run 3 to check CNM and "quenching" if any.

Outline

ALICE Forward Calorimeter (FOCAL)

- Nuclear modification of the gluon density at small$-x$
  - isolated photons in pp and pPb collisions.





ALICE Forward Calorimeter (FOCAL)

- Nuclear modification of the gluon density at small$-x$
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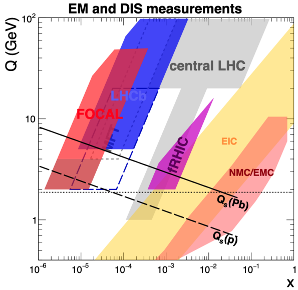
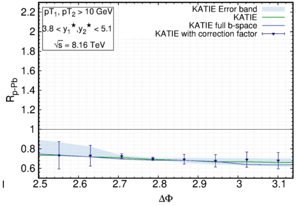
- Non-linear QCD evolution
  - measurements of forward azimuthal correlations: (p0, γ^{iso}, jet)$_{trigg}$ x (p0, jet)$_{assoc}$.
  - Quarkonia in UPC.





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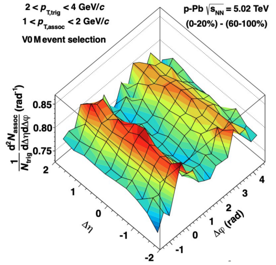
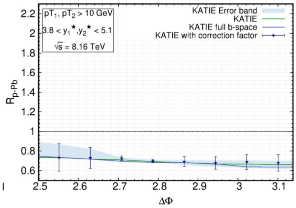
  - azimuthal correlations using FoCal and central ALICE or muon arm.





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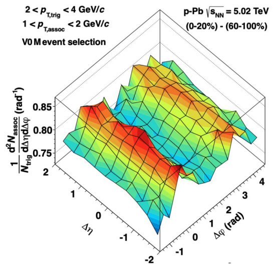
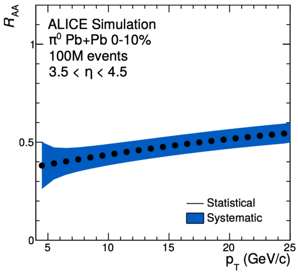
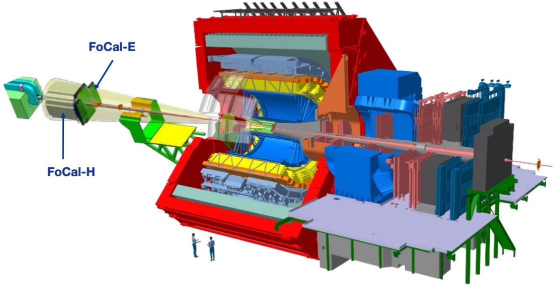
- Long-range flow-like correlations
  - azimuthal correlations using FoCal and central ALICE or muon arm.
- Jet quenching at forward rapidities
  - high-pT neutral pion in PbPb.
- More measurements being studied for the TDR
  - Weak bosons in pp/p-Pb.
  - Isolated photons in Pb-Pb.





ALICE Forward Calorimeter (FOCAL)

- FOCAL is an upgrade project planned to be installed during long shutdown 3.
- It will be situated 7 m away from the interaction point.
- It will 90x90x130 cm^2 in dimensions with pseudo-rapidity range $3.4 < \eta < 5.8$.



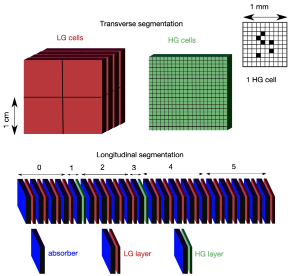
- It consists of two main parts:
  - Electromagnetic calorimeter.
  - Hadronic calorimeter.

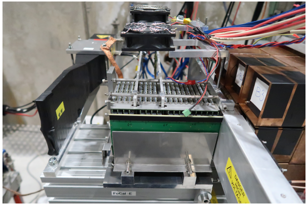
FOCAL Letter of Intent

FOCAL-E and FOCAL-H

FOCAL-E:

- The electromagnetic calorimeter is a Si+W sampling calorimeter with high granularity.
- It has 18 layers W+Si pads, and 2 W+Si pixels, with total length of $\backsim$ 20cm.
- Main goal of pixel layers is shower separation.





FOCAL-E and FOCAL-H

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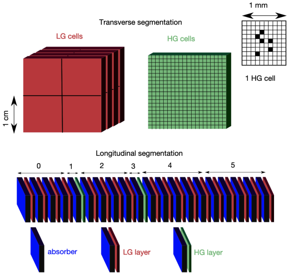
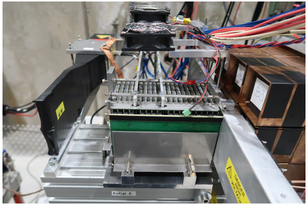
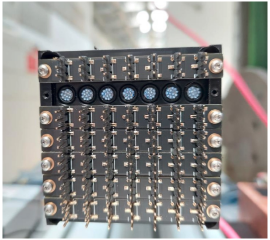
- The electromagnetic calorimeter is a Si+W sampling calorimeter with high granularity.
- It has 18 layers W+Si pads, and 2 W+Si pixels, with total length of ∽ 20cm.
- Main goal of pixel layers is shower separation.

FOCAL-H:

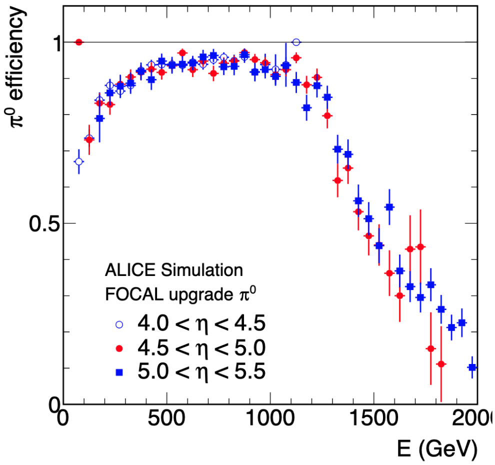
- The hadronic calorimeter will be used for photon isolation and jet measurements.
- It has a length of 110 cm.
- it consists of Copper tubes parallel to beam pipe (diameter 2.5 mm), filled with scintillating fibers (diameter 1 mm).

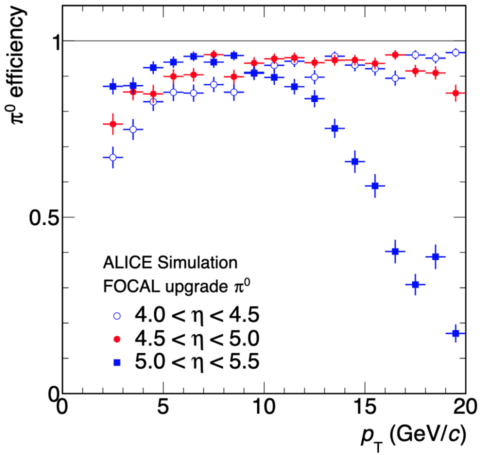






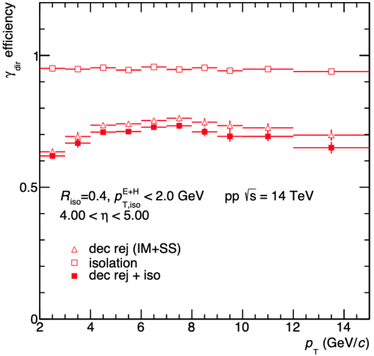
FOCAL performance: Neutral pion measurement

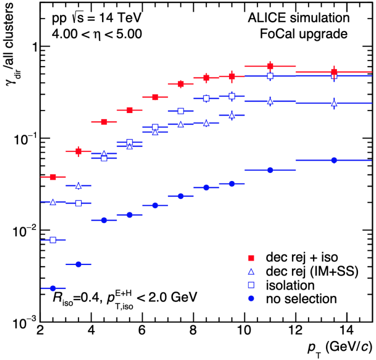




- Reach in Energy is the similar in all rapidities.
- Drop at high energy since photon separation gets more difficult.

FOCAL performance: Isolated photons



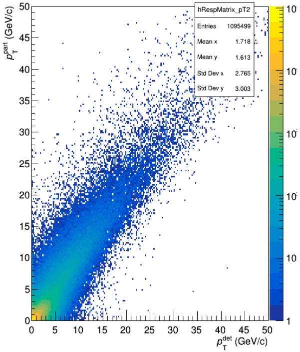


- Several cuts has been applied to reject background: isolation, invariant mass, and shower shape.
- The FOCAL shows a high performance for the identification of isolated photons.

FOCAL jets and testbeam

FOCAL jets:

- Jets in FOCAL are reconstructed from clusters from the ECAL and HCAL.
- They are reconstructed in fiducial acceptance $3.2 + R < \eta_{jet} < 5.5 - R$.
- Match particle level and cluster jets geometrically.



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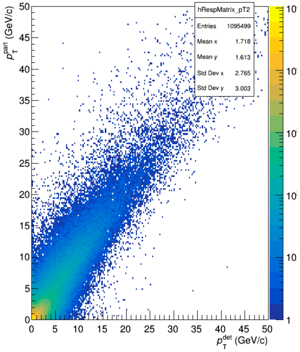
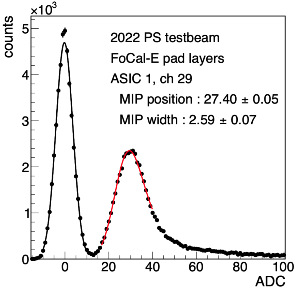
FOCAL testbeam:

- The FOCAL prototype has been tested at the PS and SPS.
- Shot with different particle beams: electrons and hadrons.





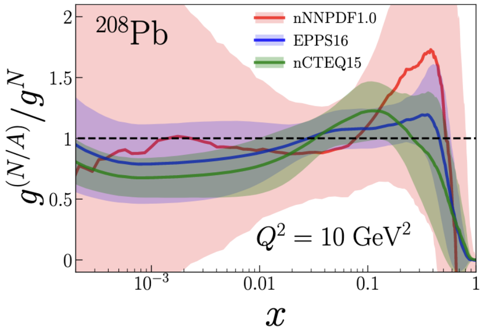
Summary and outlook

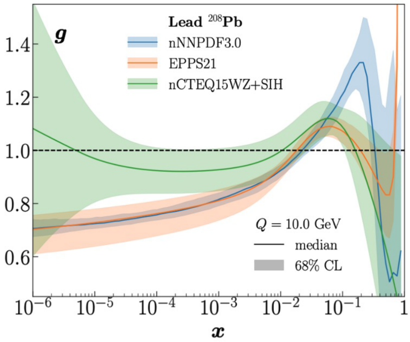
- Improve precision of Bayesian analysis by including new data from LHC and new initial state models.
- ALICE data analysis on flow observables and jets.
- Active work on FoCal technical design report ongoing $\Rightarrow$ first version to LHCC in March 2023.

Thank you for your attention!

Backup

Backup: nPDF old vs new





nNNPDF3.0, EPJ.C82 (2022) 6, 507 ;
EPPS21, EPJ.C82 (2022) 5, 413