Tagging protons in p-O interactions

24 October 2022
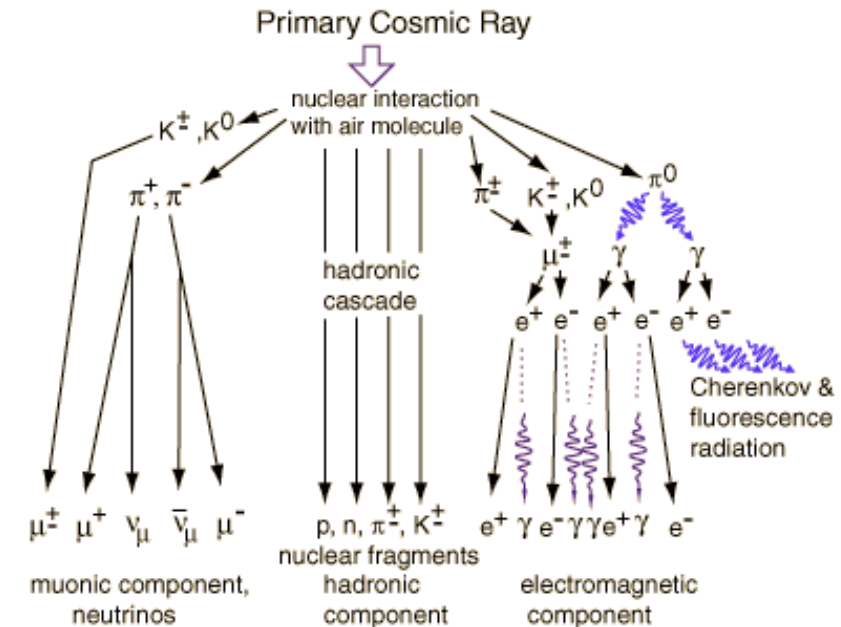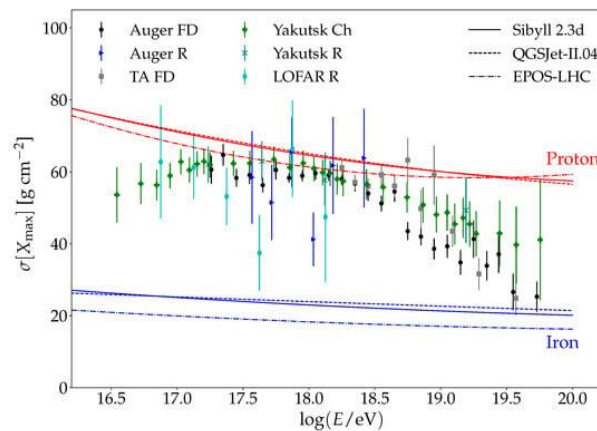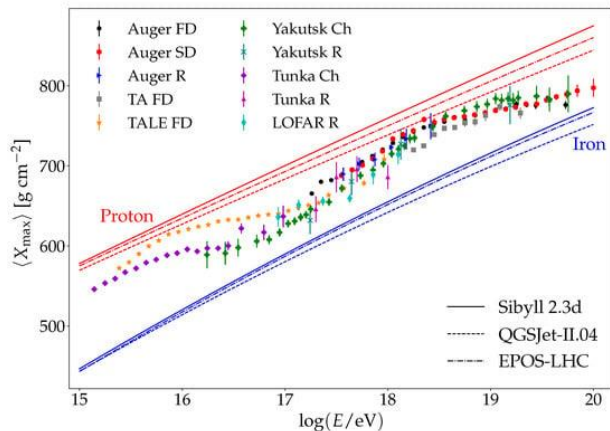
Michael Pitt (BGU)

with a lot of help from Mario Deile

Introduction

Oxygen ions at the LHC

- Oxygen ions $\left(^{16}_{8}O\right)$ will be injected at the LHC for the first time.

- OO and pO runs are scheduled to take place in 2024 (ref[1]), duration of ~one week

- Target: luminosity of $\mathcal{L}\sim nb^{-1}$, and pileup rates of $\mu \leq 0.02$ (ref[2])

- Main goal of the run is to provide an input for cosmic ray modeling

https://inspirehep.net/literature/2107517

http://hyperphysics.phy-astr.gsu.edu/hbase/Astro/cosmic.html

----

[1] F. Moortgat, *"Physics expectations – LPC"*, LHC Performance Workshop 2022, https://indico.cern.ch/event/1097716/
[2] R. Bruce "Studies for an LHC pilot run with oxygen beams", IPAC2021, https://cds.cern.ch/record/2783801

Proton tagging in p-O runs

Proton kinematics :

- Intact protons **lose a fraction of momentum** $(\xi = \Delta p/p)$

  and scattered at small angles $(\theta_x^*, \theta_y^*) \rightarrow$ they deflected

  away from the beam and measured by PPS

$$\delta x(z) = x_D(\xi) + v_x(\xi)x^* + L_x(\xi)\theta_x^*$$
$$\delta y(z) = y_D(\xi) + v_y(\xi)y^* + L_y(\xi)\theta_y^*$$
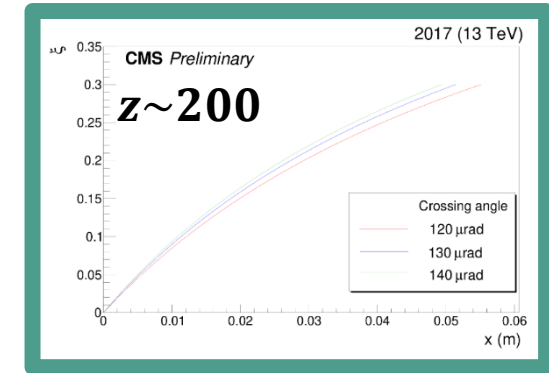
Proton tagging in p-O runs

Proton kinematics :

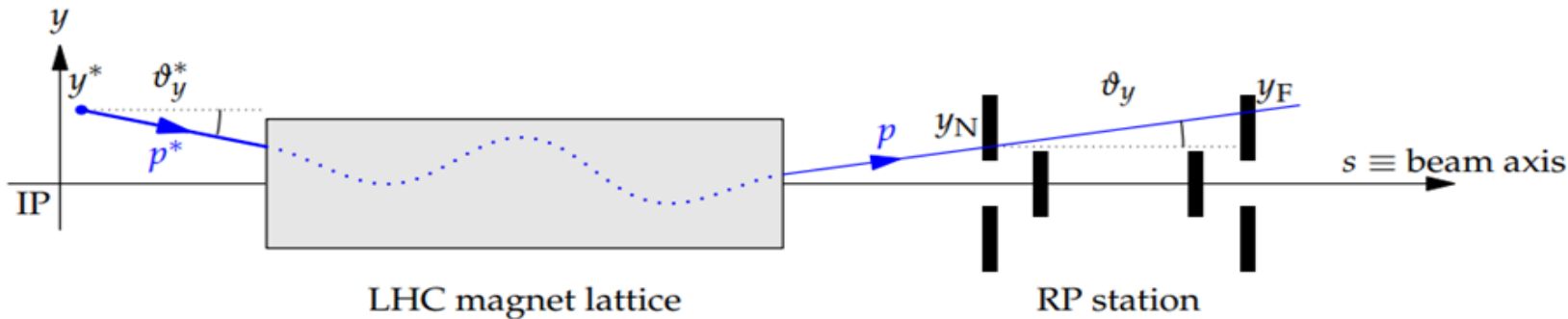- Intact protons **lose a fraction of momentum** $(\xi = \Delta p/p)$

  and scattered at small angles $(\theta_x^*, \theta_y^*) \rightarrow$ they deflected

  away from the beam and measured by PPS

$$\delta x(z) = x_D(\xi) + v_x(\xi)x^* + L_x(\xi)\theta_x^*$$

$$\delta y(z) = y_D(\xi) + v_y(\xi)y^* + L_y(\xi)\theta_y^*$$

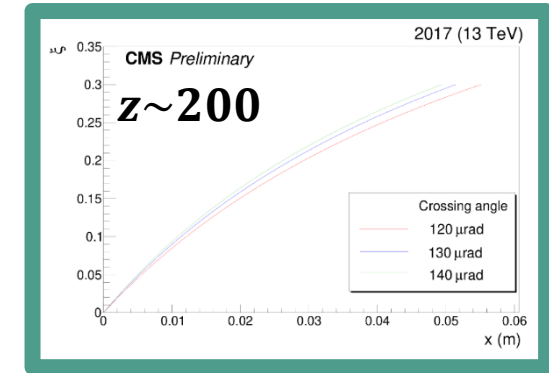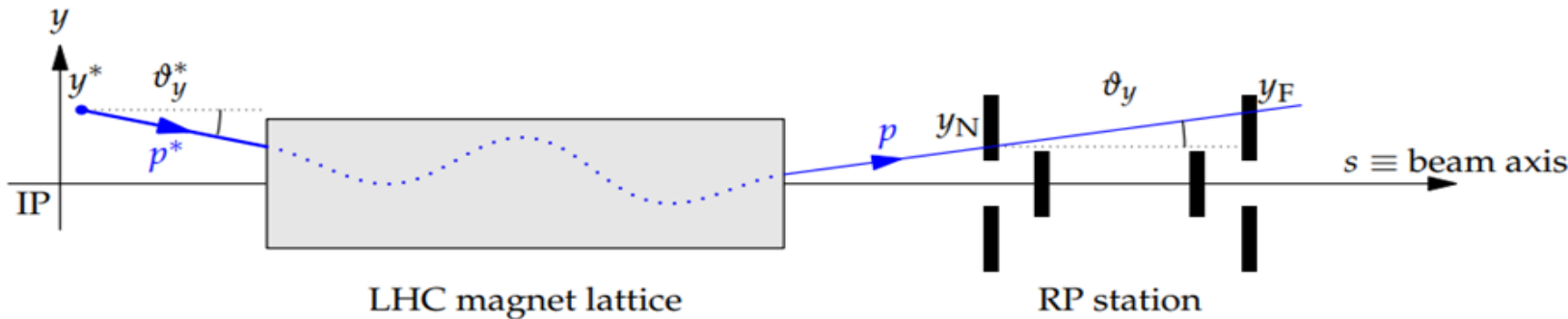
$z \sim 200$
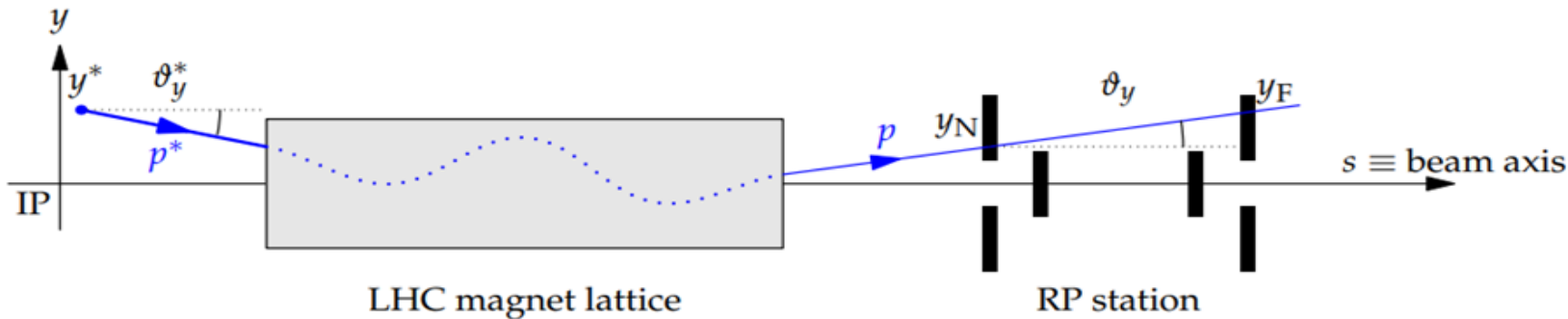
IP5 as an example

Proton tagging in p-O runs
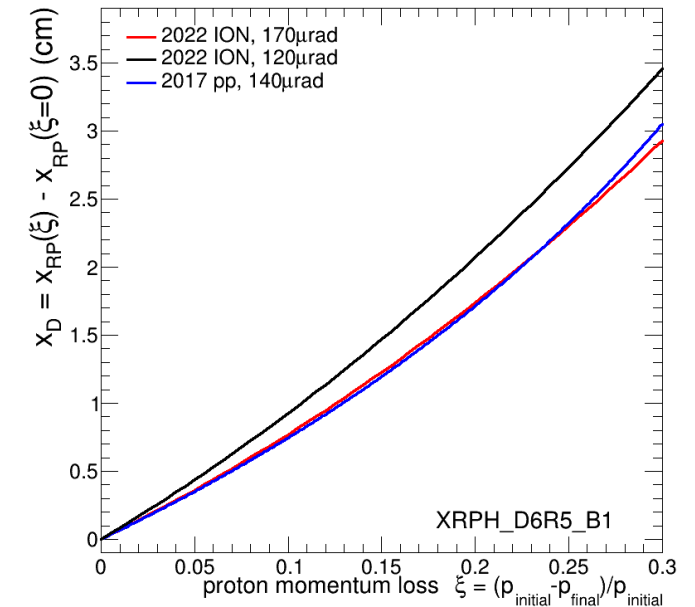
Proton kinematics :

- Intact protons **lose a fraction of momentum** $(\xi = \Delta p/p)$

  and scattered at small angles $(\theta_x^*, \theta_y^*) \to$ they deflected

  away from the beam and measured by PPS

$$\delta x(z) = x_D(\xi) + v_x(\xi)x^* + L_x(\xi)\theta_x^*$$

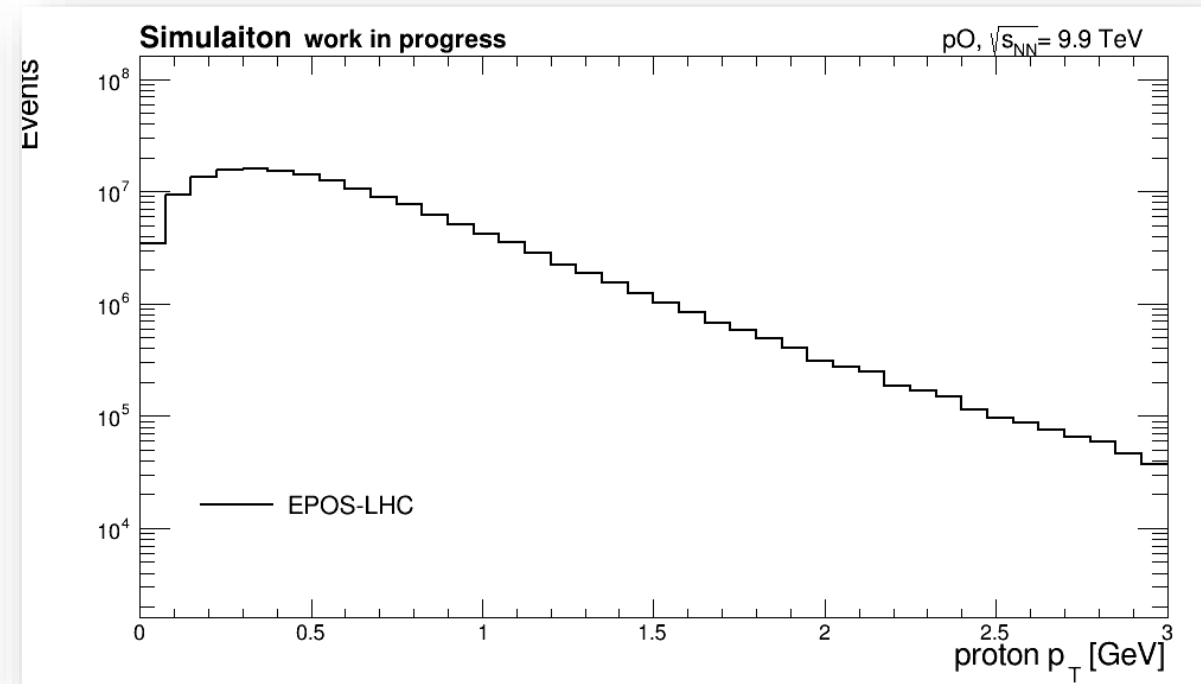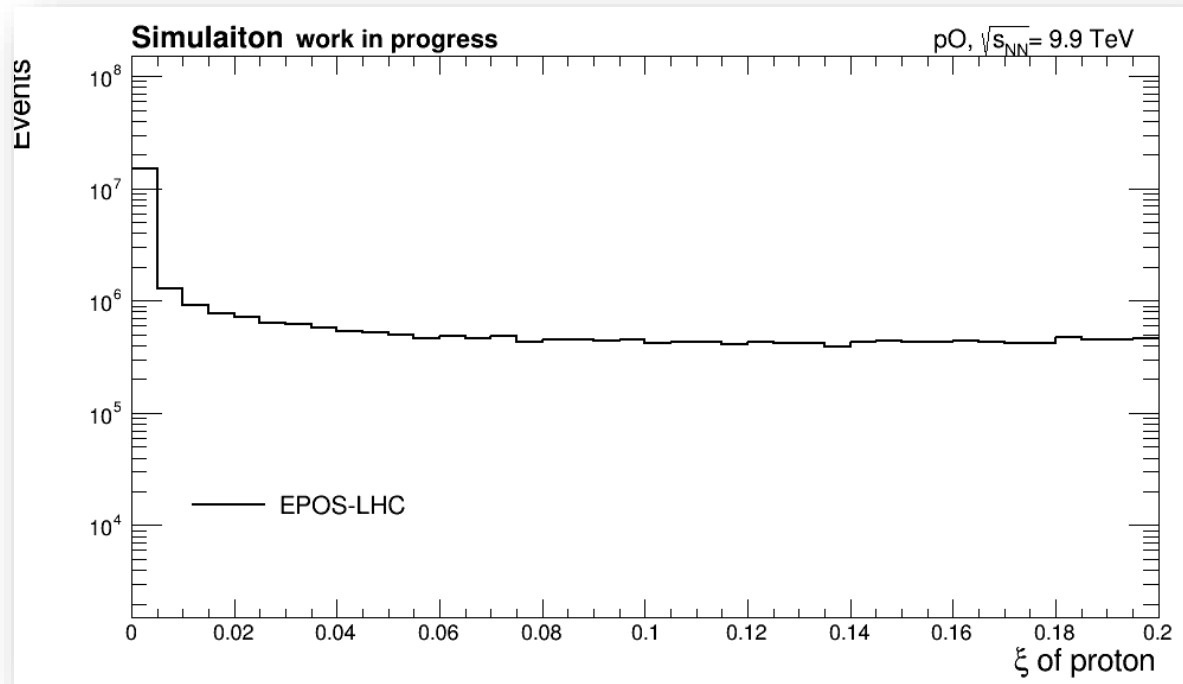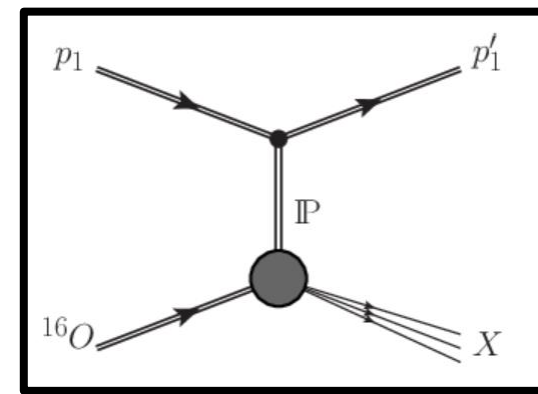$$\delta y(z) = y_D(\xi) + v_y(\xi)y^* + L_y(\xi)\theta_y^*$$
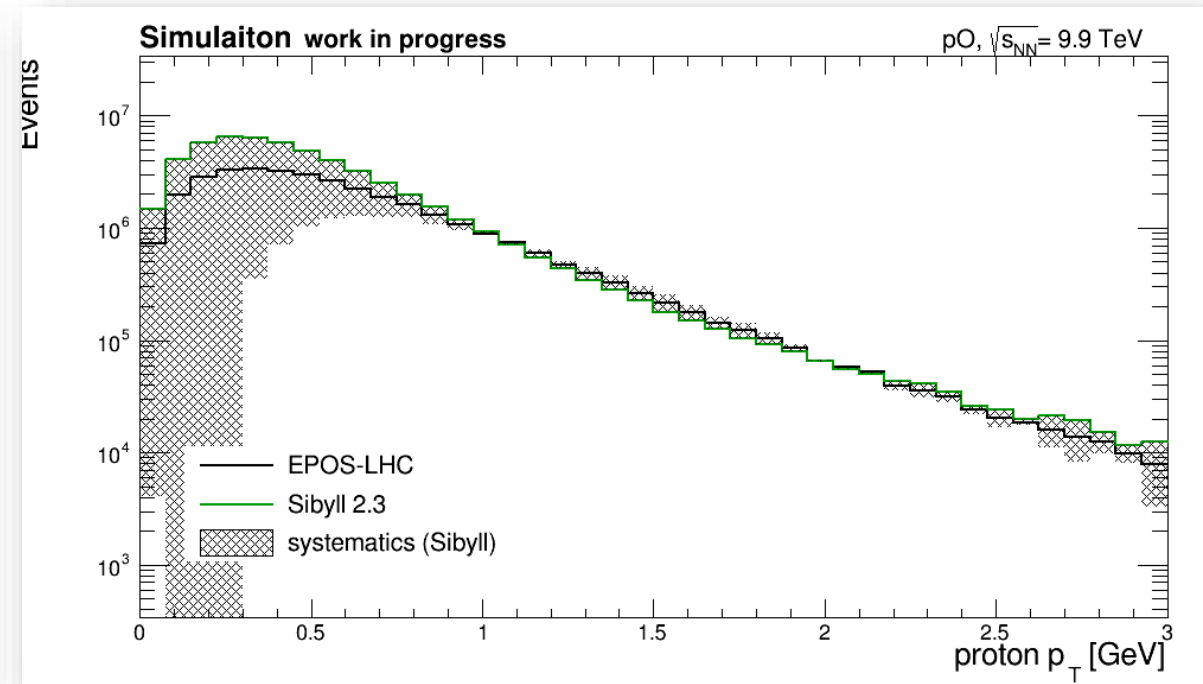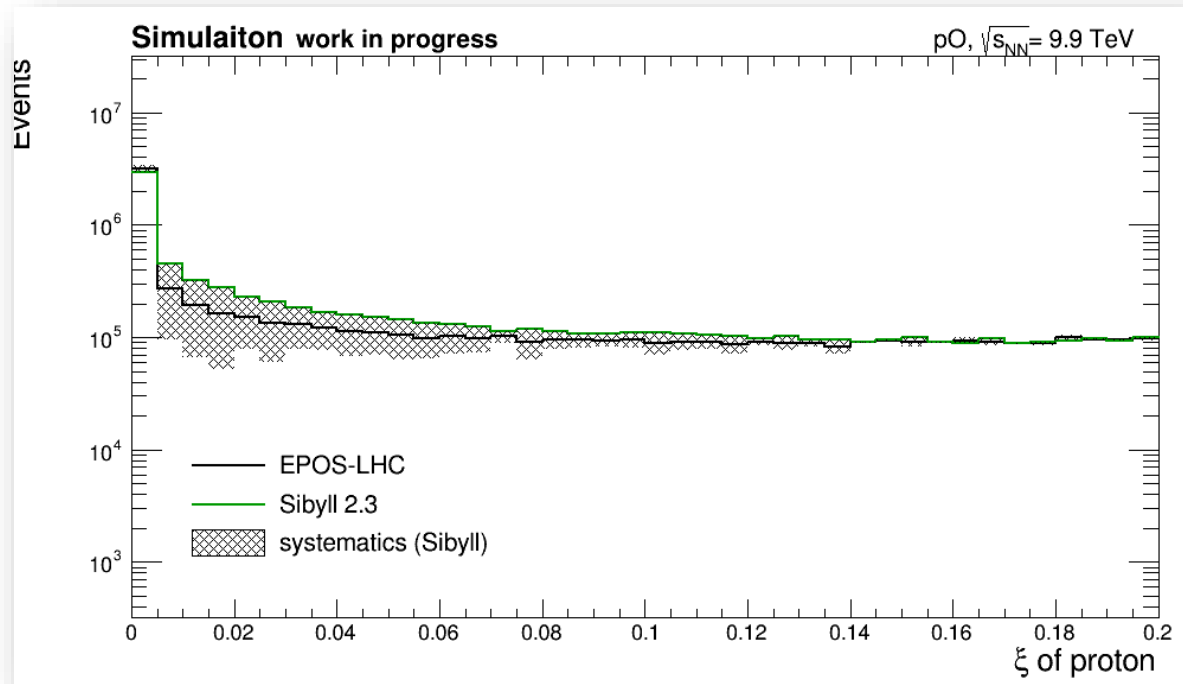

$z\sim200$

IP5 as an example

Proton Kinematics

- About ~20% of p-O interaction are diffractive scattering of protons

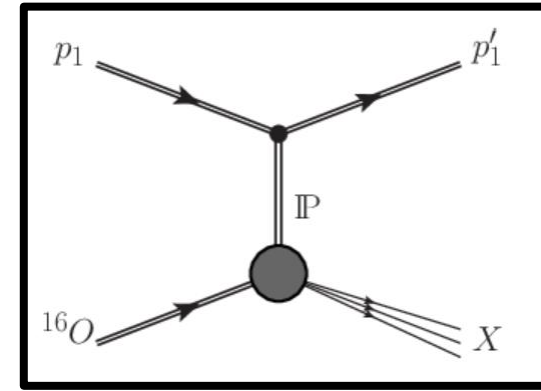- In 2-4% of all events proton momentum is within 2.5% < ξ < 15%

Proton Kinematics

- About ~20% of p-O interaction are diffractive scattering of protons

- In 2-4% of all events proton momentum is within 2.5% < ξ < 15%

- Comparison between EPOS-LHC and Sibyll2.3 – some difference between the generators

Diffraction in p-O runs

- Events with diffractive proton are characterized with presence of large rapidity gaps (LRGs)

- This component are weakly constrained in the current models

CMS-PAS-HIN-18-019

Diffraction in p-O runs

- Events with diffractive proton are characterized with presence of large rapidity gaps (LRGs)

- This component are weakly constrained in the current models

- Using the RG, some diffractive events escape detection

CMS-PAS-HIN-18-019

GAP = PF > 1 GeV

Diffraction in p-O runs

- Events with diffractive proton are characterized with presence of large rapidity gaps (LRGs)

- This component are weakly constrained in the current models

- Using the RG, some diffractive events escape detection, but can be recovered using proton tag
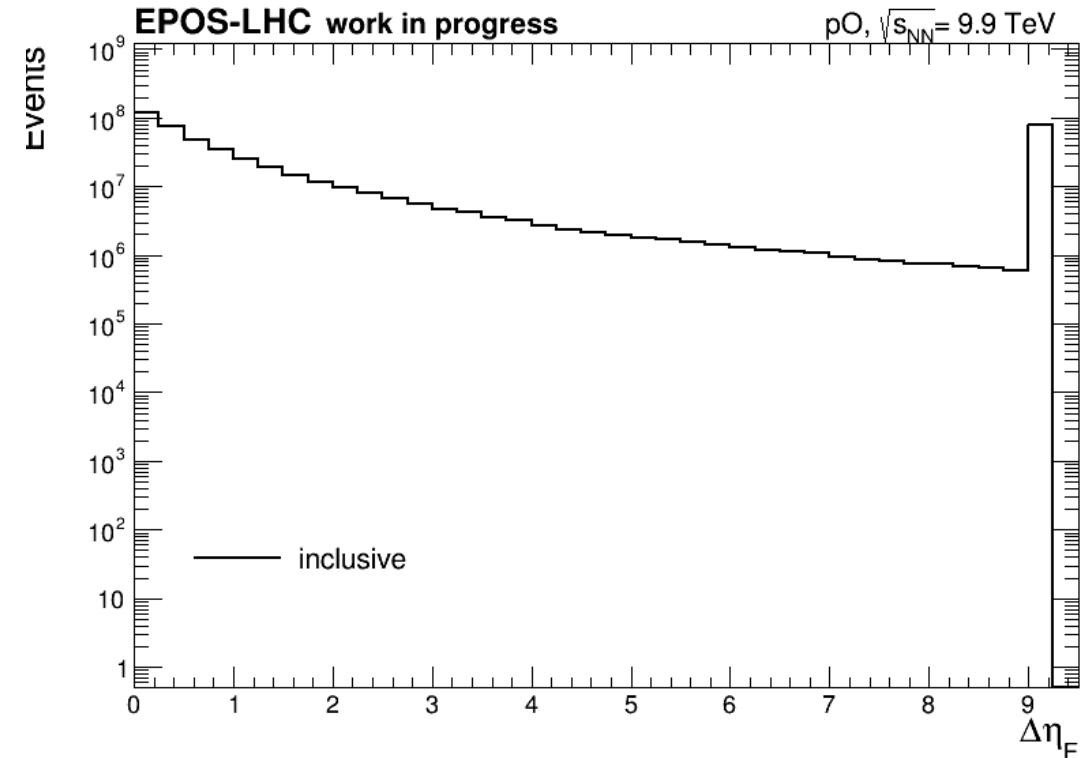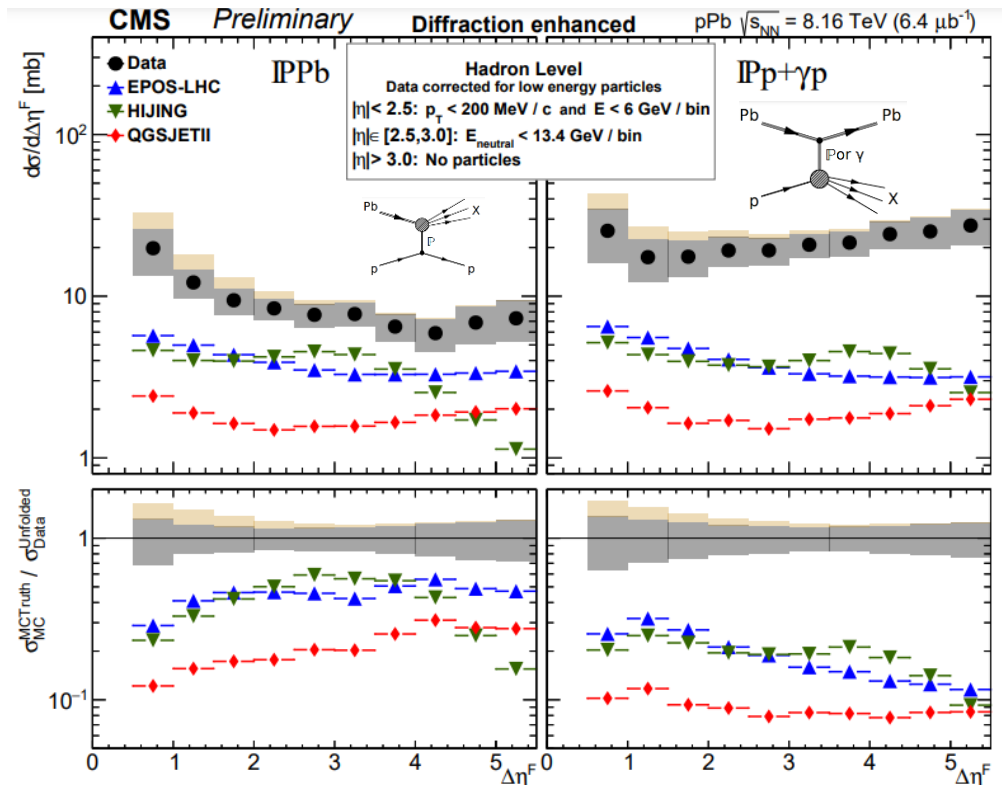
GAP = PF > 1 GeV
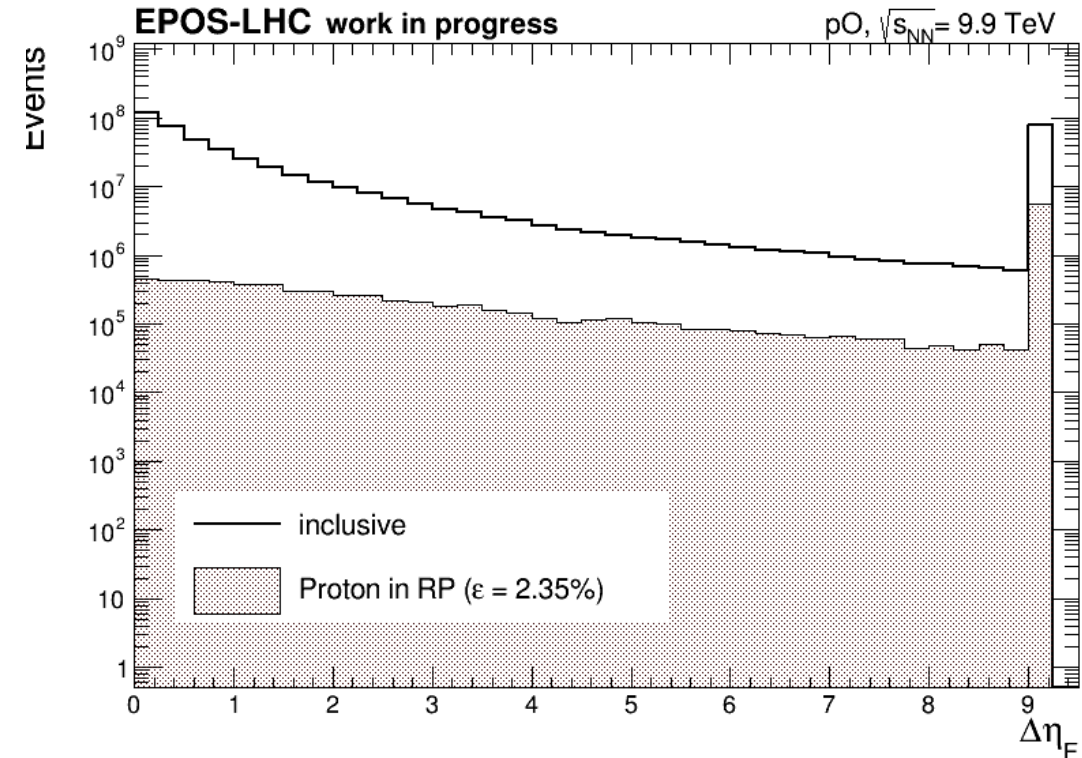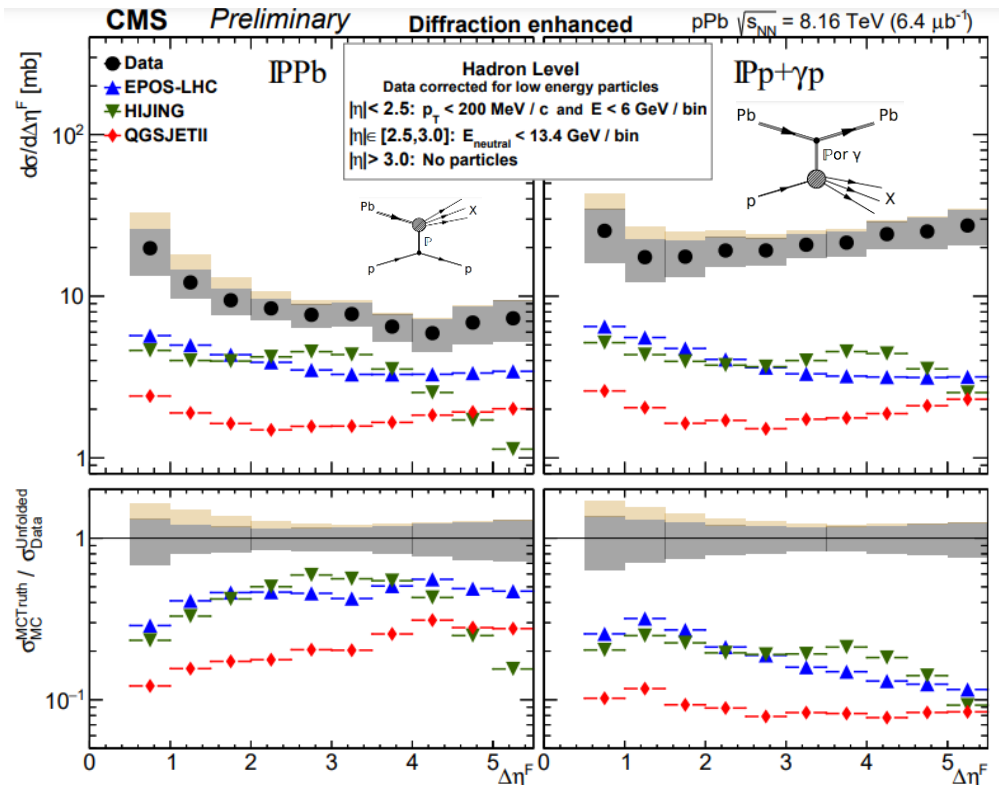
Diffraction in p-O runs

- Events with diffractive proton are characterized with presence of large rapidity gaps (LRGs)

- This component are weakly constrained in the current models

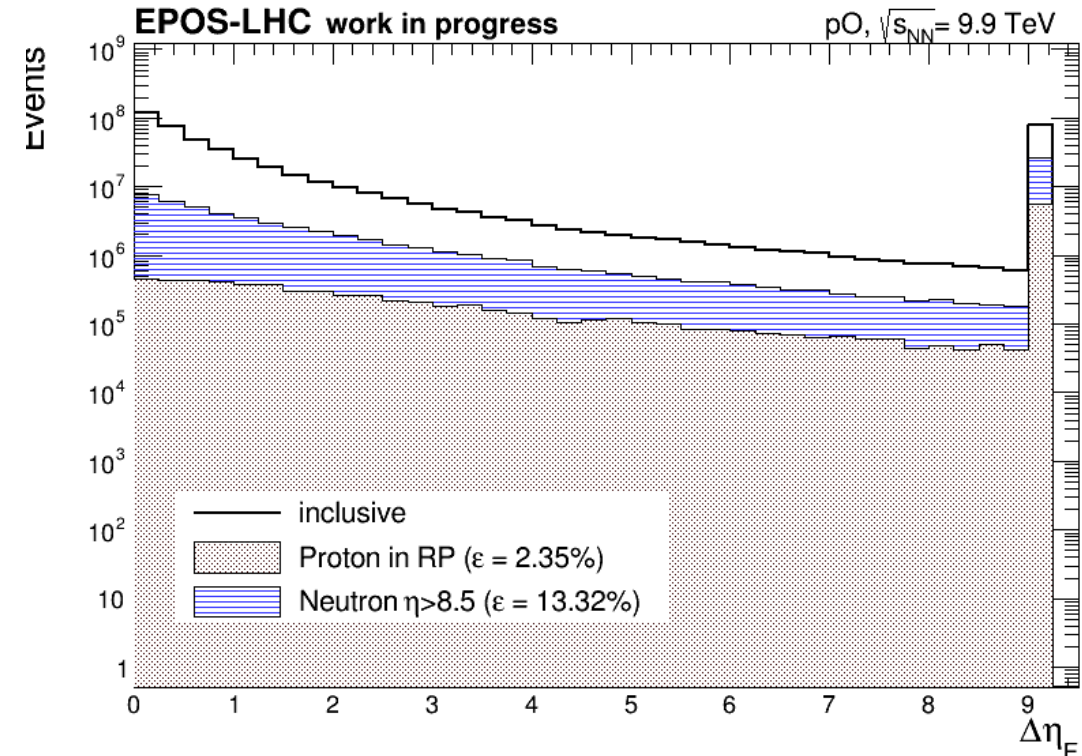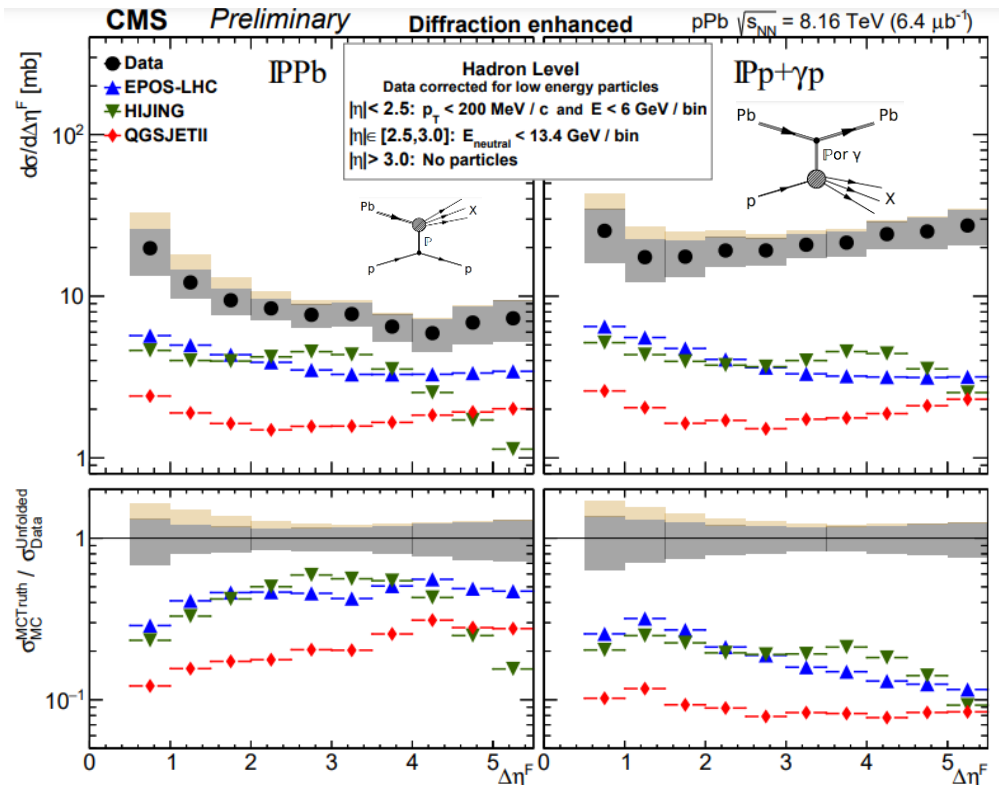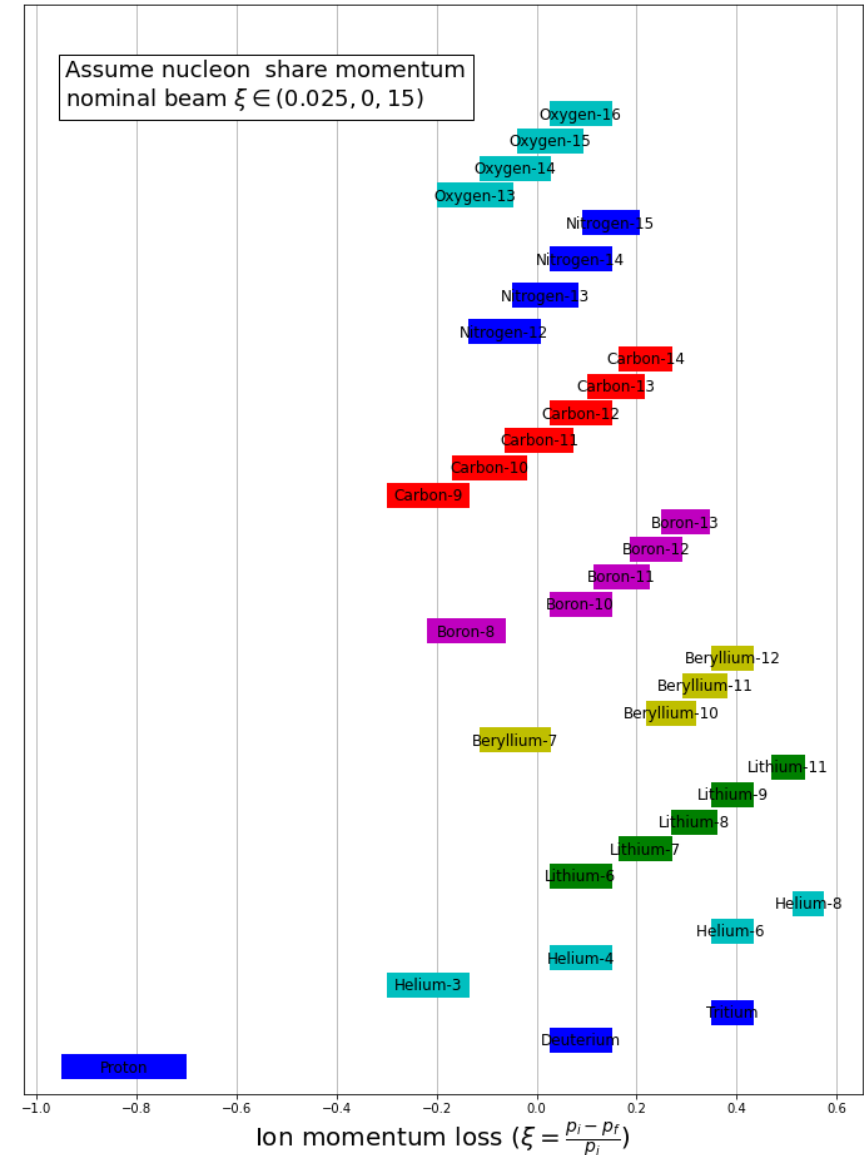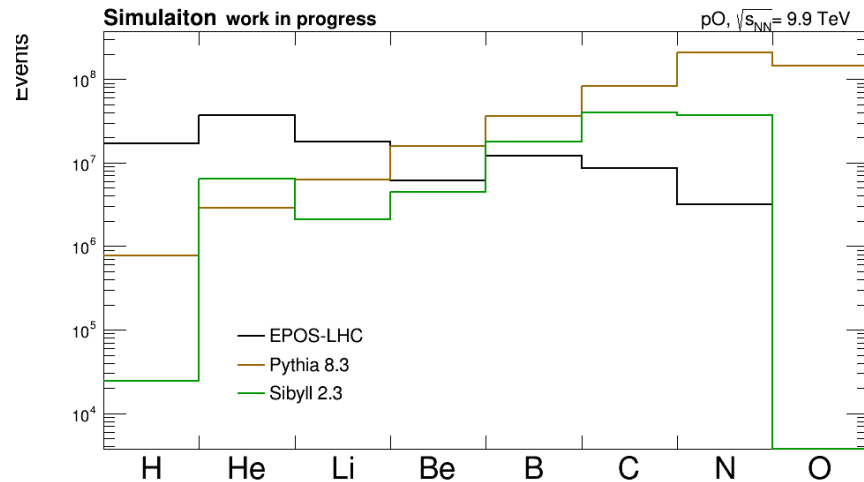- Using the RG, some diffractive events escape detection, but can be recovered using p/n tag

CMS-PAS-HIN-18-019

GAP = PF > 1 GeV

Can we tag ions?

- On the ion side, oxygen ions will disintegrate, protons and neutrons will carry half of the beam momentum and ion remnants can form various isotopes.

- While neutrons can be measured with ZDC, protons have very low momentum to reach the RP.

- Yet, some lighter ions with different kinematics can reach the RP

- Will we see some of them as bumps in the ξ spectra?

Assume nucleon share momentum
nominal beam ξ ∈ (0.025, 0, 15)

Oxygen-16
Oxygen-15
Oxygen-14
Oxygen-13
Nitrogen-15
Nitrogen-14
Nitrogen-13
Nitrogen-12
Carbon-14
Carbon-13
Carbon-12
Carbon-11
Carbon-10
Carbon-9
Boron-13
Boron-12
Boron-11
Boron-10
Boron-8
Beryllium-12
Beryllium-11
Beryllium-10
Beryllium-7
Lithium-11
Lithium-9
Lithium-8
Lithium-7
Lithium-6
Helium-8
Helium-6
Helium-4
Helium-3
Tritium
Deuterium
Proton

Ion momentum loss ($\xi = \frac{p_i - p_f}{p_i}$)

Simulaiton work in progress   pO, $\sqrt{s_{NN}}$ = 9.9 TeV

Events

10^8

10^7

10^6

10^5

10^4

— EPOS-LHC
— Pythia 8.3
— Sibyll 2.3

H   He   Li   Be   B   C   N   O

Summary

Proton tagging

- There are no plans to use proton tagging at the LHC in p-O runs (AFAIK)

- Proton tagging allows measuring diffractive contribution to the total cross-section

- It covers a complementary phasespace to the standard pO program, which can motivate PPS / APF to consider participating in these runs

Ion tagging (?)

- Forward spectrometers can be sensitive to ions within the kinematic region

- Can a combined measurement of forward spectrometer + ZCD shade light on ion disintegration?

- More realistic modeling of Oxygen remnants using the DPMJET is still ongoing

Backup

M. Pitt @ LHC Forward Physics meeting