Prospect studies for Proton Oxygen Collisions at ATLAS and LHCf.

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Presentation Overview

1. ATLAS p-O run
2. Hadronic Models/soft QCD
3. ATLAS forward physics detectors
4. study on MC Event Generators
5. Beam optics studies for pO

ATLAS p-O run

- during Run 3 special p-O run at LHC
- in previous p-p run $\sqrt{s} = 13 TeV$
  $\rightarrow$ energies in rest frame of up to 10^{17} eV.
- background of ultra peripherical collisions is lower than in p-Pb collissions
- high hit multiplicities on the oxygen remnant side

Hadronic Models/soft QCD

- in the region of low momentum transfer perturbative approaches don't work
- phenomenological approaches, based on Regge Theory are needed to describe the initial proton nucleus collision
- particles scatter by exchanging virtual pomeron
- the different models vary strongly in their predictions

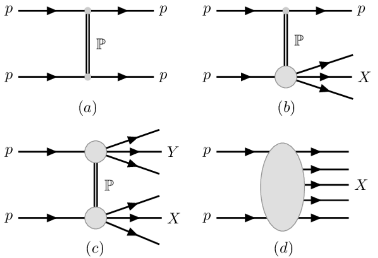


Figure: pomeron exchange: (a) elastic , (b) single diffraction, (c) double diffraction and (d) non-diffraction.

forward detectors

- aim: how to detect very very forward particles?
- two different solutions for charged and neutral particles
- roman pots inside the beampipe can detect charged particles (AFP and ALFA)
- neutral particle detectors are positioned on the Y intersection of the beampipes (ZDC and LHCf) (η ¿ 8.4)

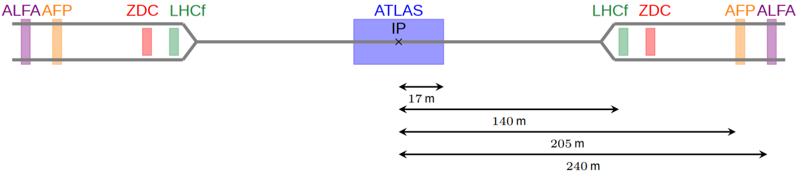


Figure: Atlas forward detectors

study on MC Event Generators

- studied 6 different event generators
- EPOSLHC, DPMJET, PYTHIA, QGSJET, QGSJETII and SIBYLL
- sampleset of 100000 events for each generator
- proton beam of 6.8 TeV and oxygen beam of 3.4 TeV per nucleon
- -η oxygen remnant side; η proton remnant side

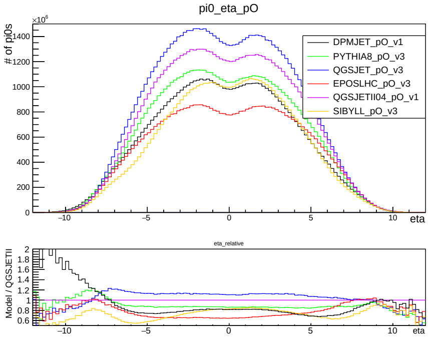


Figure: π^0 full η spectrum

study on MC Event Generators

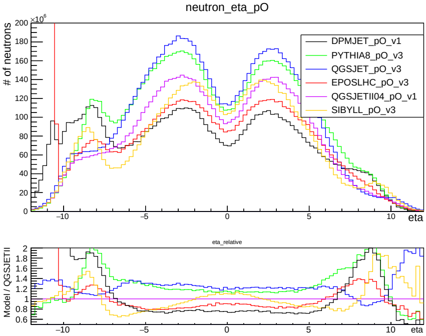


Figure: neutron full η spectrum

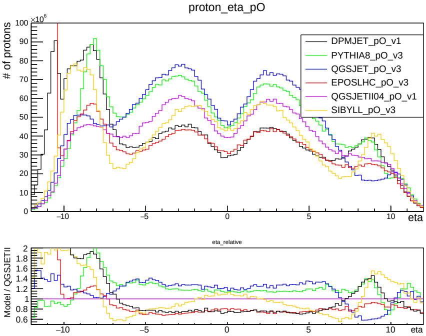


Figure: proton full η spectrum

- huge discrepancies in the forward spectra of protons and neutrons, big difference in central region
- EPOSLHC peak on oxygen remnant side goes up to 700×10^6

study on MC Event Generators

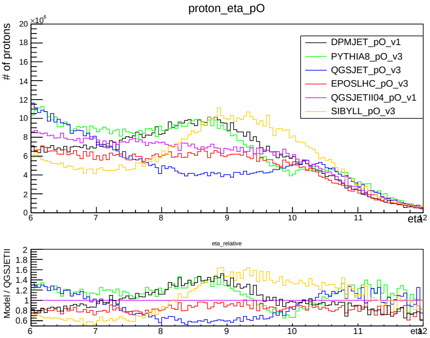


Figure: protons on the proton remnant side

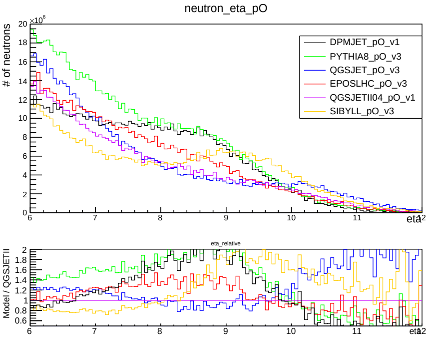


Figure: neutrons on the proton remnant side

- very different modeling of the expected proton bumps at the proton remnant side
- not every generator expects a bump of neutrons at proton remnant side

study on MC Event Generators

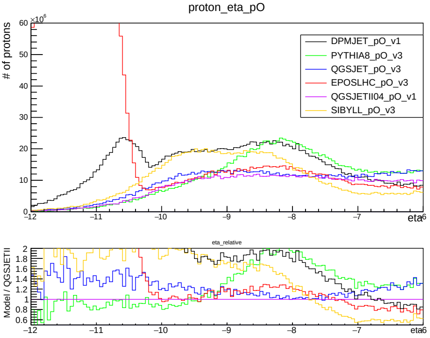


Figure: neutrons on the oxygen remnant side

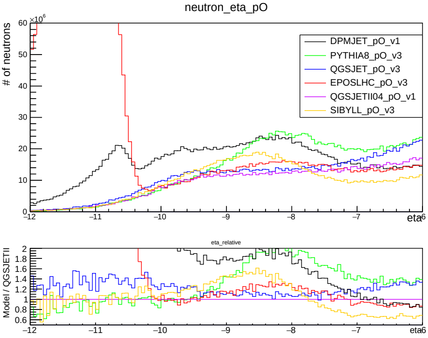


Figure: protons on the oxygen remnant side

- huge EPOSLHC peak again
- very different modeling of the peak at the oxygen remnant side, QGSJET and QGSJETII have almost no peak

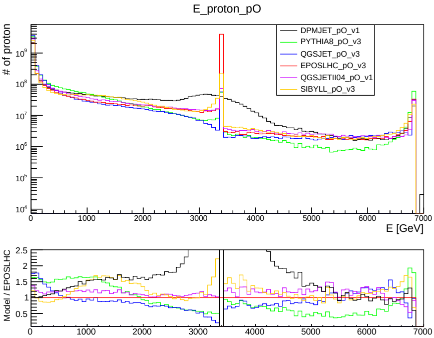


Figure: proton energy spectrum

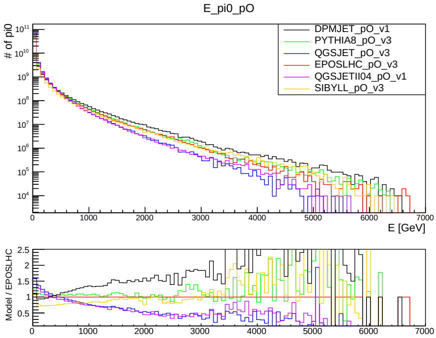


Figure: π^0 energy spectrum

- very different modeling of protons at peaks of 6.8 TeV (proton beam energy) and 3.4 TeV (oxygen nucleon beam energy), DPMJET models peak as a bump!
- very different modeling of high energy π^0

Beam optics studies for pO

- goal: motivate joint data taking between the four forward detectors AFP, ALFA, ZDC and LHCf.
- simulate the propagation of protons along the beampipe, with given beam parameters
- Yusuf has done p-p beam optics studies
- can use the same setup for p-oxygen collisions
- beam parameters can be adjusted to optimize the combined acceptance of the detectors

Figure: Beampipe with collimators and dipols

Beam optics studies for pO

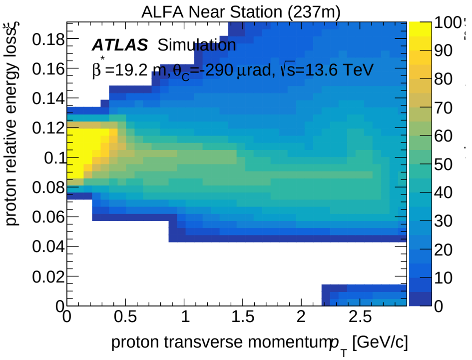


Figure: Acceptance for ALFA near station

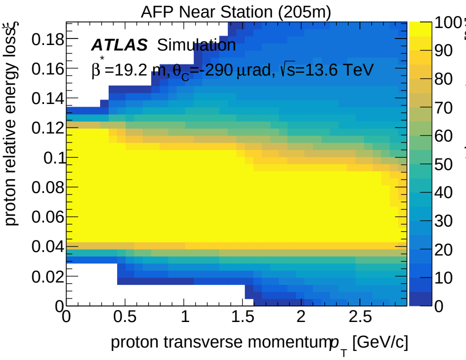


Figure: Acceptance for AFP near station

- Acceptance ($\frac{proton_{reached}}{protons}$) with fully open collimators
- proton relative energy loss $\xi = \frac{E_{beam} - E_{proton}}{E_{beam}}$

Beam optics studies for pO

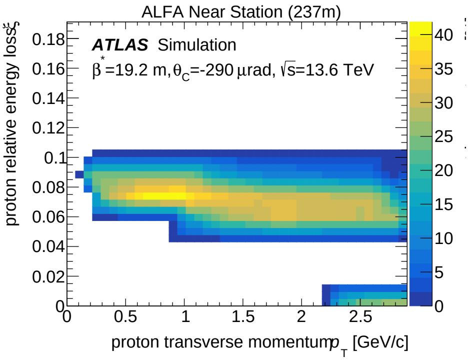


Figure: Acceptance for ALFA near station

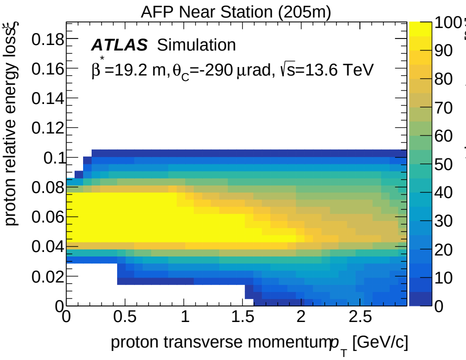


Figure: Acceptance for AFP near station

- Acceptance ($\frac{proton_{reached}}{protons}$) for half open collimators
- proton relative energy loss $\xi = \frac{E_{beam} - E_{proton}}{E_{beam}}$

conclusion

- LHC beam parameters are not yet set
  $\rightarrow$ i will test different parameters to get maximum acceptance for ALFA and AFP
- goal is to get combined data taking between detectors (convince AFP/ALFA)
- planned talk this march at DPG Dresden

backup

backup

Beam optics studies for pO

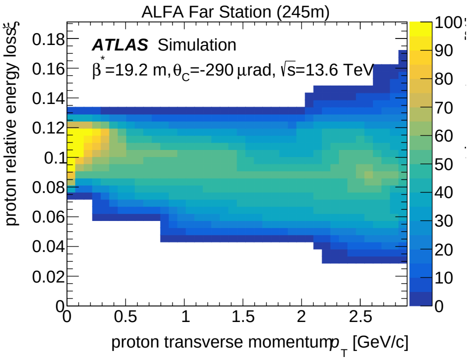


Figure: Acceptance for ALFA far station

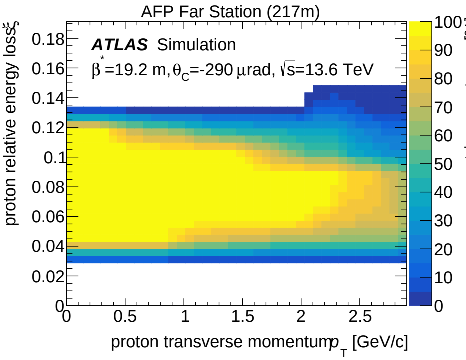


Figure: Acceptance for AFP far station

- Acceptance ($\frac{proton_{reached}}{protons}$)for the 75 % open collimator
- proton relative energy loss $\xi = \frac{E_{beam} - E_{proton}}{E_{beam}}$

Beam optics studies for pO

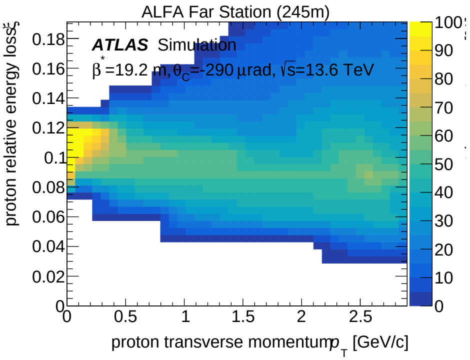


Figure: Acceptance for ALFA far station

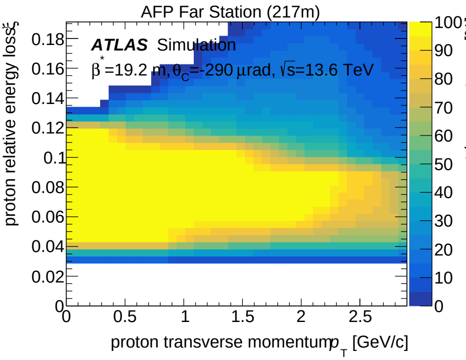


Figure: Acceptance for AFP far station

- Acceptance ($\frac{proton_{reached}}{protons}$) with fully open collimators
- proton relative energy loss $\xi = \frac{E_{beam} - E_{proton}}{E_{beam}}$

Beam optics studies for pO

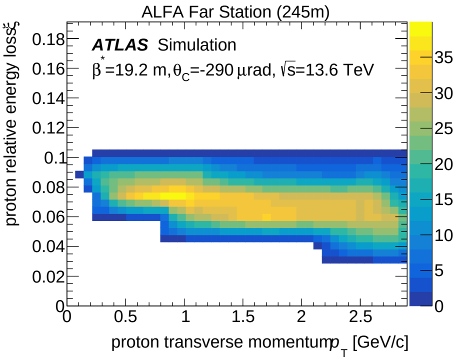


Figure: Acceptance for ALFA far station

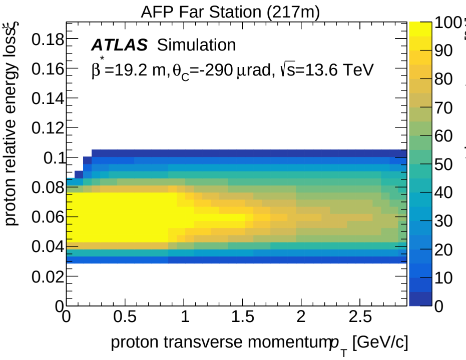


Figure: Acceptance for AFP far station

- Acceptance ($\frac{proton_{reached}}{protons}$) for half open collimators
- proton relative energy loss $\xi = \frac{E_{beam} - E_{proton}}{E_{beam}}$

energy distribution

- energy and flux span over multiple orders of magnitude
- knees at 3×10^{15} eV and 4×10^{17} eV ankle at 4×10^{18} eV
- origin of these distinct features still room for speculation
- suppression at high energies, saturation at lower energies
- in between approximately a power law $\frac{dN}{dE} \sim E^{\gamma}$
- sources solar, supernovae extragalactic and galactic

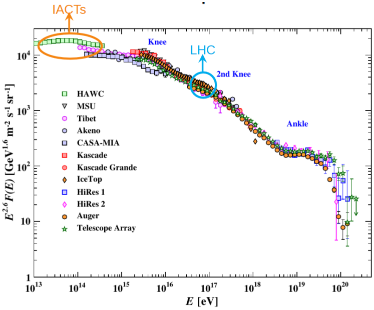


Figure: energy distribution of cosmic rays

extended air showers (EAS)

- high energy cosmic rays collide with atmospheric nuclei
- cascade of particles (EAS)
- initial p-atom collision produces pions, kaons and baryons
  $\rightarrow$ these processes rely on phenomenological studies, which vary highly in the predictions
  $\rightarrow$ collider data is needed to improve large uncertainties in astroparticle data analysis!

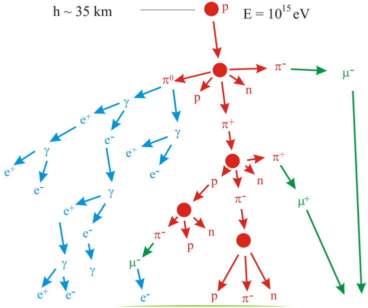


Figure: EAS induced by a proton

Introduction

- high energy particles from outside earths atmosphere
- discovery more than 100 years ago, 1912 by Victor Hess
- still many open questions, like source, propagation composition and energy
- contains 99% nuclei, 87% protons

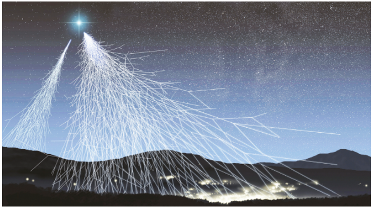


Figure: visualized cosmic ray shower in the Earth's athmosphere

a few 2D plots

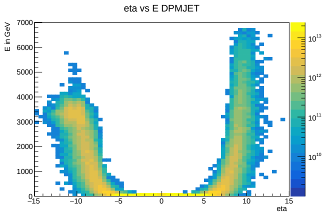
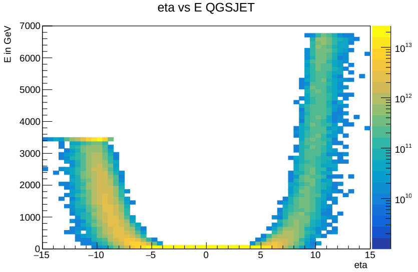


Figure: neutron energy/η distribution



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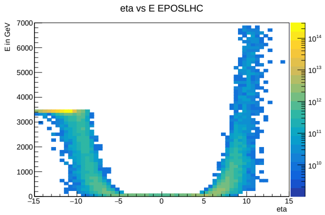
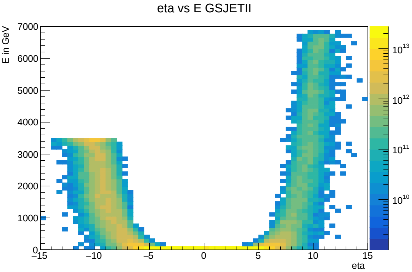


Figure: neutron energy/η distribution

- DPMJET shows no sharp peak at oxygen remnant side as expected
- EPOSLHC peak about one order of magnitude bigger than other for generators

a few 2D plots



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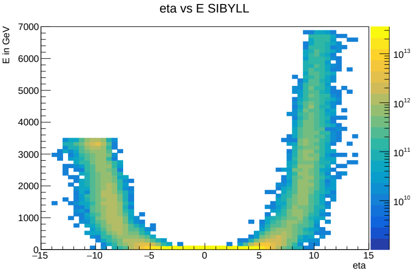


Figure: neutron energy/η distribution

- both look as expected no huge differences

correlation plots

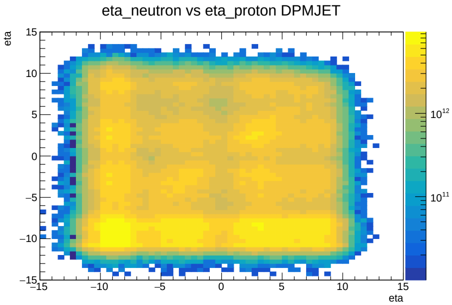


Figure: neutron η proton η correlation for DPMJET

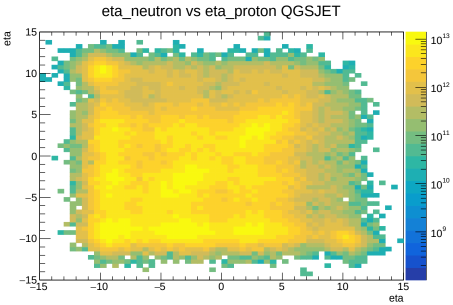


Figure: neutron η proton η correlation for QGSJET

- plotted η neutron against η proton from the same event
- correlation plots are still work in progress
- DPMJET is dominated by protons at the oxygen remnant side
- QGSJET shows many particles at the oxygen remnant side and distinct peaks at the proton side

correlation plots

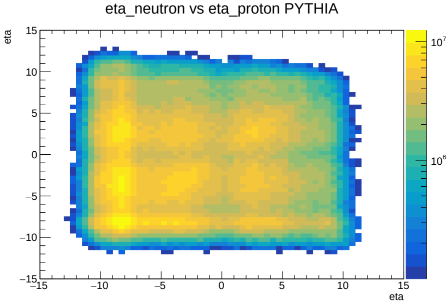


Figure: neutron/proton η correlation for PYTHIA

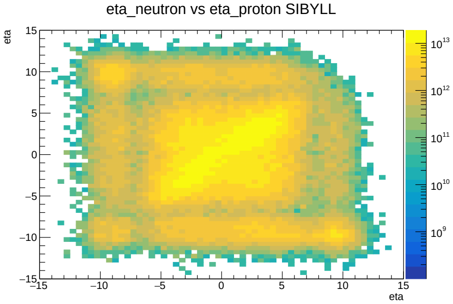


Figure: neutron/proton η correlation for SIBYLL

- for PYTHIA, neutrons at oxygen remnant side dominate
- SIBYLL shows many particles in the central region, interesting peak for neutrons at the proton remnant side

correlation plots

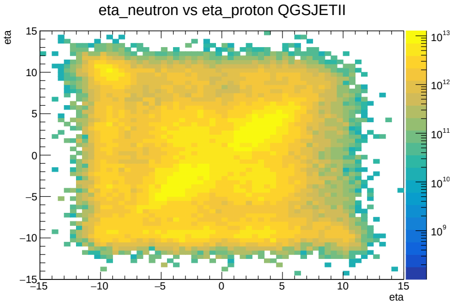


Figure: neutron/proton η correlation for QGSJETII

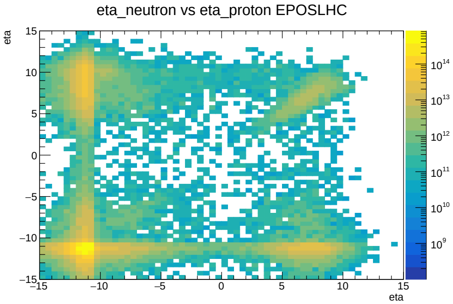


Figure: neutron η proton η correlation for EPOSLHC

- EPOSLHC shows no proton/neutron events at the central region and huge peak for both particle at the oxgen remnant side
- QGSJETII shows strong central region

composition

- 99.8% are charged particles
- 99% of them are nuclei, rest electrons and positrons
- 87% are protons 12% helium and 1% heavier nuclei
- matter composition varies highly over the energy spectrum

- direct measurements like weather balloons/satellites or experiments on the ISS
- indirect measurements using cherenkov light or fluoresence light
- both come from extended air showers (EAS)

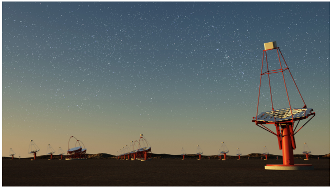


Figure: concept art for the cherenkov telescope array

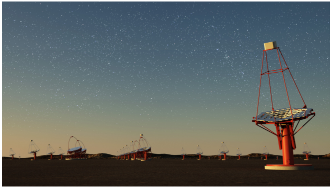
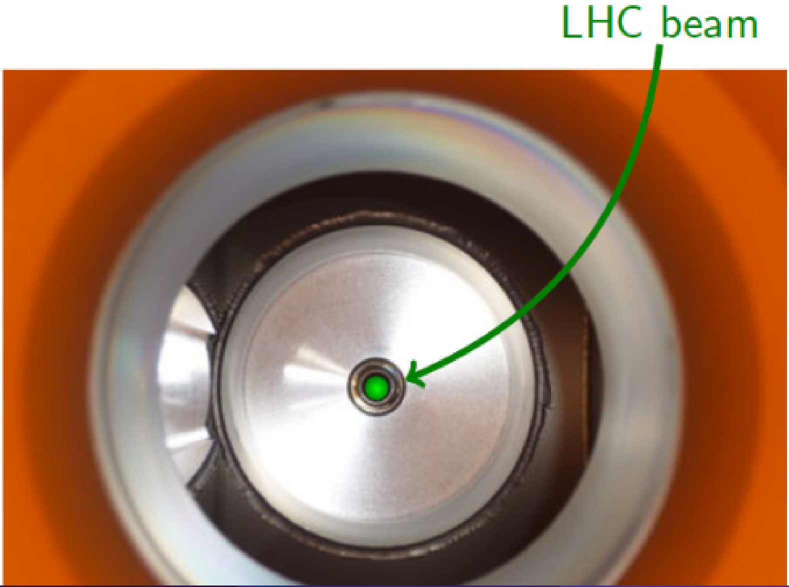


Figure: fluoresence telescope or Victor Hess in his balloon

forward detectors



forward detectors

- what about neutral particles?
- excellent opportunity at atlas Y point. (ZDC and LHCf)

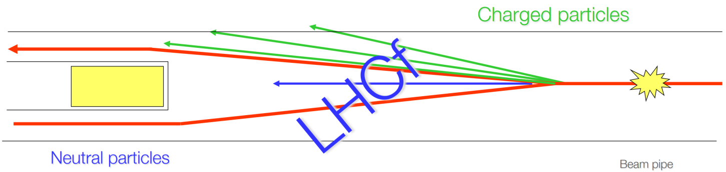
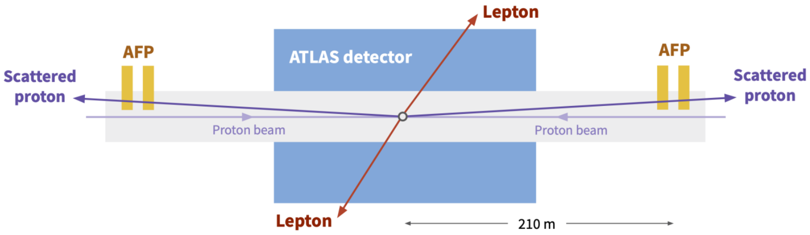


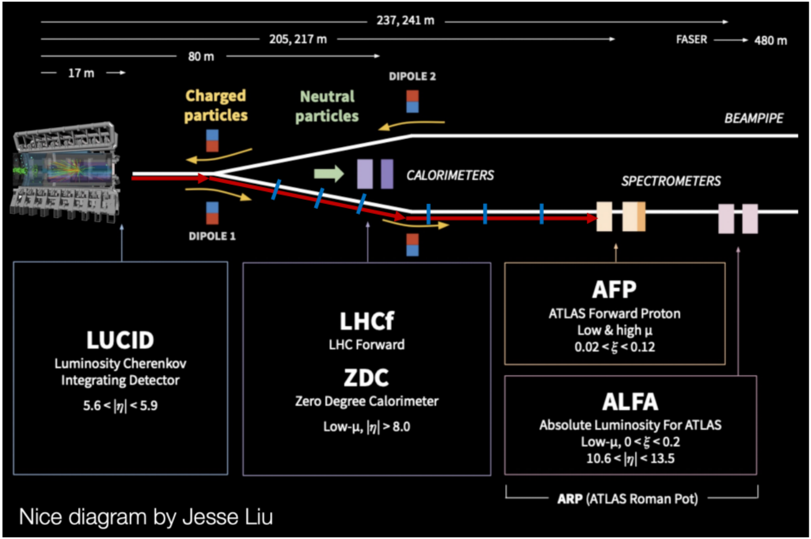
Figure: Atlas forward neutral particle detectors

forward detectors



Figure

Beampipe Layout



Figure