Studies on Combined Data-Taking of LHCf and ATLAS Roman Pots

The Study of the Potential for a Joint-Data Taking Between ATLAS, AFP, ALFA, ZDC and LHCf Detectors

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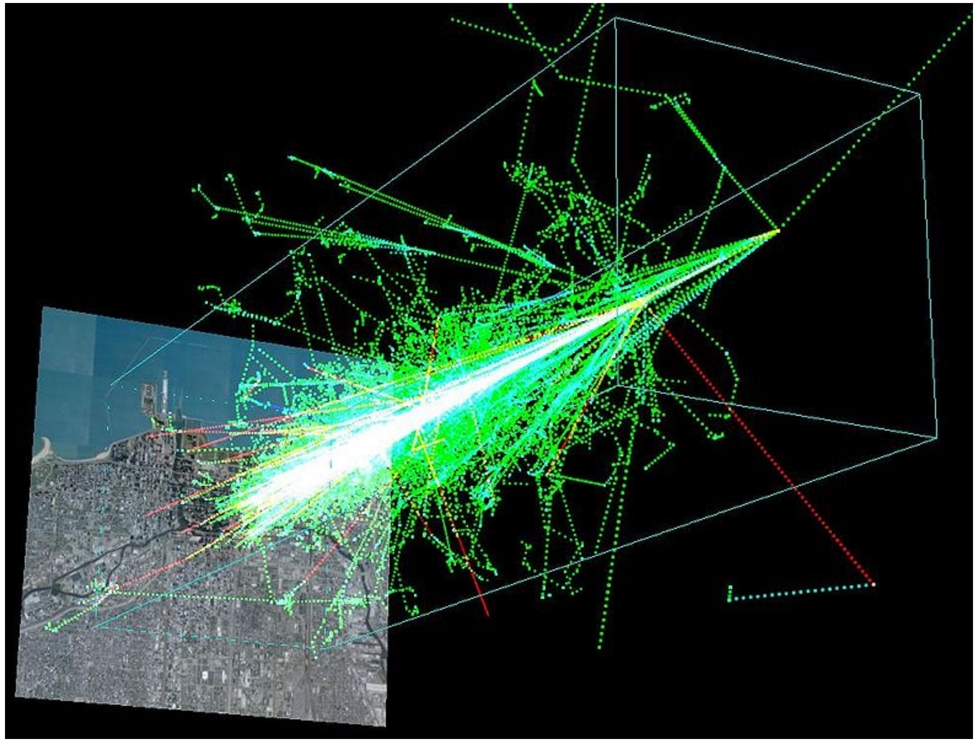
HELMHOLTZ

ATLAS EXPERIMENT

DESY.

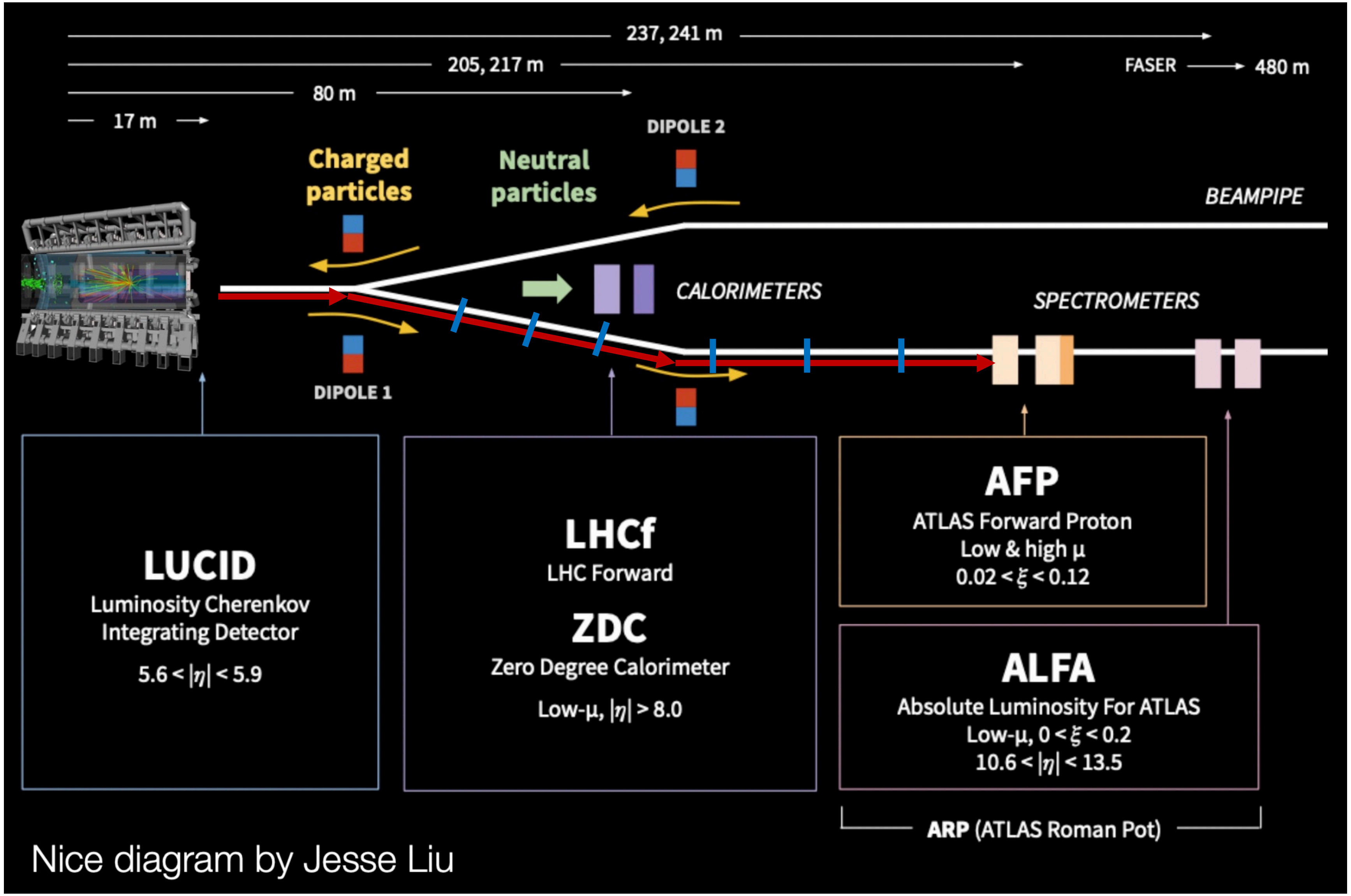
Cosmic Rays and LHC Forward Studies

- Cosmic rays are fully-ionised nuclei with relativistic kinetic energies that arrive at Earth
- Surface level measurements → using the cascades of secondary particles, called extensive air showers (EAS)
- The cascades → mostly soft hadronic interactions → **cannot** be treated by perturbative-QCD
- Soft interactions → need simulations to treat → large uncertainties
- Soft interactions → up to **~10%** of total LHC cross-section
- Very forward particles with high energies → the development of air showers
- The forward studies at LHC aim:
  - Producing constraints for air shower simulations
  - Pile-up modelling



A proton with 1 TeV energy hitting the atmosphere 20 km above the surface

ATLAS Forward Detectors



ZDC and LHCf:

-Neutral particle calorimeters

AFP and ALFA:

-Proton detection systems

: protons

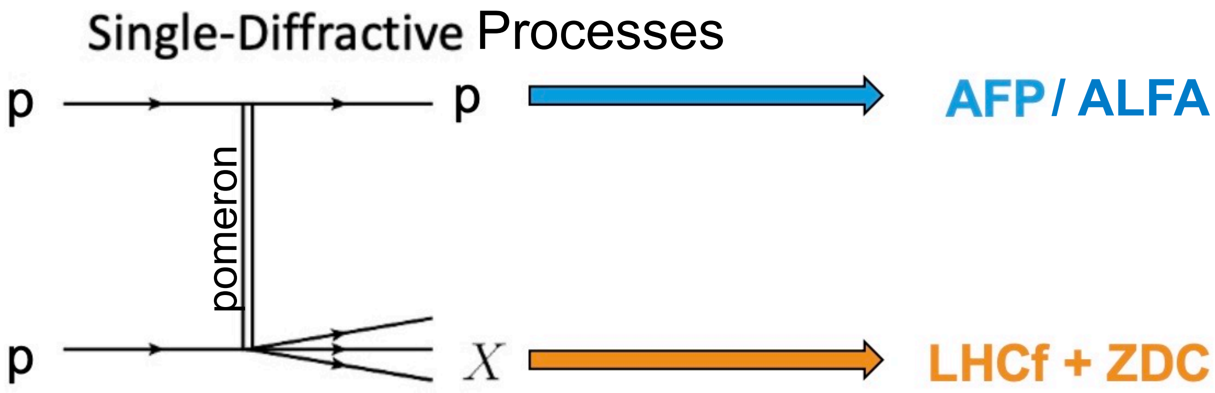
: collimators, dipoles, quadrupoles, kickers etc.

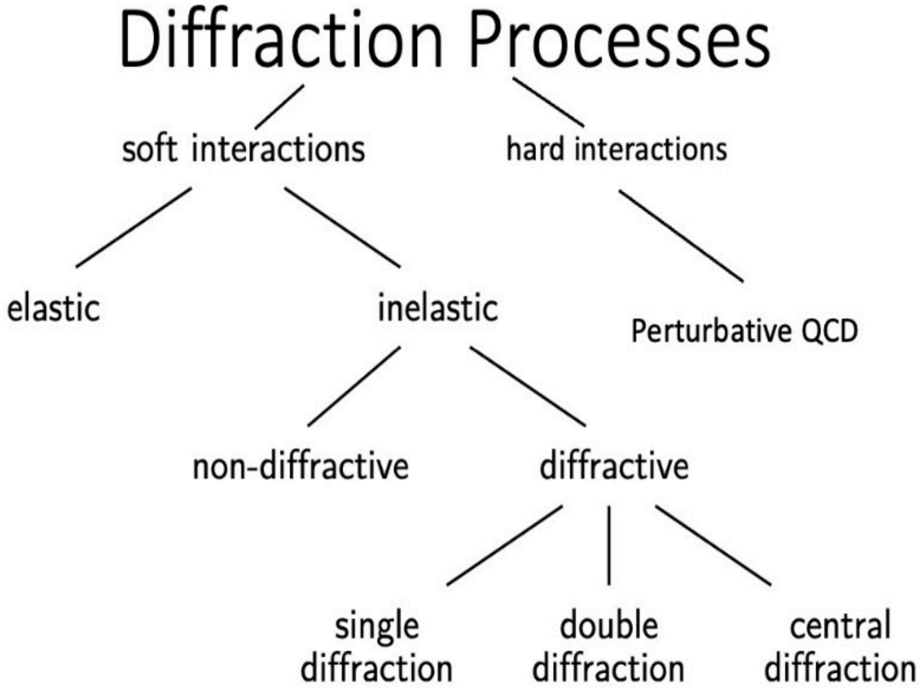
More information on [AFP and detection of diffractive events]

Motivation and Goal

Single diffractive processes

- A common acceptance → ATLAS forward detectors
- Simulated by Pythia(8)
- Diffractive processes → large rapidity gaps (**opposite sides**)





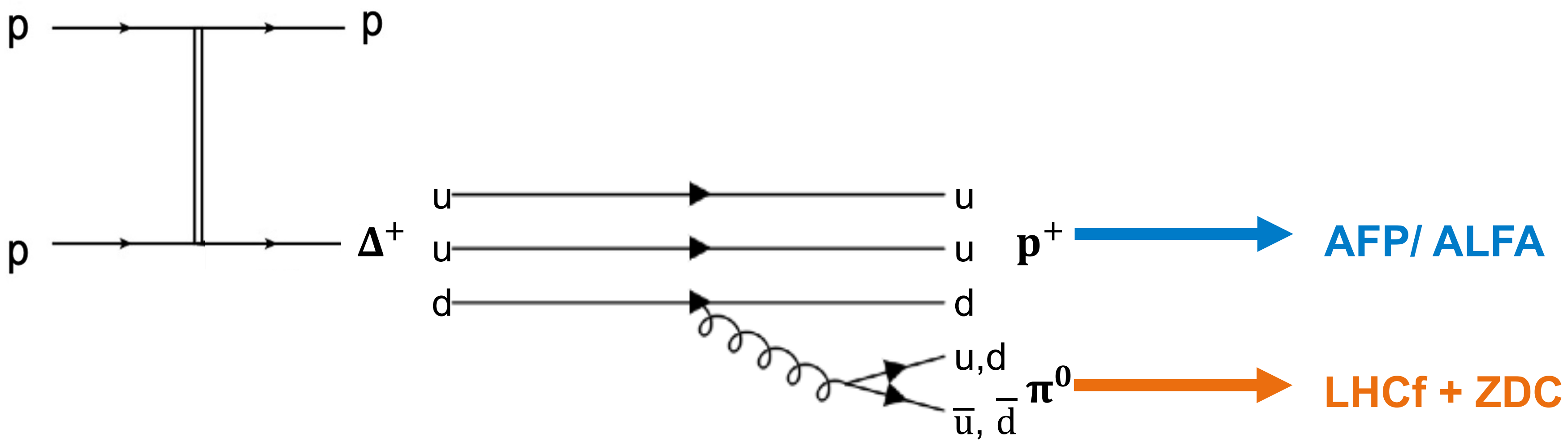
- Before studies with only neutral particle data from LHCf **or** ZDC
  - LHCf + ATLAS central veto : mixture of single diff. and double diff.

- The combination of LHCf and ZDC → improvement in the **energy resolution** of neutral particle detection
- A joint data-taking of AFP+ALFA+LHCf+ZDC→ improvement in the **identification** and **kinematic reconstruction** of SD events
  - identification of SD, and independent measurement of mass by RPs
  - hadronization by LHCf+ZDC

Motivation and Goal

Delta plus decay processes

- p → Δ^+ is a very low-mass diffractive event
  - Have not been studied thoroughly
  - Modelling has not yet developed well enough
- Simulated by Pythia(8)
  - Cross section obtained by Herwig (does not work in Pythia at high center of mass energies)
- p^+ and π^0 → **on the same side**



- A rare event with similar pattern to SD (has **3.27 nb** cross section according to Herwig)
  - Cross section estimates can be improved by a joint data taking
  - Even an upper limit constraint could improve estimation of low-mass diffractive event contribution
- Event differentiation (against SD) using RPs and LHCf/ZDC is high

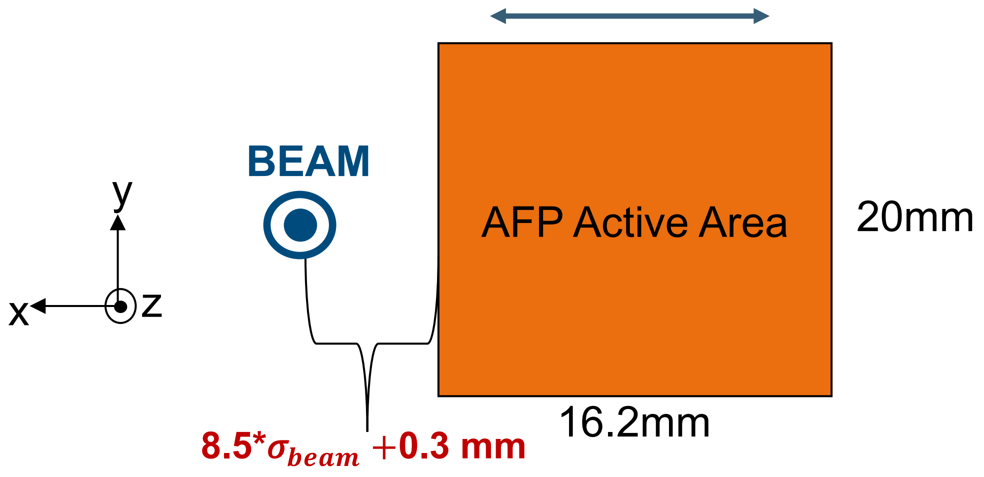
- Similar topology is expected for diffractive bremsstrahlung and pi0-sstrahlung

Acceptance Calculation

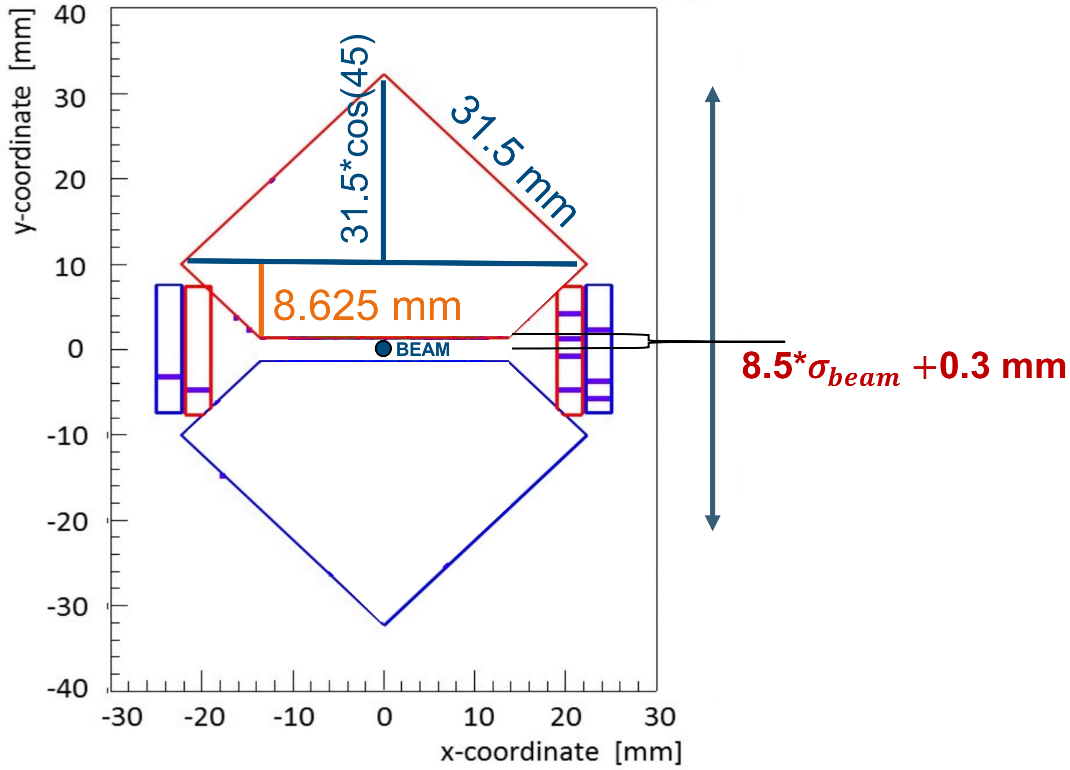
E_{beam} = 6.5 TeV, E_{proton} = Scattered proton

$$acceptance = \frac{\#proton_{reached}}{\#proton_{total}}$$ for the protons sharing the same ξ and pT, where $$\xi = \frac{E_{beam} - E_{proton}}{E_{beam}}$$

AFP Active Area



ALFA Active Area



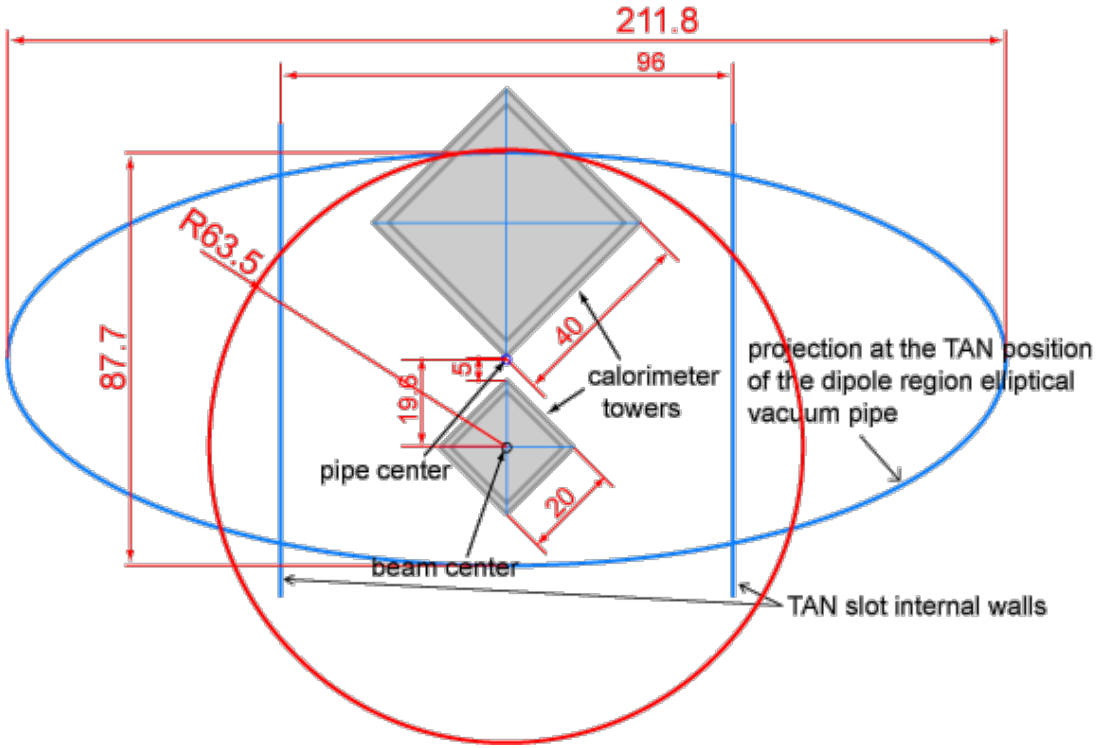
- Further selection on $\#proton_{reached}$ is applied according to beam-detector distance and detector active area

S. Abdel Khalek *et al* 2016 *JINST* **11** P11013

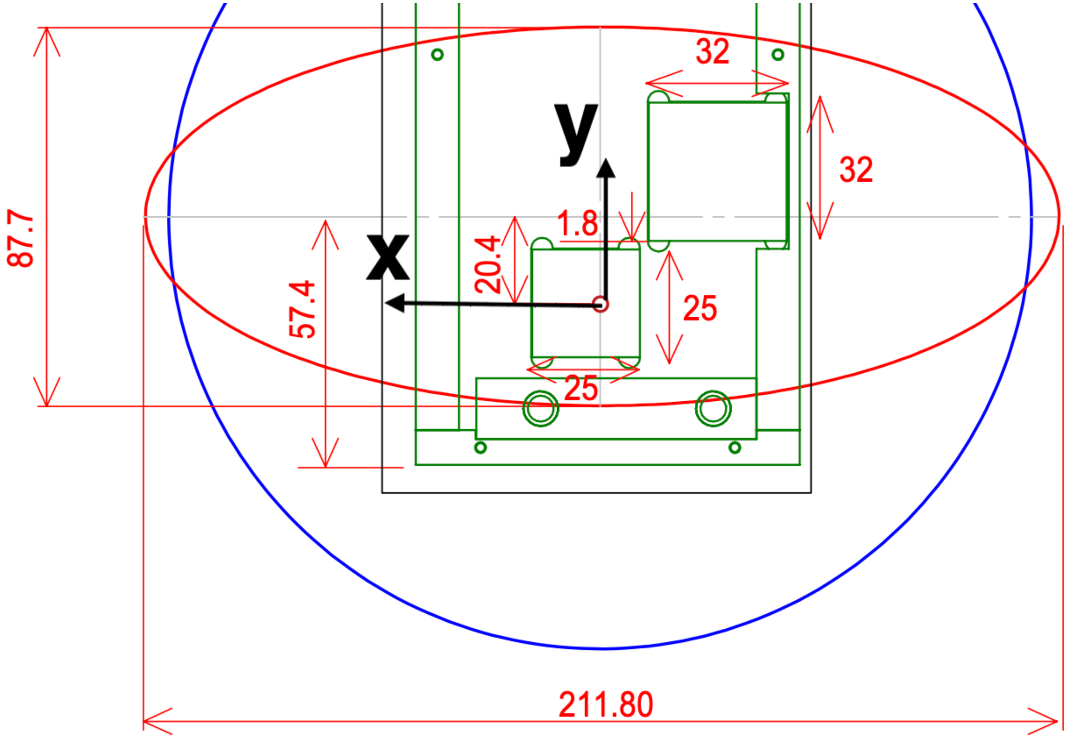
Acceptance Calculation for LHCf

- Reconstructed π^0 acceptance → two γ
  - Both γ need to hit the LHCf active areas
  - E_γ > 200 GeV
- E_n > 200 GeV

LHCf Arm 1



LHCf Arm 2



Acceptance Calculations

$\text{Acceptance}_{MC} = \frac{\#proton_{bin}}{\#proton_{total}} * 100$ → Common Acceptance = acc_{RP}[%] x acc_{MC} [%]

For all plots, binning is exactly the same with RPs data set: E_{loss}: 0 → 0.15, steps: 0.015 (GeV)
Pt : 0 → 3, steps: 0.1 (GeV)

For SD:

$\#proton_{bin}$:

- When there is any signal in **LHCf detector active area** (n or γ)
- Signal must be in the opposite side of the intact proton

$\#proton_{total}$:

- Number of events

For Delta Decay:

$\#proton_{bin}$:

- When there is a pion signal in **LHCf detector active area** (2 γ)
- Signal must be in the same side of the decay proton

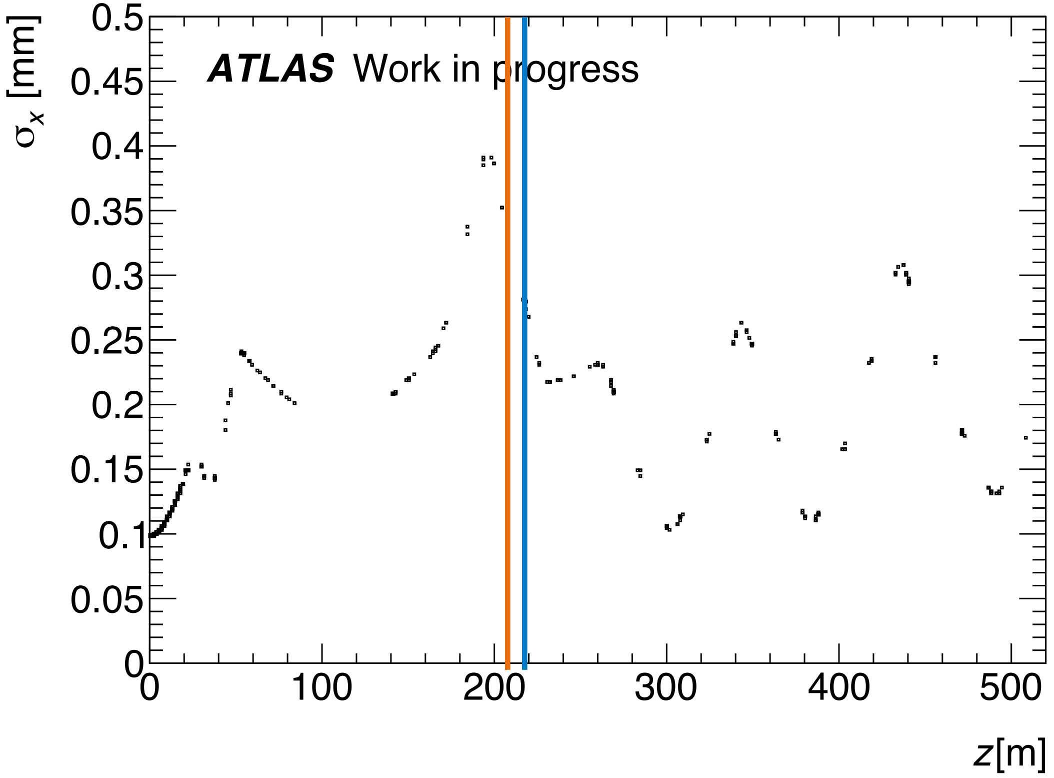
$\#proton_{total}$:

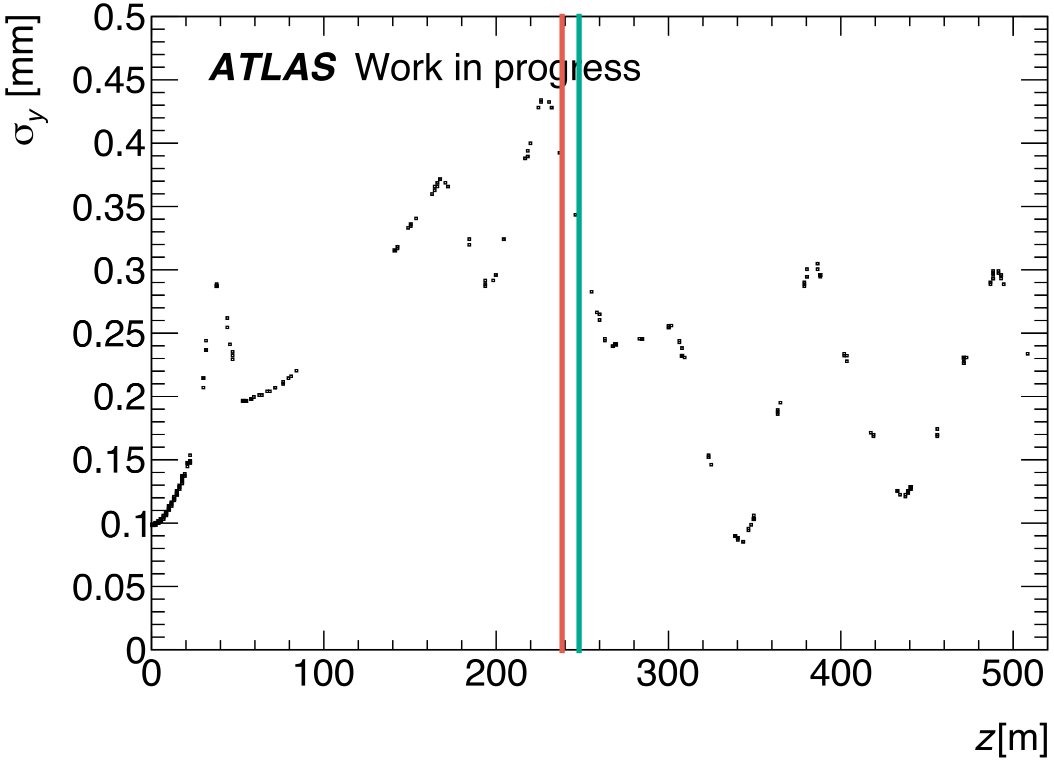
- Total number of protons that are decay products of a Δ^{+}

Beam Width Plots

Beam conditions for special low-μ run for LHCf (in September): "beta* = 19.2 m" and "crossing-angle=-290 µrad"

The x-axis of the plots are in the same order as the protons path followed in the LHC, taking "0" as IP1





: AFP Near Station : σ_x = 0.353 mm

: AFP Far Station : σ_x = 0.282 mm

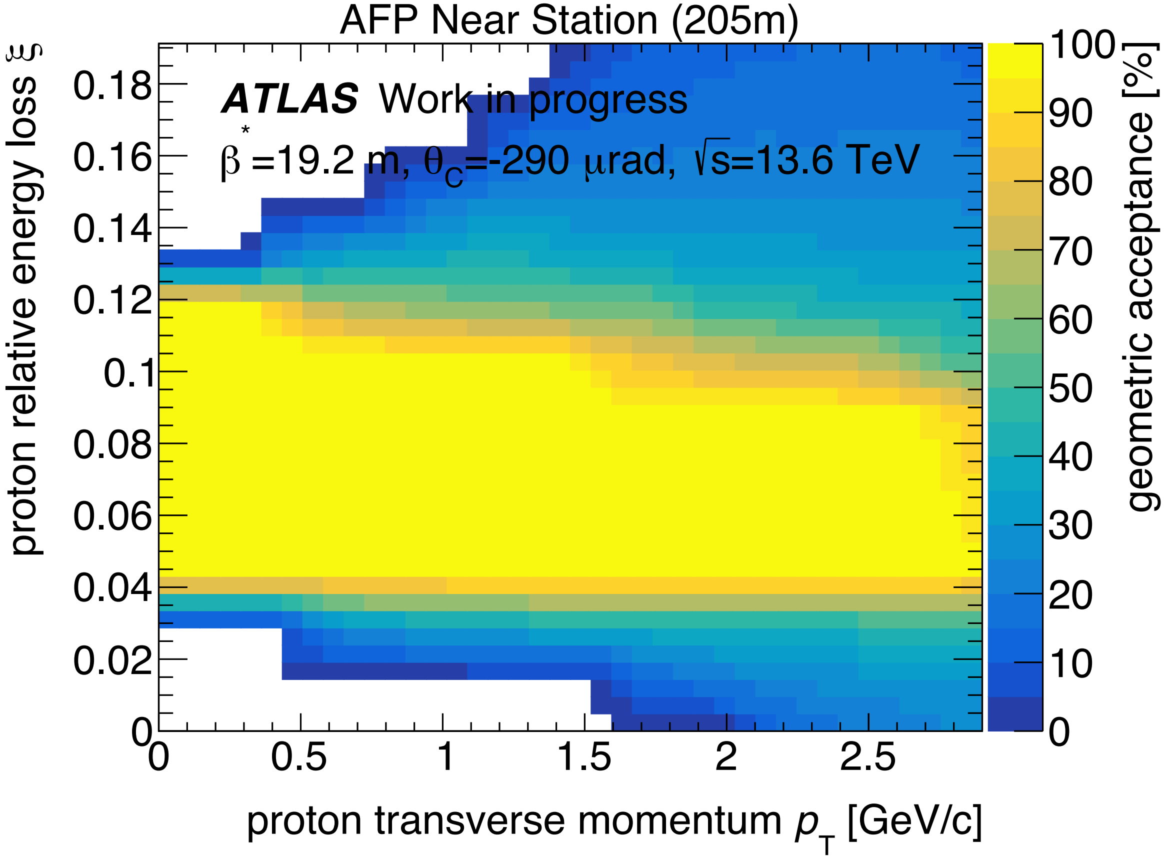
: ALFA Near Station : σ_y = 0.393 mm

: ALFA Far Station : σ_y = 0.344 mm

AFP vs ALFA

With fully open collimators (@80σ)

$d = 11.5*\sigma_{beam} + 0.3\ mm + 0.5\ mm$



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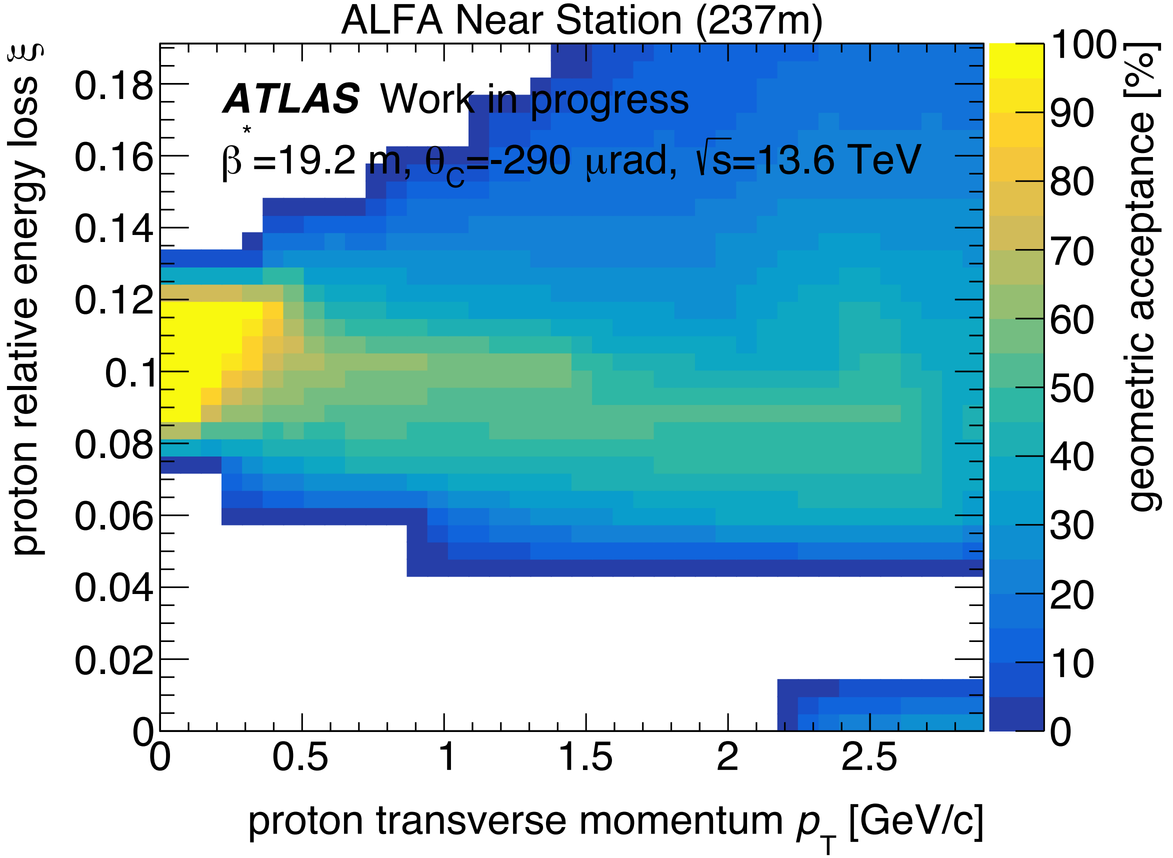
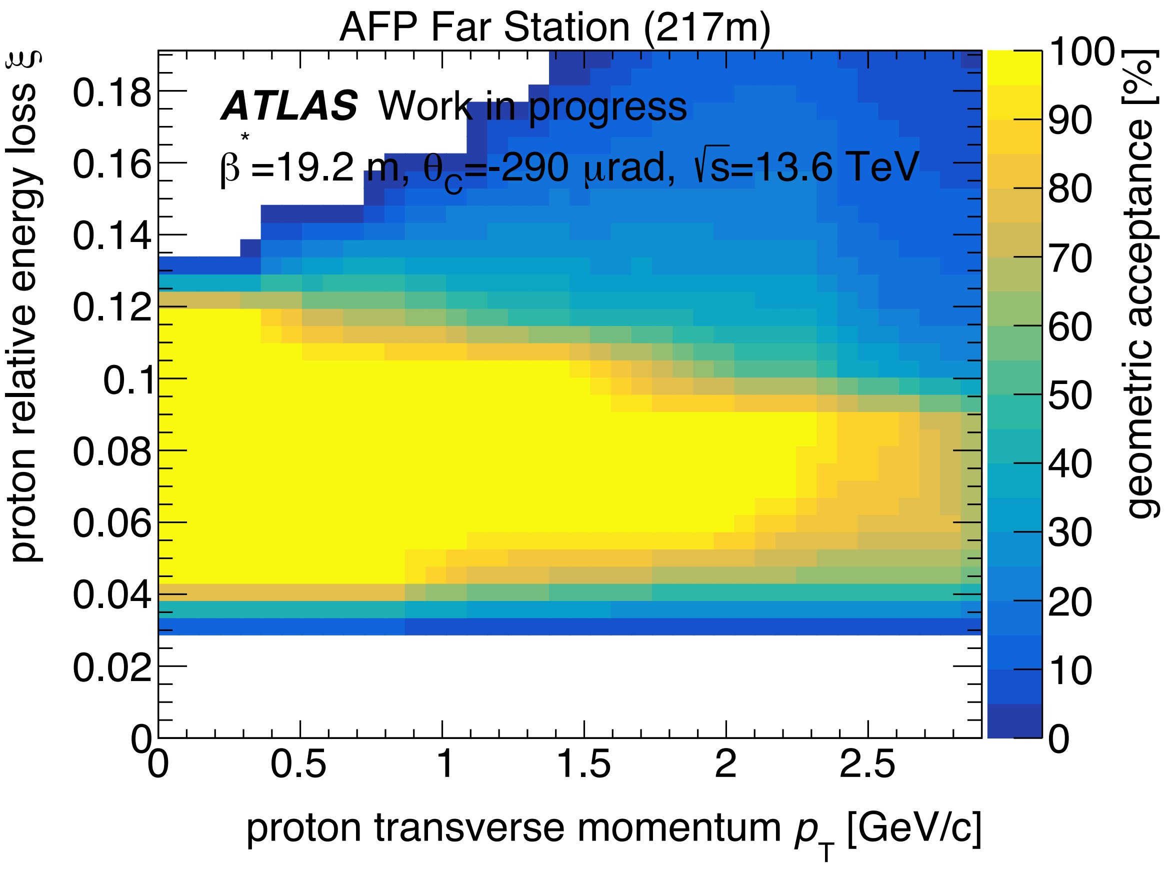


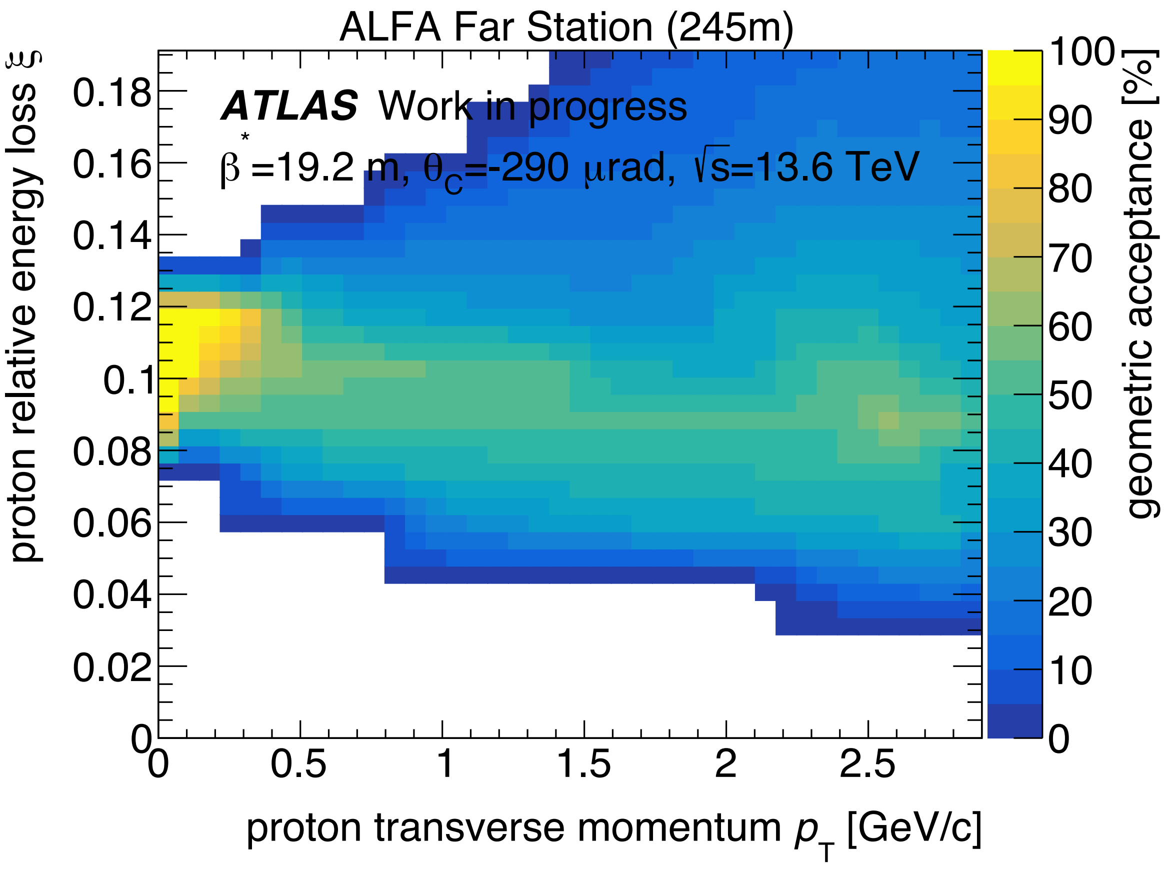
AFP vs ALFA

With fully open collimators (@80σ)

d = $11.5 * \sigma_{beam}$ + 0.3 mm + 0.5 mm

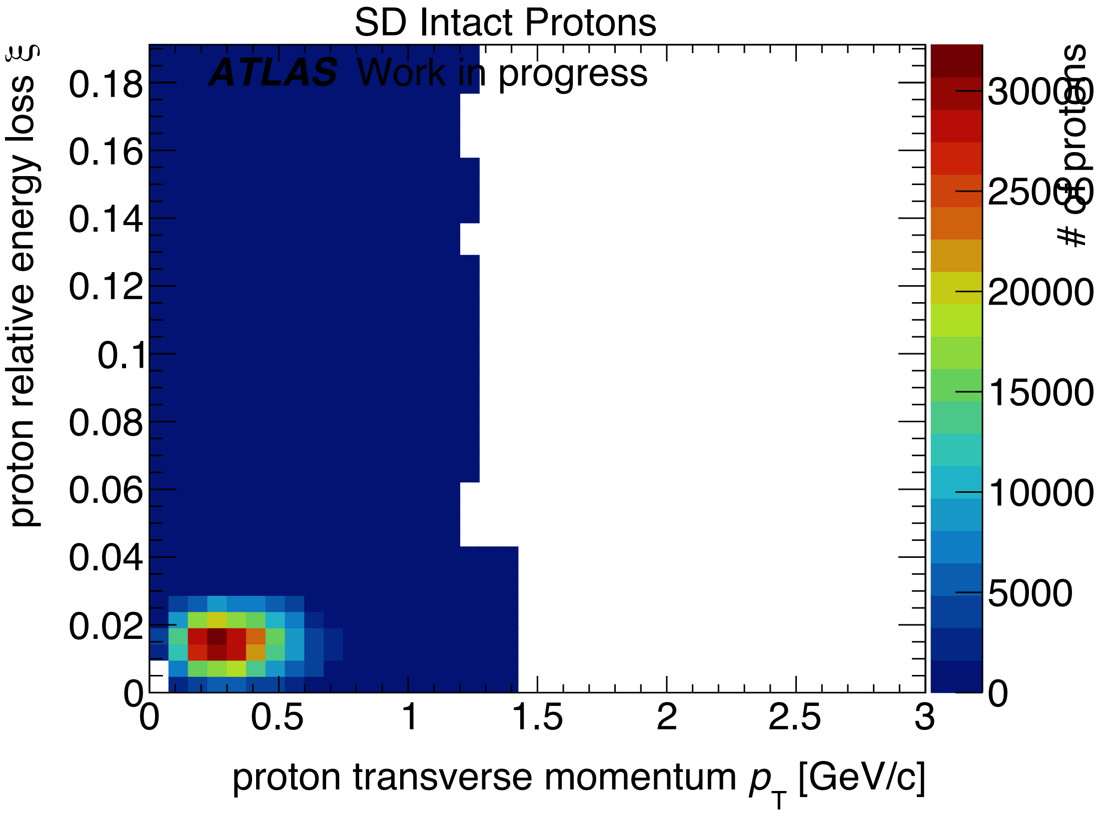


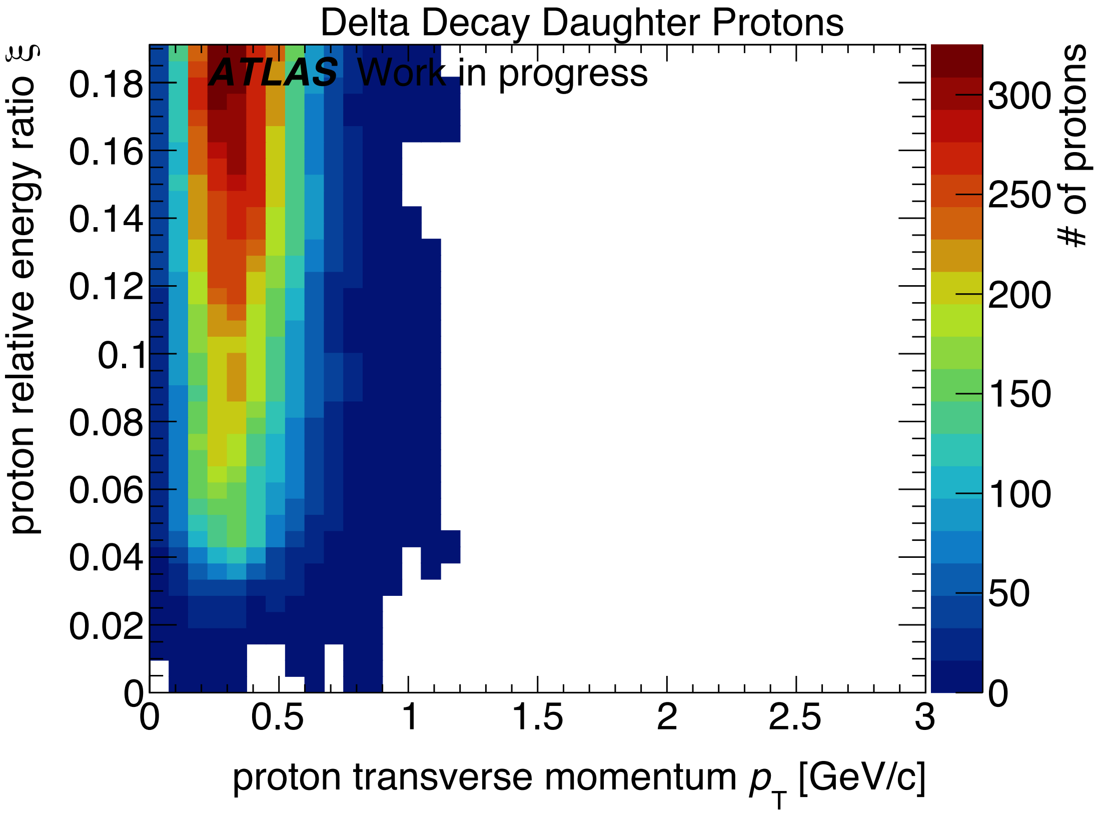
d = $11.5 * \sigma_{beam}$ + 0.3 mm + 0.5 mm



Single Diffractive vs Delta Decay

In terms of raw proton numbers and distributions (for 1.000.000 events)

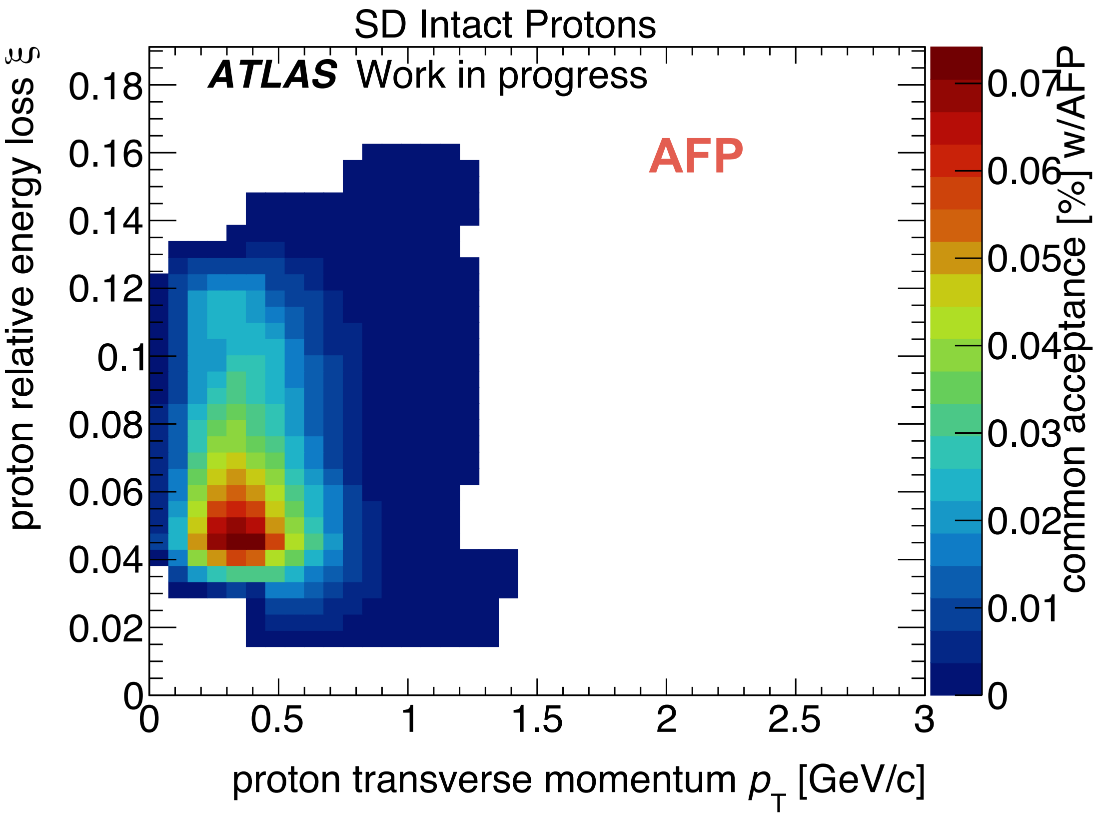


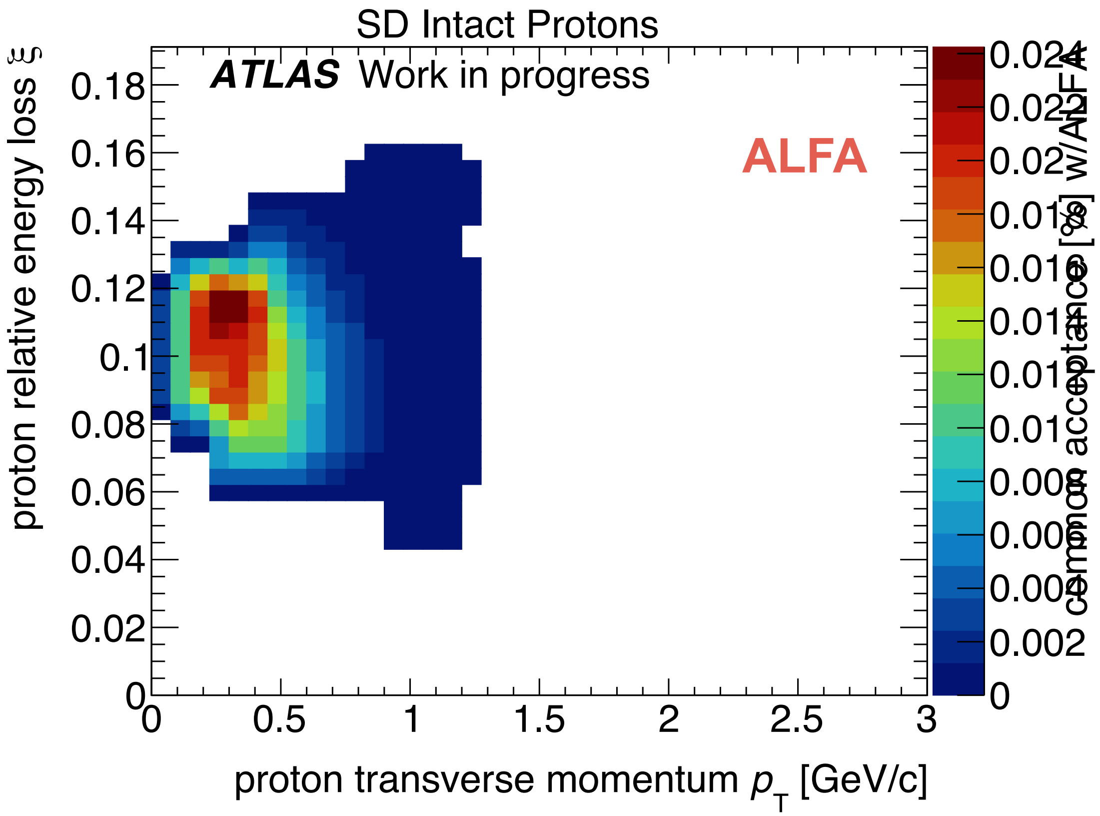


Single Diffractive

Collision Rate = Number of Bunches (150) x mu (0.02) x Revolution Rate (11.2 kHz) x Trigger Efficiency (100%) = **33.6 kHz**

Total Event Rate = $\sum$ (Collision Rate x Common Acceptance x $\frac{\sigma_{SD}\,(12.86\,mb)}{\sigma_{inelastic}\,(78.55\,mb)}$)





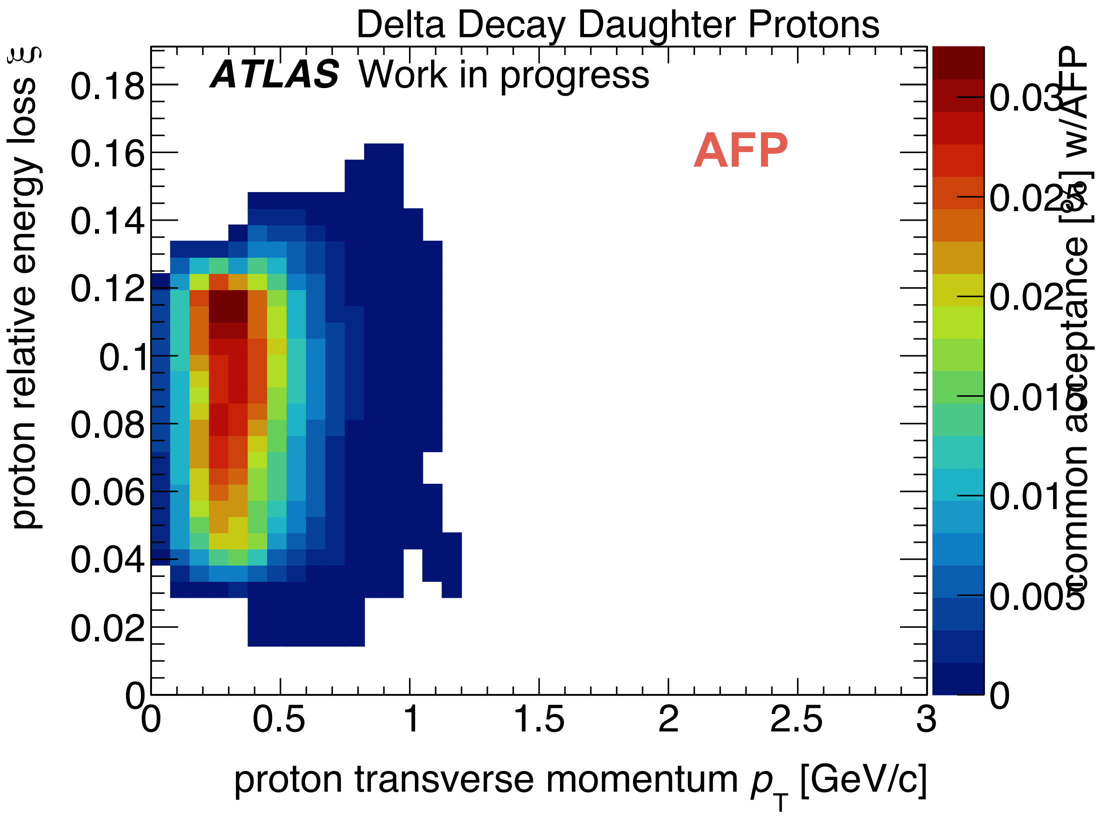
$Event_{rate}$ = **68.5259** Hz

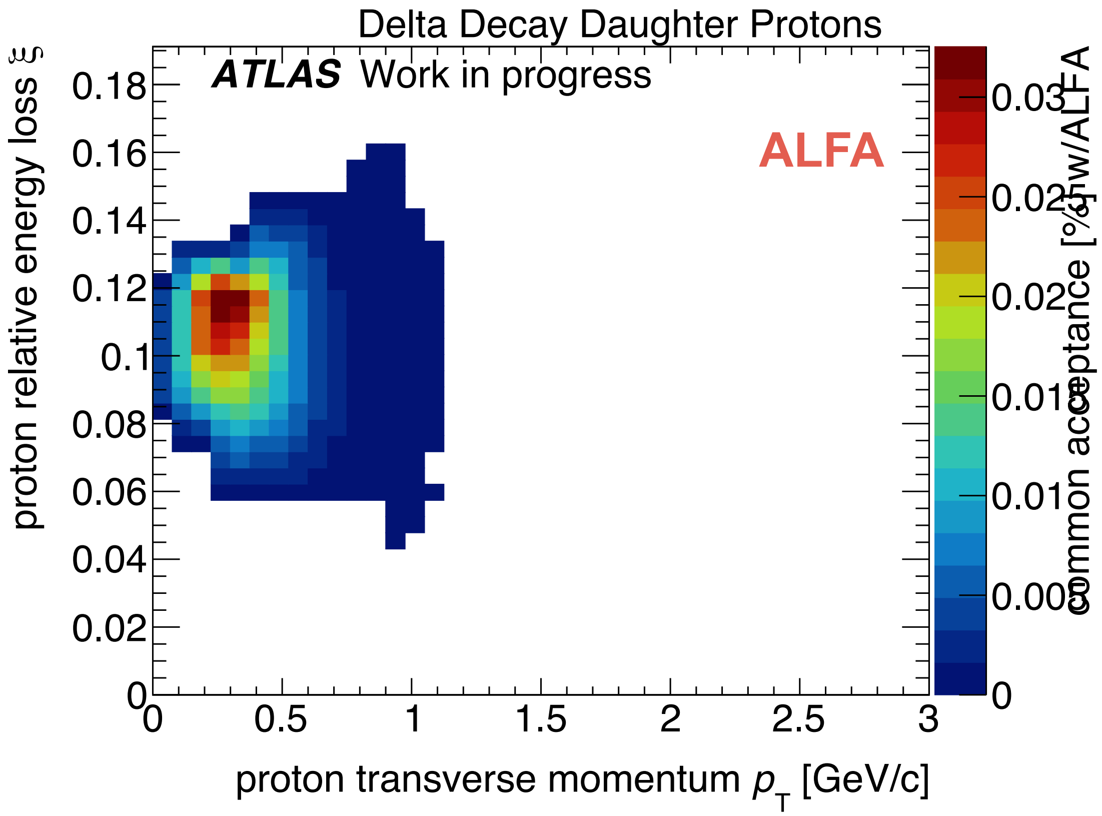
$Event_{rate}$ = **19.1872** Hz

Delta Decay

Collision Rate = Number of Bunches (150) x mu (0.02) x Revolution Rate (11.2 kHz) x Trigger Efficiency (100%) = **33.6 kHz**

Total Event Rate = $\sum$(Collision Rate x Common Acceptance x $\frac{\sigma_{delta}\ (3.27\ nb)}{\sigma_{inelastic}\ (78.55\ mb)}$)





$Event_{rate}$= **9.3206e-05** Hz

$Event_{rate}$= **4.7085e-06** Hz

Conclusion

- Joint data taking → improve the **identification** and **kinematic reconstruction**

- Both ALFA and AFP promise about the same level of event rate

- Single diffractive events are **promising** with inclusion of ARPs
- Delta decay events are rare
  - Cross section estimation comes **only** from Herwig (not possible to cross check w/ Pythia)
  - A limit on the cross section might be possible with the joint data taking

- Inclusion of both ALFA and AFP may increase statistics/covered larger kinematical range and potentially provide sample to study relative ALFA-AFP alignment

- The study was made with regular discussions in ATLAS+LHCf, LHCf+ZDC and technical meetings (e.g. Proton CP meetings)

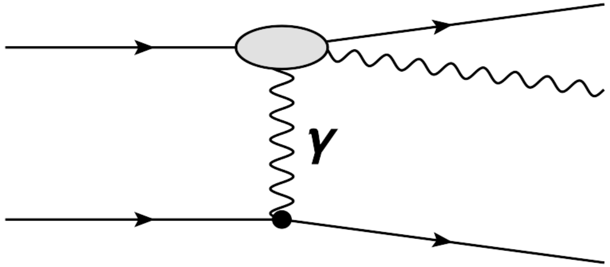
- Next step: A pub-note preparation for the studies

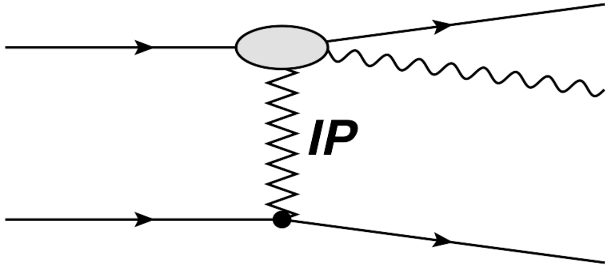
Backup

Motivation and Goal

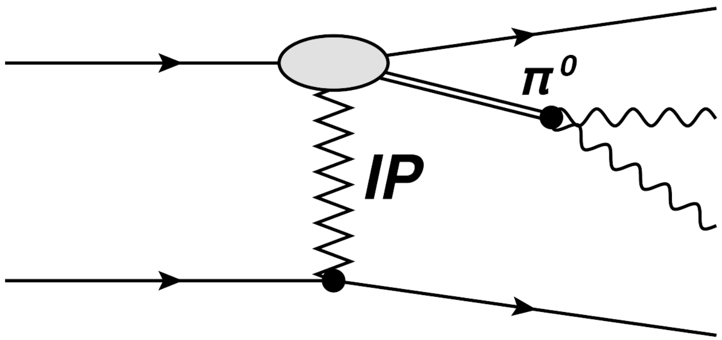
Classical and diffractive bremsstrahlung processes

- Similar topology expected for diffractive bremsstrahlung and pi0-strahlung
- p + p → p + p + γ





- p + p → p + p + π^0



- No results for these processes yet
- A discussion point for the joint data taking