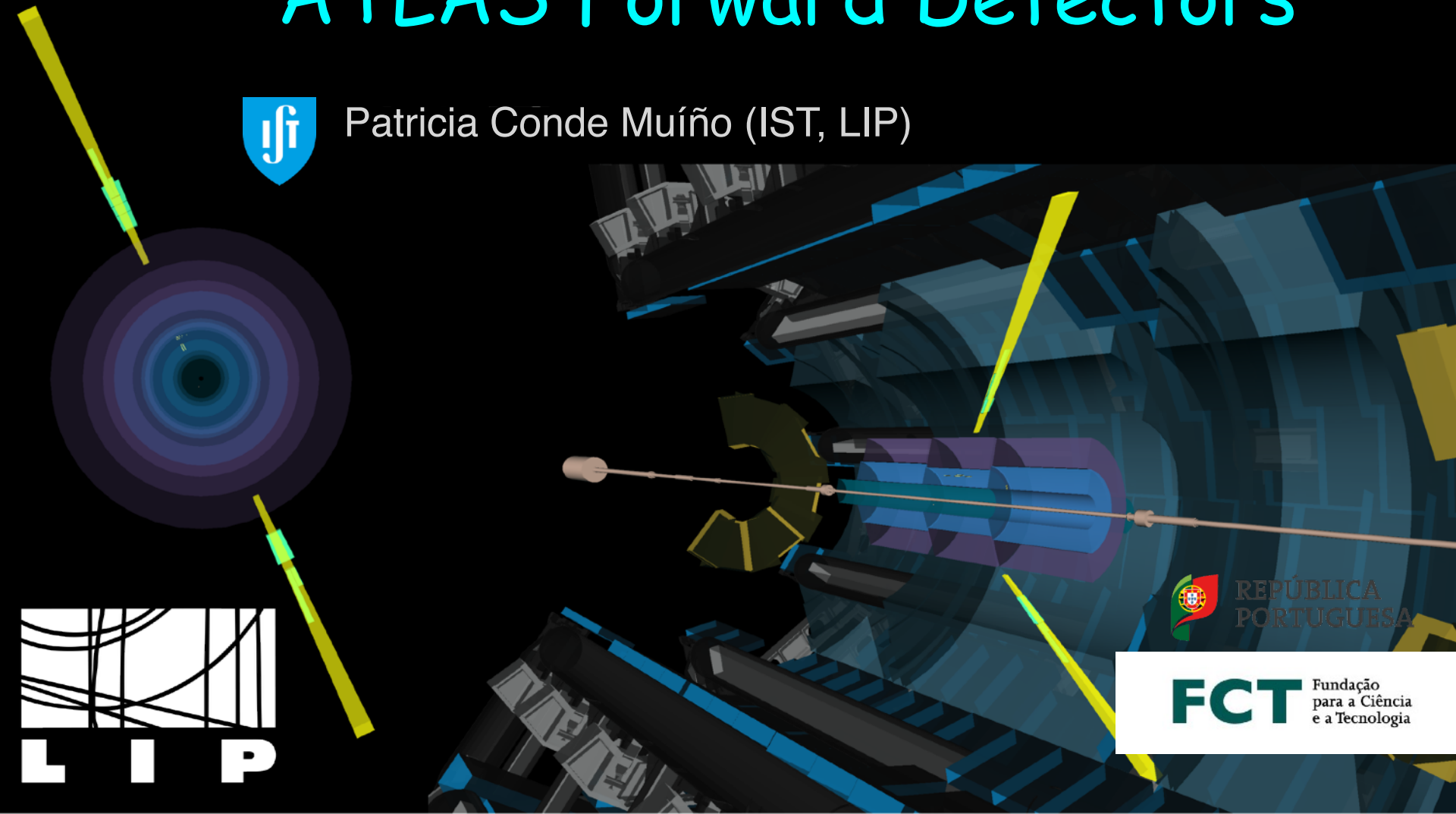
Physics with the ATLAS Forward Detectors

Patricia Conde Muíño (IST, LIP)

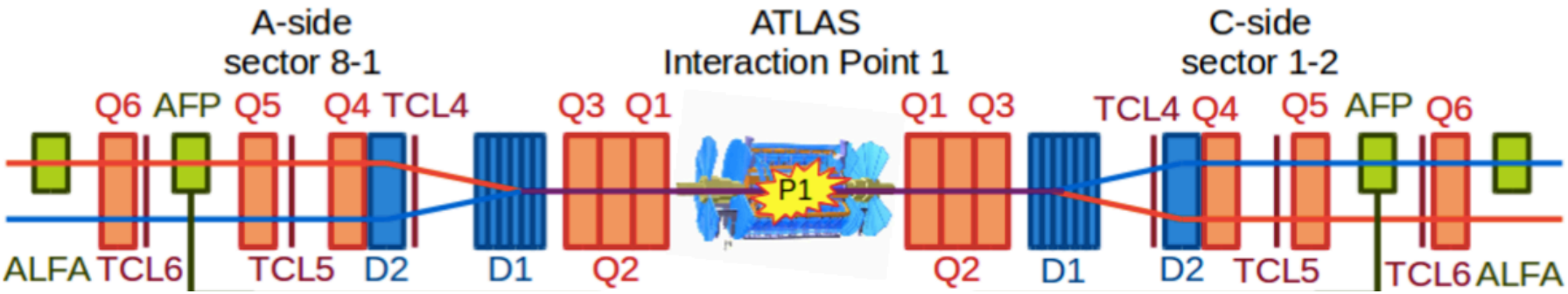


REPÚBLICA PORTUGUESA
FCT Fundação para a Ciência e a Tecnologia

Outline

- What are the ATLAS Roman Pot (ARP) detectors?
- Which physics can we do with them?
  - Searches for new physics
  - Diffractive physics
- Status of the project

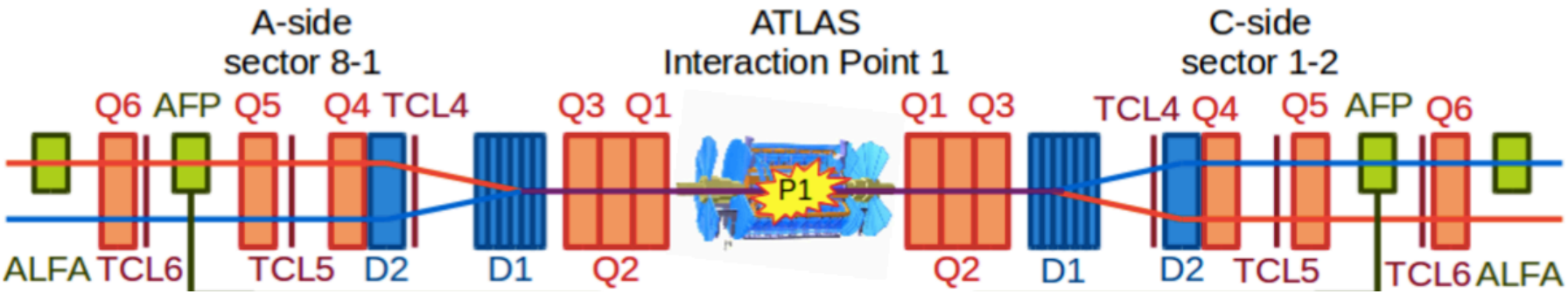
ATLAS Roman Pot Detectors

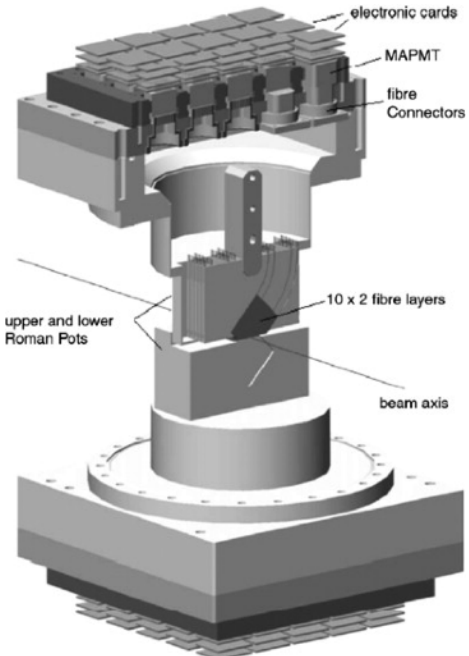


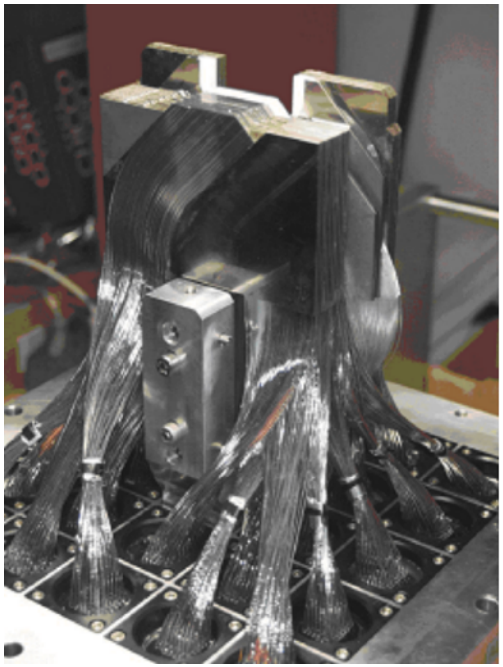
- Two sets of detectors
  - ATLAS Forward proton tagging detectors (AFP)
  - Absolute Luminosity detector (ALFA)

ATLAS Roman Pot Detectors

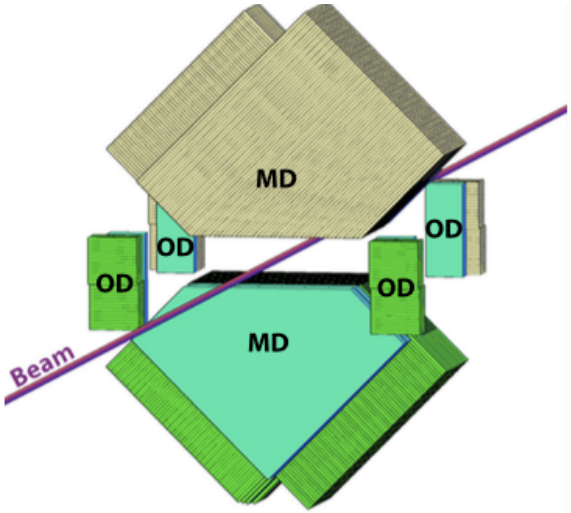
- ATLAS Luminosity detector ALFA



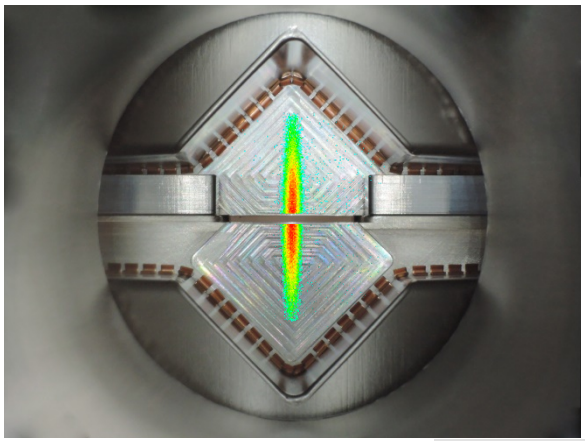


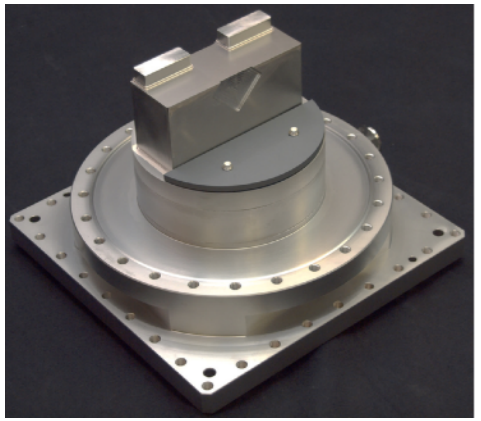


ALFA



- Measure scattered p at mm distance from beam
  - Detector resolution of 30 μm in x, y
  - Precise alignment
    - Overlap detector with precision 10 μm
- Square-shaped scintillating fibres
  - aluminised (body, mirrored at top)
  - Staggered layers
- Read out by MAPMTs
- Housed in Roman Pots to approach the beam
- Operates at low luminosity and with special optics

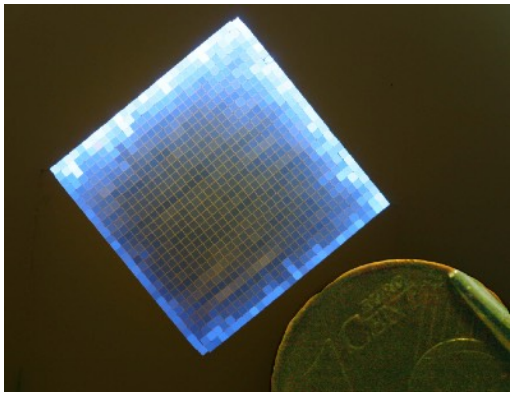




Luminosity: $L = \frac{N_1 \cdot N_2 \cdot n \cdot f \cdot \gamma}{4 \cdot \pi \cdot \varepsilon \cdot \beta^*} F$

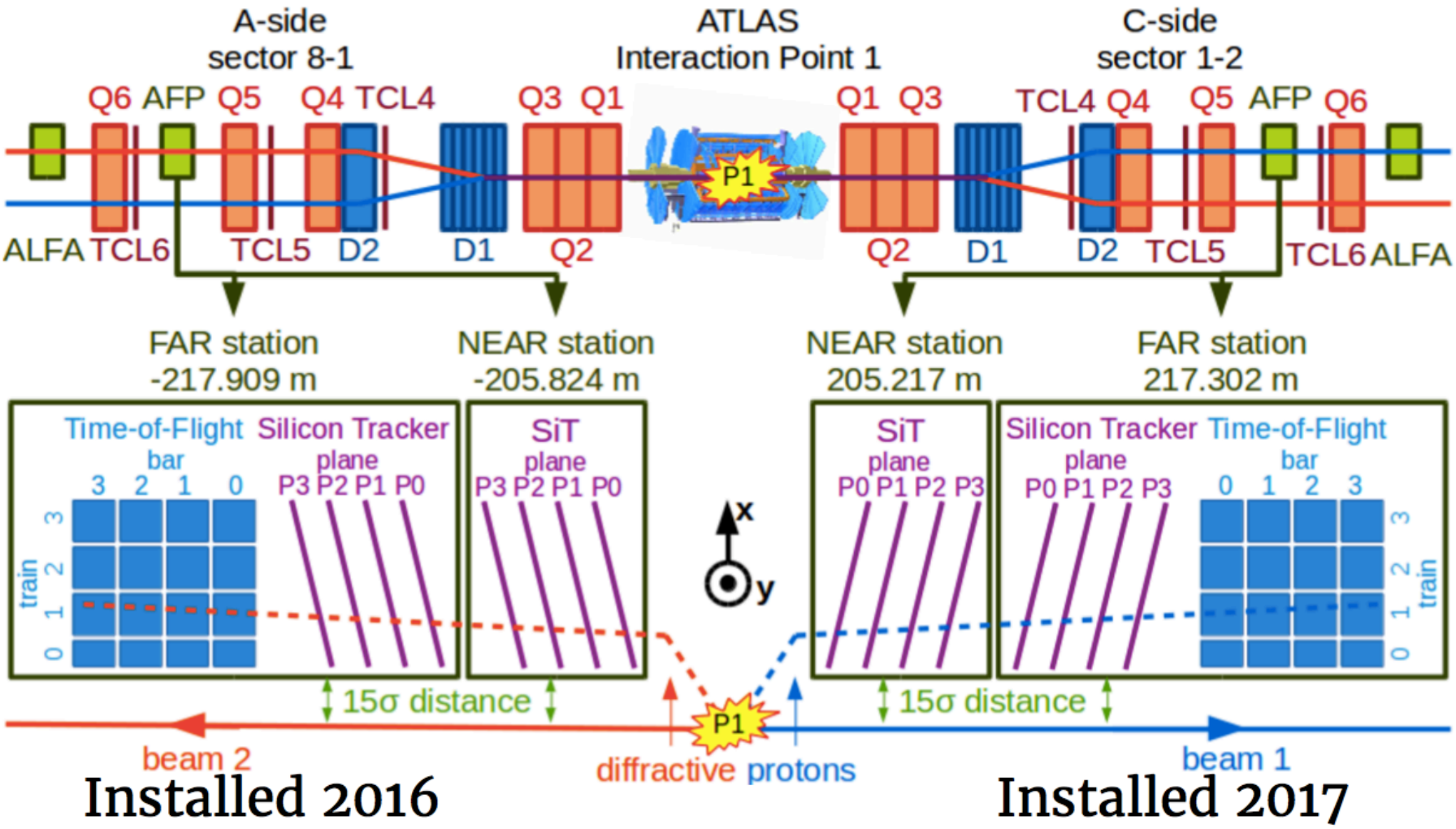
Portuguese contributions to ALFA

- Fibre preparation
- Detector Control System



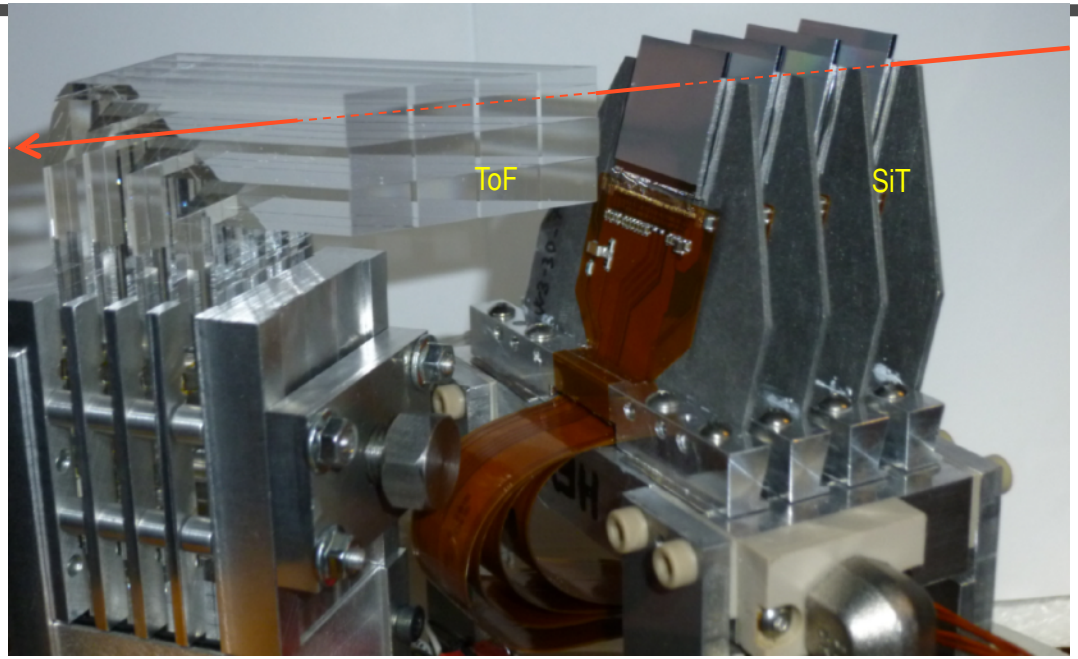
ATLAS Roman Pot Detectors

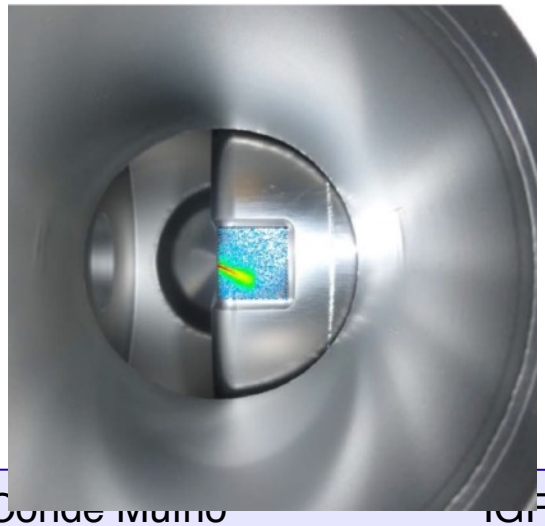
- ATLAS Forward proton tagging detectors



ATLAS Forward Proton tagging detectors

- Horizontally inserted RP
- Tracking detectors:
  - slim-edge 3D ATLAS IBL pixel sensors bonded with FE-I4 readout chips.
  - σ_x = 6 μm, σ_y = 30 μm
  - Trigger: majority vote (2 out of 3)

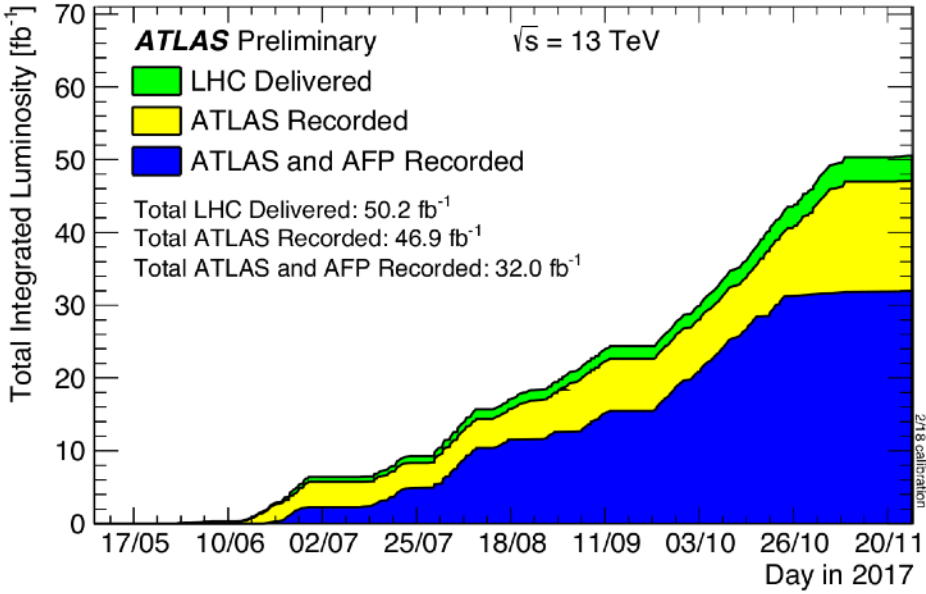




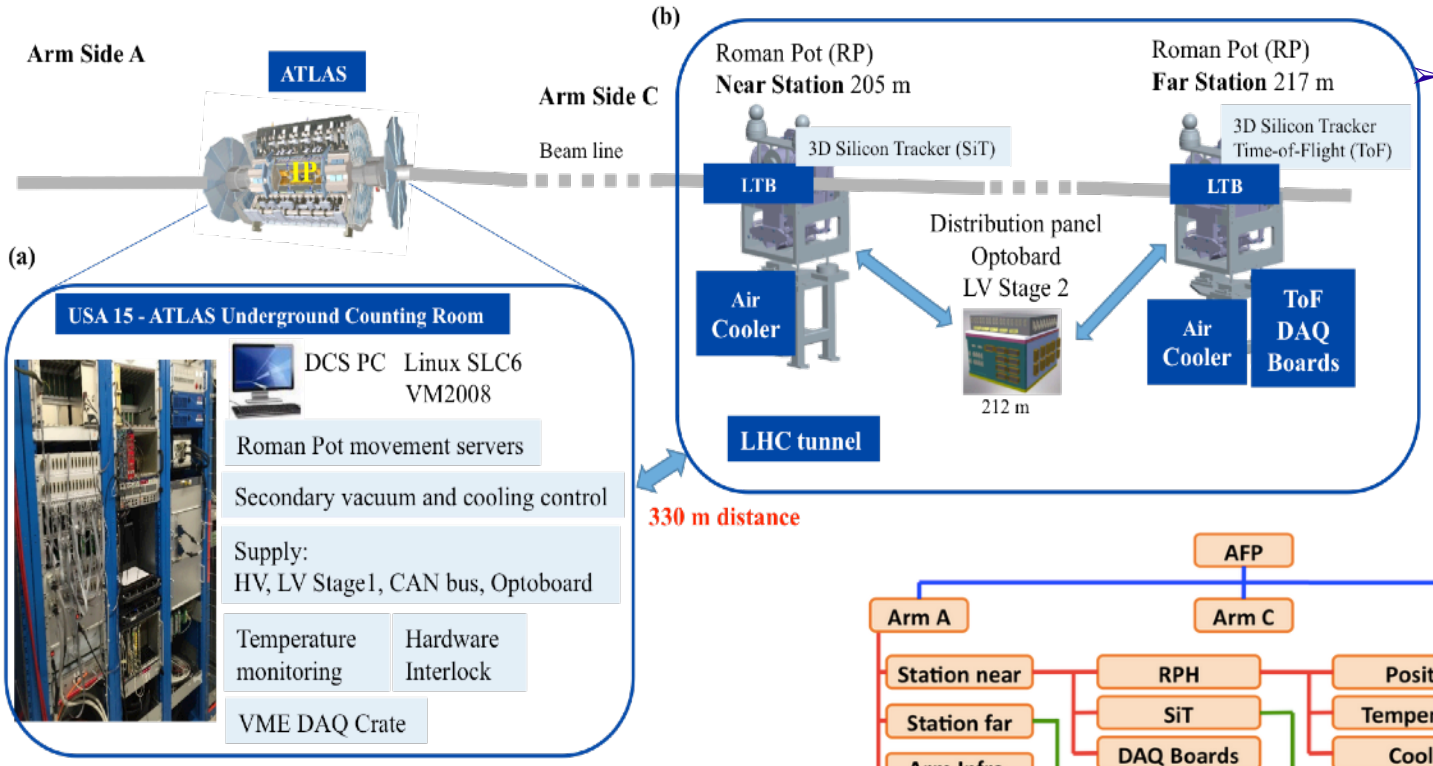
- Time of flight measurement
  - Pile-up suppression: primary vertex z_{ID} and z_{ToF}
    - σ_t ~20 ps
  - Quartz bars at the Cerenkov angle
  - Readout by Photonis MCP-PMT

AFP data taking

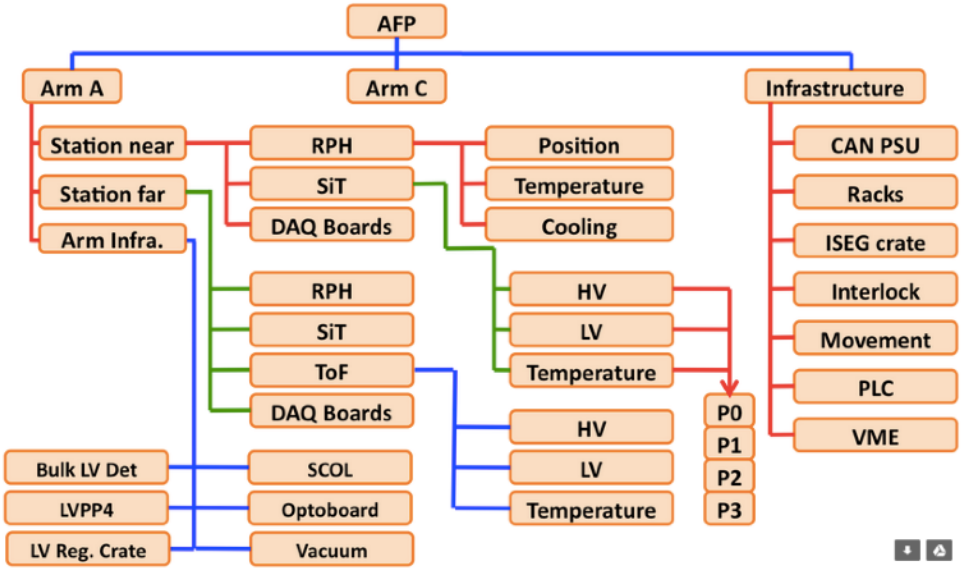
- Staggered installation (YETS 2016, 2017)
  - Recorded luminosity
    - ~80 fb^{-1} in 2017/18
  - But no ToF measurement yet due to problems with MCP-PMT



AFP Detector Control System



Main challenge: cope with the large variety of sub systems

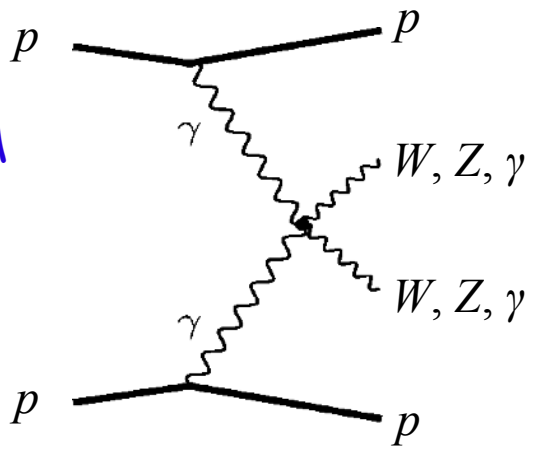


- Provides tools and services for detector operation:

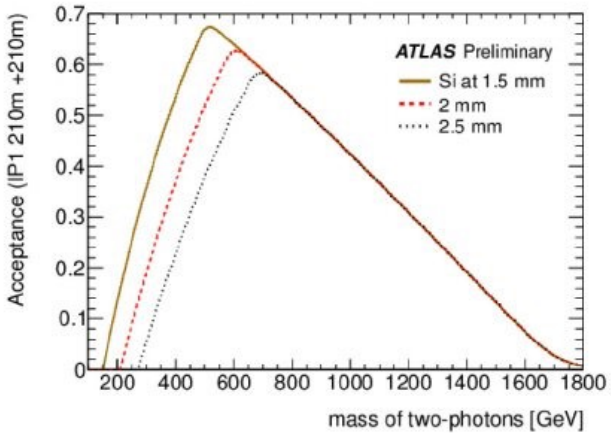
FiniteStateMachine, archiving, alerts, graphical user interfaces

Quartic gauge boson couplings

- AFP converts the LHC in a photon-photon collider!
- Quartic Gauge Boson Couplings introduced in the SM due to the non abelian nature of the EW symmetry
  - Very precise predictions:
    - WWWW, $\gamma\gamma$WW, WWZZ exist
    - ZZZZ, $\gamma\gamma$ZZ: only at loop level
  - Might be modified by BSM physics
- Exclusive production
  - Match m_{inv} in central detector and in AFP



$$\xi_i^p = \left(E_0 - E_i^p\right)\Big/E_0\,, \quad m_{pp} = \sqrt{\xi_1^p \xi_2^p s}\,, \quad y_{pp} = \frac{1}{2}\ln\left(\xi_1^p/\xi_2^p\right)$$

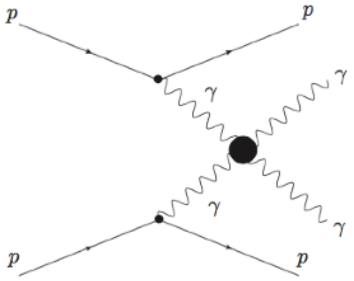


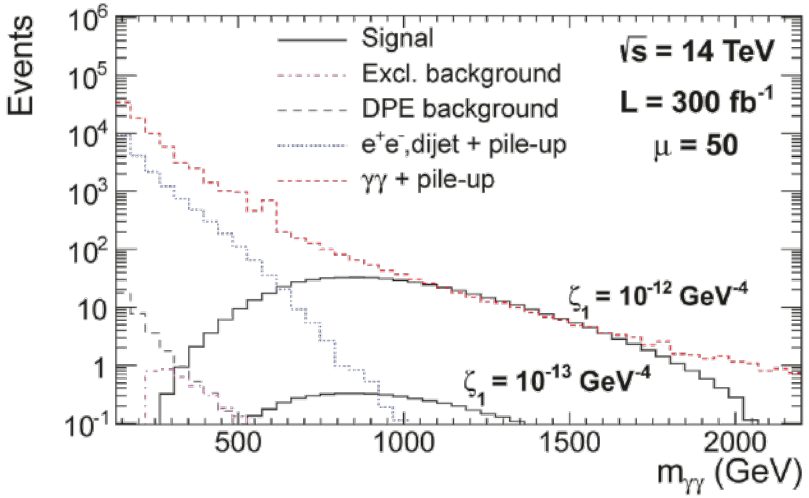
- AFP missing mass resolution ~4% (now ~10%)

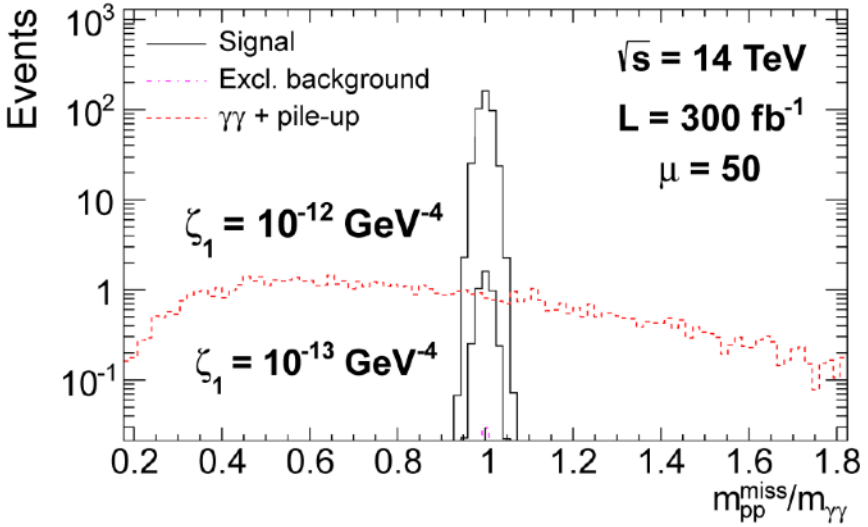
Search for $\gamma\gamma \rightarrow \gamma\gamma$ anomalous couplings

- Low Cross sections: ~few fb; but clean!
- Exclusive production
  - Powerful background rejection tool
- With 300 fb^{-1} sensitive to effective $\gamma\gamma\gamma\gamma$ couplings of ~10^{-14} GeV^{-4}

$$\mathcal{L}_{\gamma\gamma\gamma\gamma} = \zeta_1^{\gamma} F_{\mu\nu} F^{\mu\nu} F_{\rho\sigma} F^{\rho\sigma} + \zeta_2^{\gamma} F_{\mu\nu} F^{\nu\rho} F_{\rho\sigma} F^{\sigma\mu}$$







From M. Saimpert, E. Chapon, S. Fichet, G. von Gersdorff, O. Kepka, B. Lenzi, C. Royon;

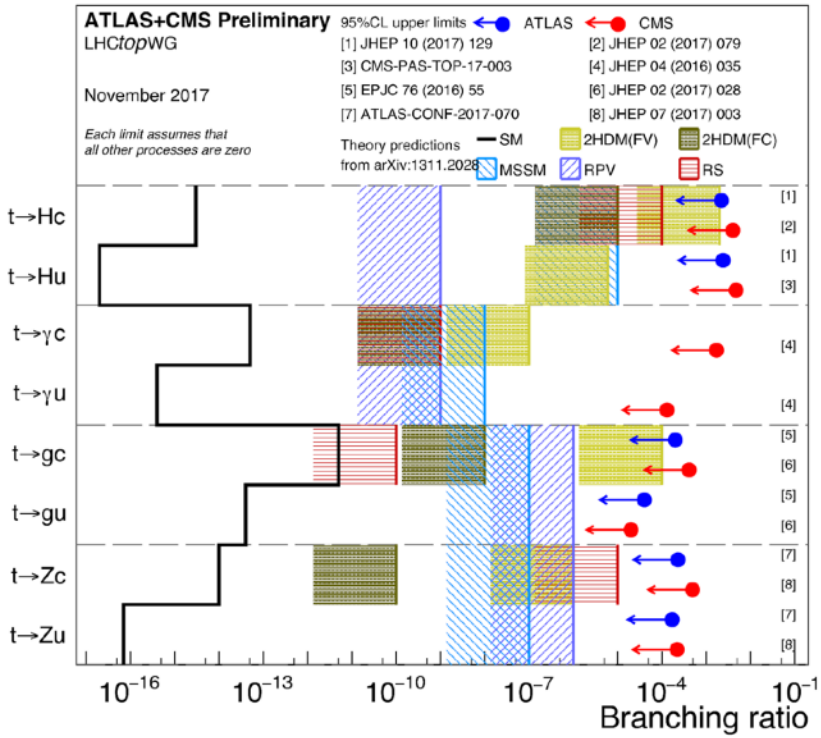
$\gamma\gamma$WW and $\gamma\gamma$ZZ anomalous couplings

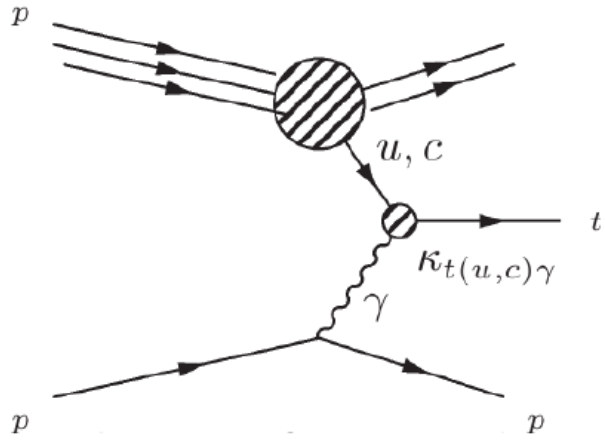
Couplings	OPAL limits [GeV^{-2}]	Sensitivity @ $\mathcal{L} = 30$ (200) fb^{-1} 5σ	95% CL
a_0^W/Λ^2	[-0.020, 0.020]	5.4 10^{-6} (2.7 10^{-6})	2.6 10^{-6} (1.4 10^{-6})
a_C^W/Λ^2	[-0.052, 0.037]	2.0 10^{-5} (9.6 10^{-6})	9.4 10^{-6} (5.2 10^{-6})
a_0^Z/Λ^2	[-0.007, 0.023]	1.4 10^{-5} (5.5 10^{-6})	6.4 10^{-6} (2.5 10^{-6})
a_C^Z/Λ^2	[-0.029, 0.029]	5.2 10^{-5} (2.0 10^{-5})	2.4 10^{-5} (9.2 10^{-6})

- Improve LEP sensitivity by more than 4 orders of magnitude with 30/200 fb^{-1} at LHC, and of D0/CDF results by ~2 orders of magnitude
- AFP improves the results obtained with central detector only by 2 orders of magnitude
- Reaches the sensitivity needed for extra-dimensions models!!

Flavour Changing Neutral Currents in top production

- FCNC top quark interactions strongly suppressed in the SM
  - Can be considerably enhanced in New Physics Models



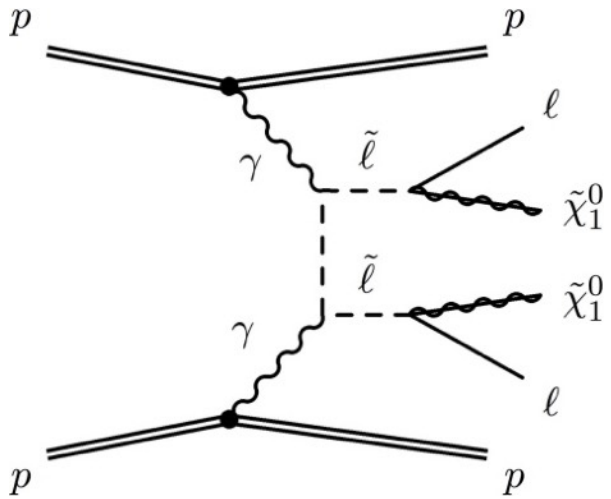


- Probing utγ and ctγ couplings
- Single diffractive mode
- Main irreducible backgrouns: γp interactions producing a W+jets
- Complements other analysis done at ATLAS

Search for dark matter

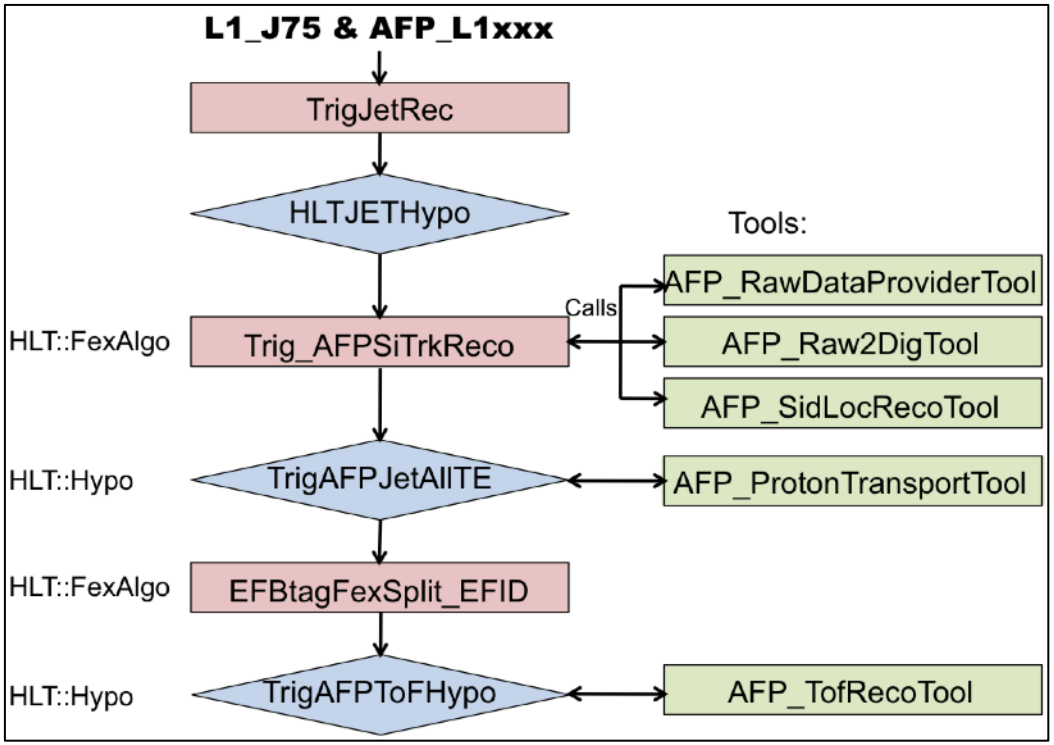
1812.04886 [hep-ph] V. Khoze, L. Harland-Lang, M. Ryskin, and M. Tasevsky

- In compressed mass scenario
  - compressed mass scenario → small MET
  - exclusive process → precise mass measurement
- Selection
  - Double-tag AFP, 2 tracks
  - Soft leptons: few GeV
  - $|z_{ll} - z_{ToF}| < 1$ mm, no other vertex within 1mm
- S/B ~1 at μ=50. ToF necessary !
- Needs dedicated trigger



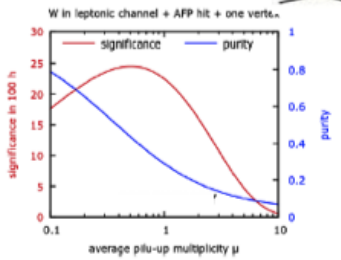
AFP Central Exclusive Production di-jet trigger

- Being developed at LIP
- Requires matching central detector information and ToF and tracking information from AFP
- Could be the base for other dedicated triggers



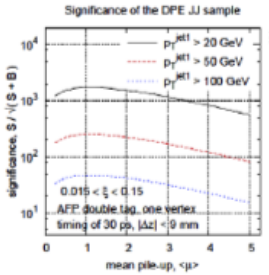
Other physics topics

SD W



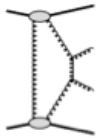
Charge asymmetry → flavour composition of Pomeron

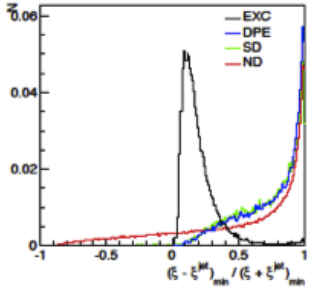
DPE jets



Kinematic (β) dependence of Pomeron structure

Exclusive jets (single tag)

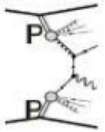


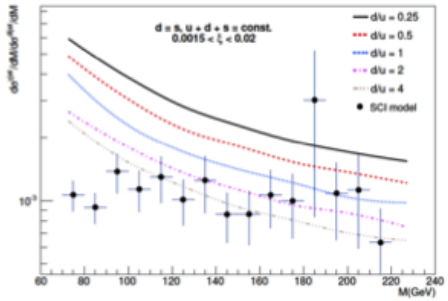


Unintegrated gluon distributions

"Standalone" MC simulations

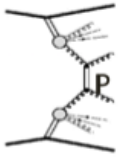
SD&DPE γ+jet

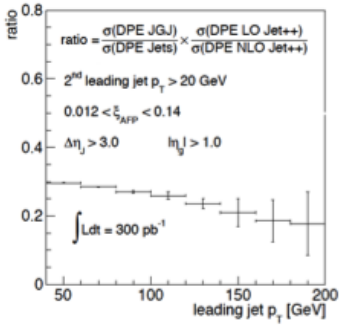




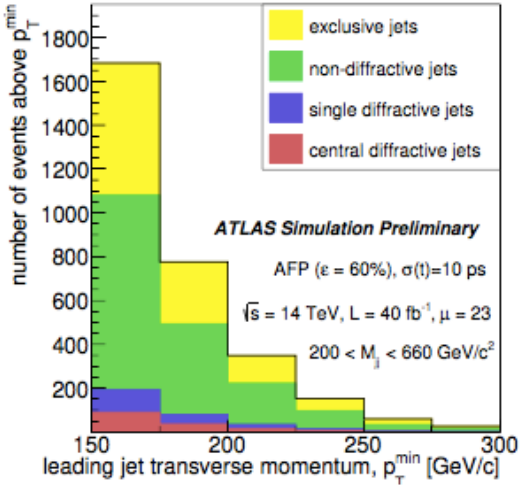
Never measured before! Distinguishes between diffraction mechanisms

SD jgj, DPE jgj





Never measured before! BFKL dynamics



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Summary and conclusions

- ATLAS Roman Pot detectors enlarge the physics topics of ATLAS
  - Searches for anomalous quartic gauge boson couplings, dark matter, FCNC in top quark production, …
  - Single diffraction, central diffraction, …
- The Portuguese ATLAS group has contributed to
  - Fibres preparation for ALFA
  - Detector control system (ALFA, AFP)
  - Exclusive trigger implementation and performance
- Detectors are now operational and a lot of data has been collected
  - Expect first physics soon!

Backup