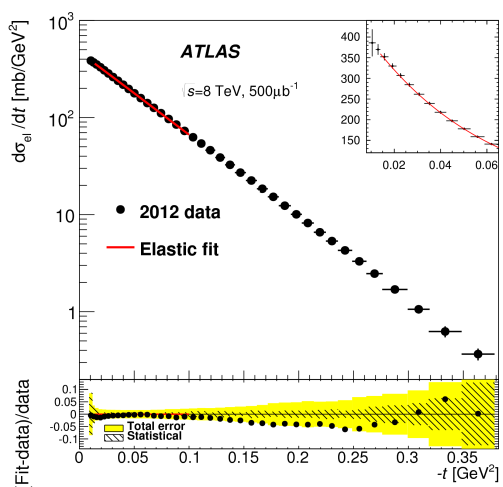
ATLAS forward & diffractive physics

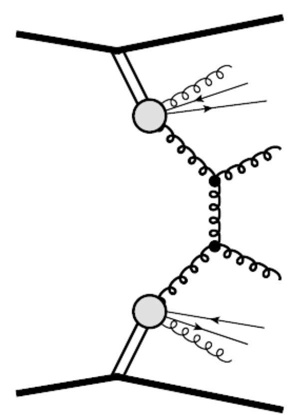
- ATLAS Forward detectors
- Diffractive physics
- Elastic physics
- Run requests

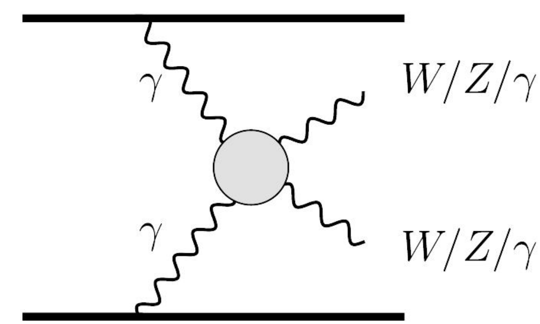
Ulla Blumenschein,

on behalf of the ATLAS collaboration

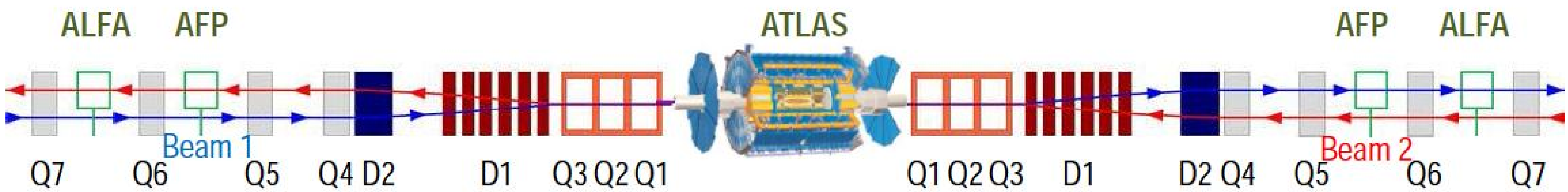


(b)





ATLAS Forward Proton detector (AFP)



- 2x2 horizontal roman-pot stations, ~200m from IP
- 3D pixel sensors
- ToF cerenkov detectors in far stations

Tagging diffractive and exclusive events by presence of forward proton(s)

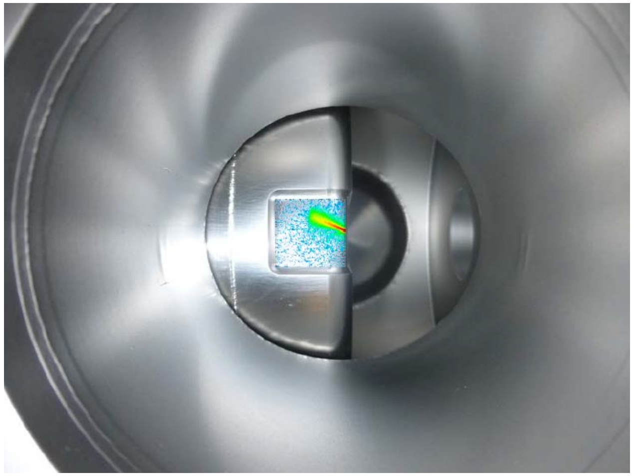
Rejection of diffractive interactions from pile-up, using ToF detectors

A priori no limitations on instant. luminosity → participate in standard data taking

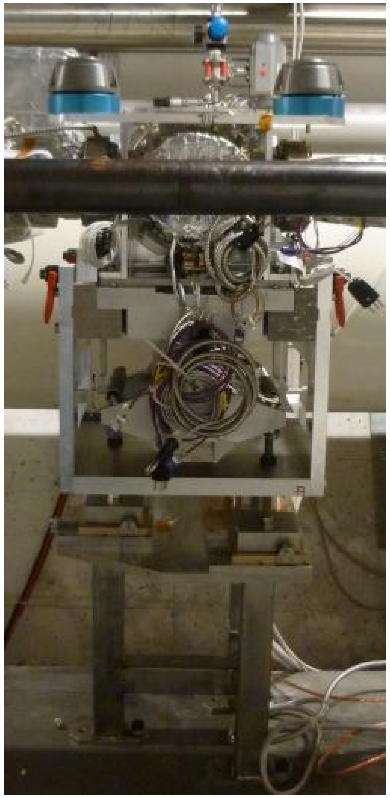
Staged installation:

- *2016: One arm with 2 stations:*
  - *→ beam environment*
  - *→ single diffraction*
- *EYETS: 2nd arm with 2 stations*
  - *ToF detectors*

AFP as seen from outgoing proton beam + hit pattern overlay



AFP station



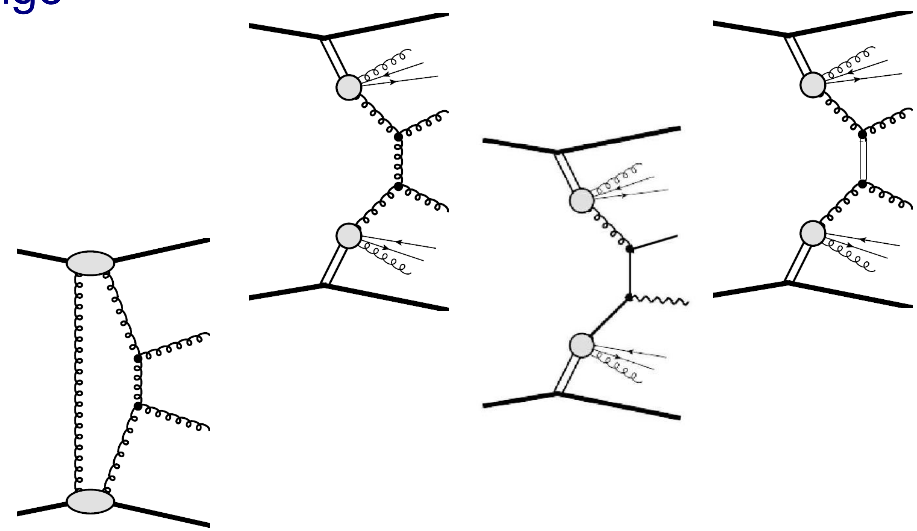
Physics with AFP at high μ

Standard low-ß high-luminosity data taking*
Two tagged protons: reject pileup & other backgrounds, momentum transfer t

Hard central diffraction, double pomeron exchange

- DPE jets, γ+jets, jet-gap-jet production

→ structure and universality of the pomeron,
  BFKL Pomeron
→ gap survival probability (rescattering)



Exclusive Jets

→ cross section measurement
→ constrain other exclusive processes

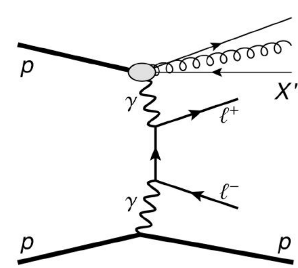
Two-photon processes

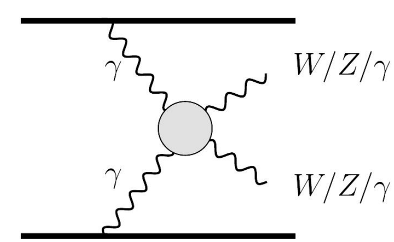
- γγ → ll

→ calibration, alignment

- γγ → γγ, WW, ZZ

→ anomalous quartic gauge couplings



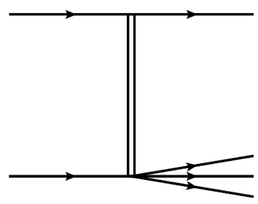


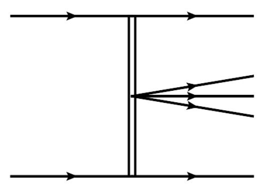
Typically small cross sections → participate in all standard physics runs

Diffractive physics with AFP at low-μ

Processes with larger cross sections, pile-up free environment

Soft diffraction:

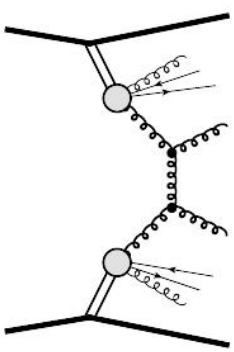


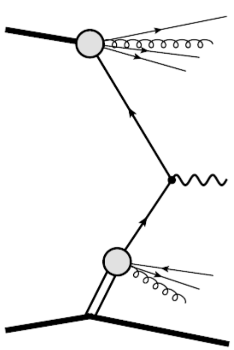


- Minimum Bias: Charged particle multiplicity, rapidity, and transverse momenta $\longrightarrow$ *UE and BEC*
  Charged-particle η gaps
- Heavy Flavour: diffractive D*, B, $\bar{D}D$ pairs

$\longrightarrow$ *general properties of diffractive events*

Requirements: nominal optics, low μ~ 0.05, 100 nb^{-1}





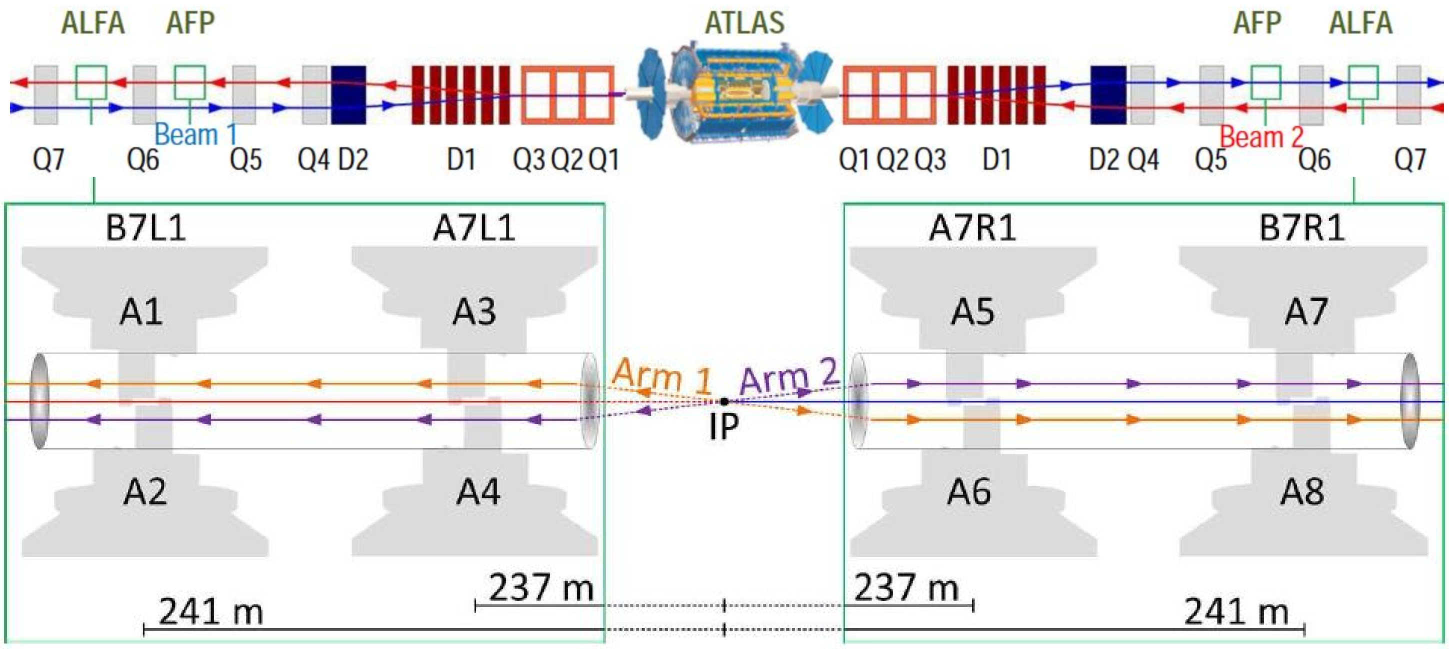
Hard diffraction:

- Jets, Jet-gap-jet
- γ+jets
- Drell-Yan, W, W charge asymmetry

$\longrightarrow$ *Pomeron structure, gap survival probability*

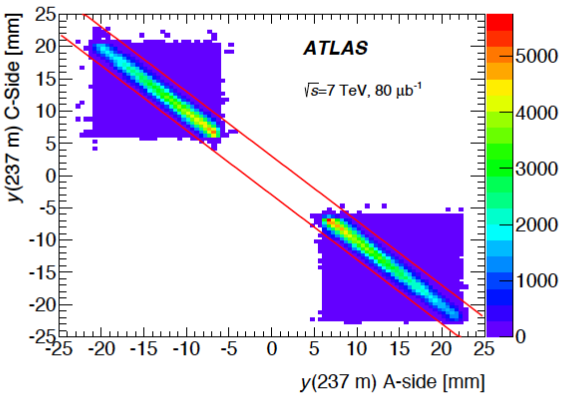
Requirements: nominal optics, moderate μ~0.5-1, 1-10 pb^{-1}

The ALFA detector



2x2 vertical Roman-Pot pairs, ~240m from IP, scintillating-fiber detectors

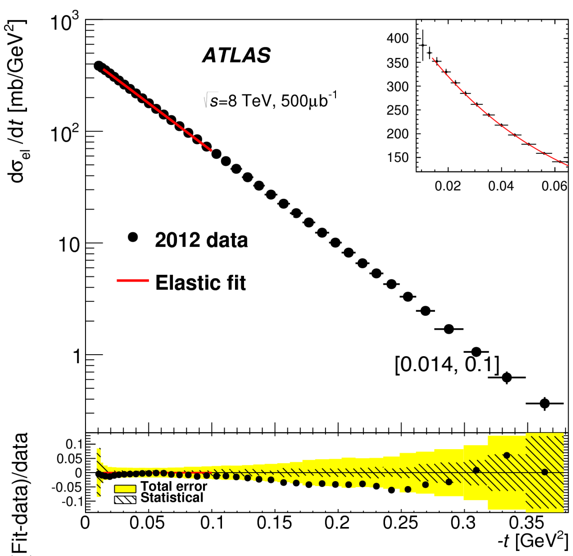
Designed to measure small-angle proton scattering ($|\eta| > 8.5$)
- *Elastic physics: protons in opposite hemispheres*
- *Diffractive physics: opposite or same hemisphere*



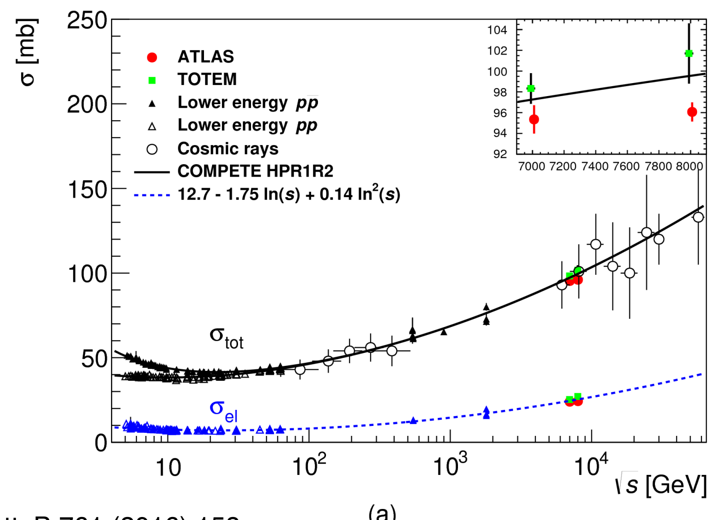
- Run1: $\sqrt{s}$ = 7TeV and $\sqrt{s}$ = 8TeV, β^* = 90m
  $\sqrt{s}$ = 8TeV, β^* = 1km
- Run2: $\sqrt{s}$ = 13TeV, β^* = 90m, β^* = 2.5km

Physics with ALFA on current data

8TeV: Fit of momentum transfer t



Elastic & total pp (pp) cross sections versus √s



Nuclear Physics, Section B (2014), Phys. Lett. B 761 (2016) 158

Elastic cross section:

$$\frac{\mathrm{d}\sigma}{\mathrm{d}t} = \frac{1}{16\pi}\left|f_N(t) + f_C(t)e^{i\alpha\phi(t)}\right|^2$$

$$f_N(t) = (\rho + i)\frac{\sigma_{tot}}{\hbar c}e^{-B|t|/2}$$

$$f_C(t) = -8\pi\alpha\hbar c\frac{G^2(t)}{|t|}$$

Optical theorem:

$$\sigma_{tot}^2 = \frac{16\pi(\hbar c)^2}{1+\rho^2}\left.\frac{\mathrm{d}\sigma_{el}}{\mathrm{d}t}\right|_{t\to 0}$$

$\rho = \mathrm{Re}(f_{el})/\mathrm{Im}(f_{el})$
from lower-energy data

Published:
Elastic physics 7/8TeV, ß*= 90m

Differential elastic cross section $d\sigma_{el}$ / dt

- Elastic cross section
- Total cross section
- Nuclear slope B

⟶ *1% precision on σ_{tot} and B*

Ongoing:
Elastic and diffractive physics

- √s = 7/8/13 TeV data, ß* = 90m
- √s = 8TeV: ß* = 1km data
- √s = 13TeV, ß* = 2.5km

Elastic physics at different √s

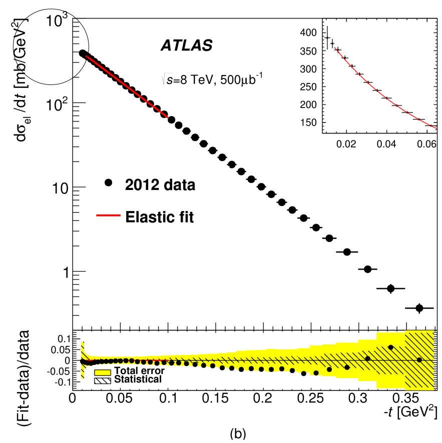
Lower cms energies

8TeV fit: -t in [0.014,0.1]

Extend to smaller |t|:

- larger β^*
- lower $\sqrt{s}$

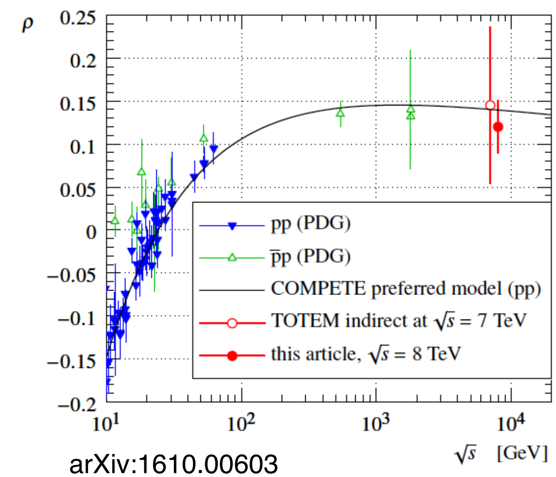
$\sqrt{s}$ = 2 TeV, β^*=400m
⟶ $t = 10^{-4}$
⟶ Coulomb-interference region



Phys. Lett. B 761 (2016) 158

Higher cms energies

High-energy evolution of ρ



arXiv:1610.00603

At $\sqrt{s}$ = 2 TeV, large β^*: very good statistical precision for the forward physics parameters.

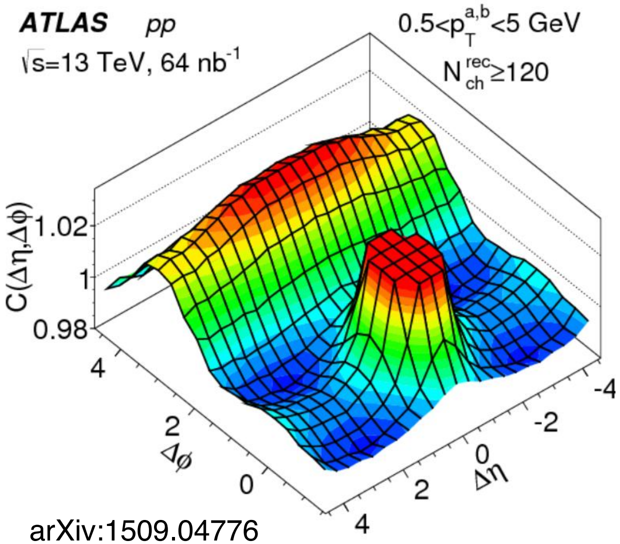
- Access to Coulomb-Interference region
- Complement measurements of the Tevatron in p pbar
- Comparison of ρ in pp and p pbar

$\sqrt{s}$ = 14TeV: extension into high-energy range

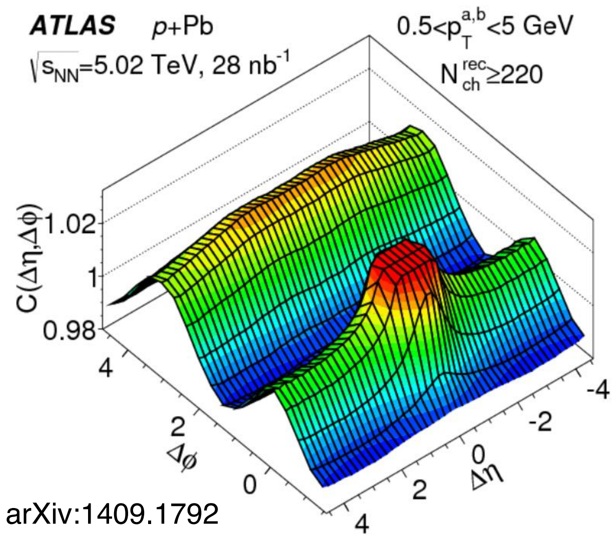
ρ measurement in the LHC range
⟶ predict the high-energy evolution of σ_{tot} beyond LHC range, probe possible flattening scenarios

- Energy evolution of σ_{tot}, B and ρ in a wide range from 2 to 14 TeV

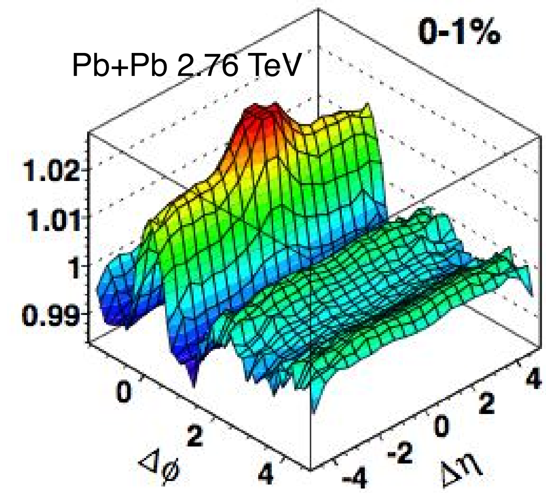
Ridge physics in pp



arXiv:1509.04776



arXiv:1409.1792



arXiv:1203.3087

Strong azimuthal correlation (ridge) for pairs separated by large $\Delta\eta$

Long-range correlation come from early time (e.g proton shape fluctuations) → final state via collective expansion.

Opportunistic participation in AFP pp runs and intensity ramps, high-multiplicity triggers

- Large # events in each charge-multiplicity for multi-particle correlations
  → Differential measurements to higher pT, longitudinal dynamics, ...
- Large int Luminosity to push to very large charge multuplicities
  → Important for comparison to other systems (pPb or peripheral PbPb)

Summary of requests

Formal requests from ATLAS for 2017

- Participation of **AFP in all standard high-μ runs**, AFP as close as possible to beam
  - $\rightarrow$ hard diffraction (DPE, exclusive jets, $\gamma\gamma \rightarrow WW/ZZ/\gamma\gamma$,..)
- **AFP diffractive low-μ program,** standard beam optics
  - $\mu \sim 0.05$: 7h with ≥ 600b $\rightarrow$ 100 nb^{-1}
    $\rightarrow$ *Soft diffraction (charged particles)*
  - $\mu \sim 1$: 7h with ≥ 600b $\rightarrow$ 2pb^{-1}
    $\rightarrow$ *hard diffraction (jets, jet η gaps, y+jets, Drell-Yan, DPE, gap survival probability,..)*
    + Ridge physics: moderate & high-multiplicity, pT and multiplicity dependence

Potential request for 2017 or later:

- **AFP diffractive:** extend μ~1 sample to 10pb^{-1}
  during intensity ramps or by levelling at end of physics fill (e.g. 4h with 2220b and μ=2)
  $\rightarrow$ *AFP: hard diffraction: W, exclusive jets, Ridge physics with hard processes*
- **ALFA: Second run at ß* 2.5km 13TeV:**
  depending on analysis of 2016 data $\rightarrow$ rather for 2018
- **ALFA $\sqrt{s}$ = 14TeV:** high β*
  depending on machine strategy: probably for run3
  $\rightarrow$ *High-energy evolution of elastic and total cross section*

Summary of requests

Interesting ideas that may be pursued in the future:

- **Low cms energy with high ß*:** $\sqrt{s}$=2 TeV, β*≈400m,
  - Elastic data (ALFA): 24h with 3b → 500 μb^{-1}
  - Diffractive data (ALFA+AFP): 8h with 600b → 30 nb^{-1}

→ *ALFA: Energy evolution of σ_{tot}, B and ρ, complement Tevatron p pbar*
Access to Coulomb interference region (low |t|)

→ *ALFA+AFP: Energy dependence of DPE*

- **p-Pb with ALFA & AFP, low-μ** (μ=0.01-0.05)

  Probability of γ radiation increasing with Z

  - ALFA, ß* = 90: Exclusive VM production *Pb → Pb + γ; γ+p → p+J/Ψ or ρ^0*
    (also: ω, Y, 2π, 4π)
  - ALFA+AFP: General soft γ+p interaction *Pb → Pb + γ; γ+p → p+X*
    (for higher integrated luminosity, also: γ+p → p + jet + jet)
  - ALFA+AFP: Exclusive bremstrahlung: *Pb+p → Pb+p+γ*

→ *photon-Pomeron interaction at higher energies, transition to soft regime*