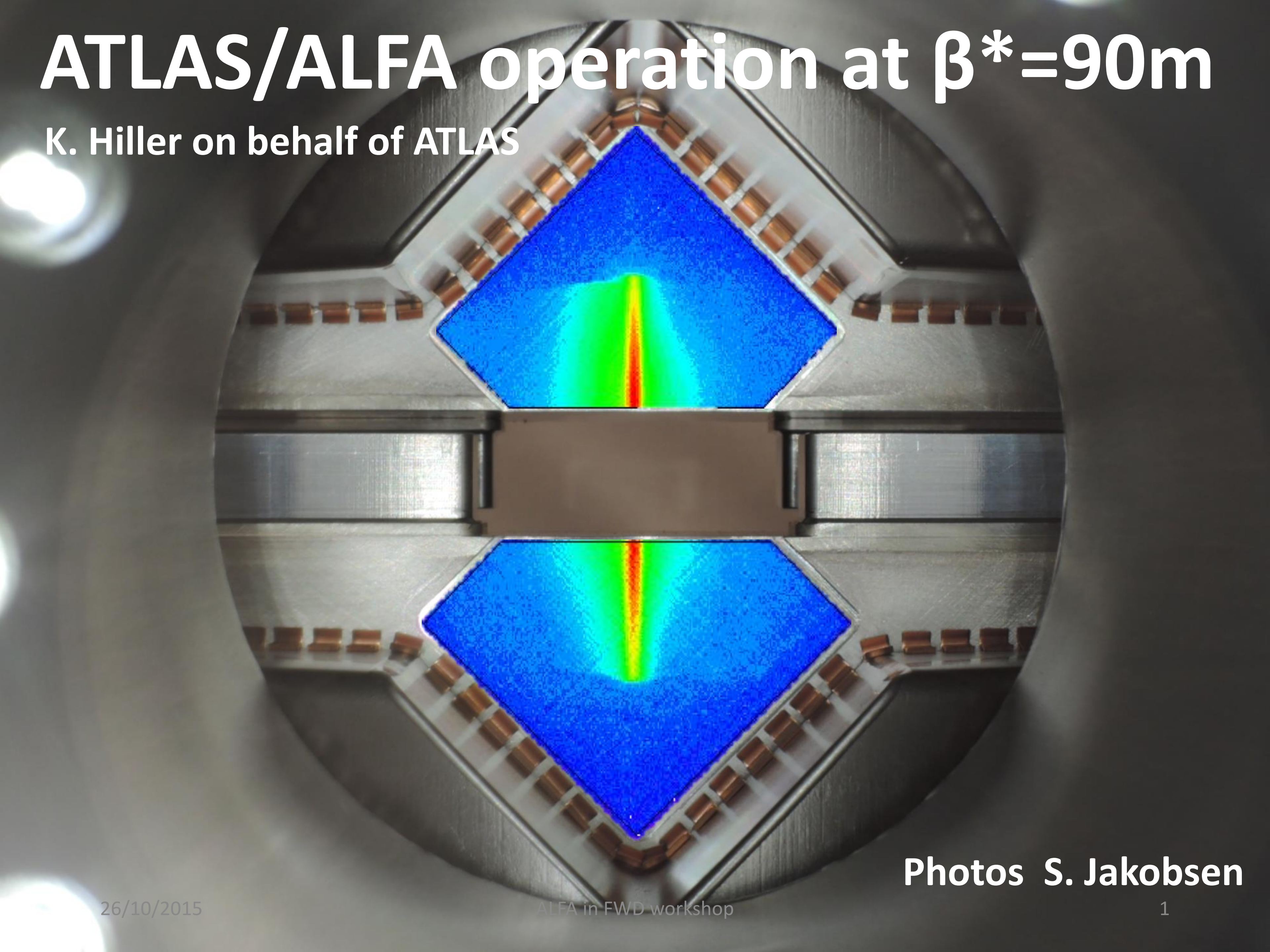
ATLAS/ALFA operation at β*=90m

K. Hiller on behalf of ATLAS

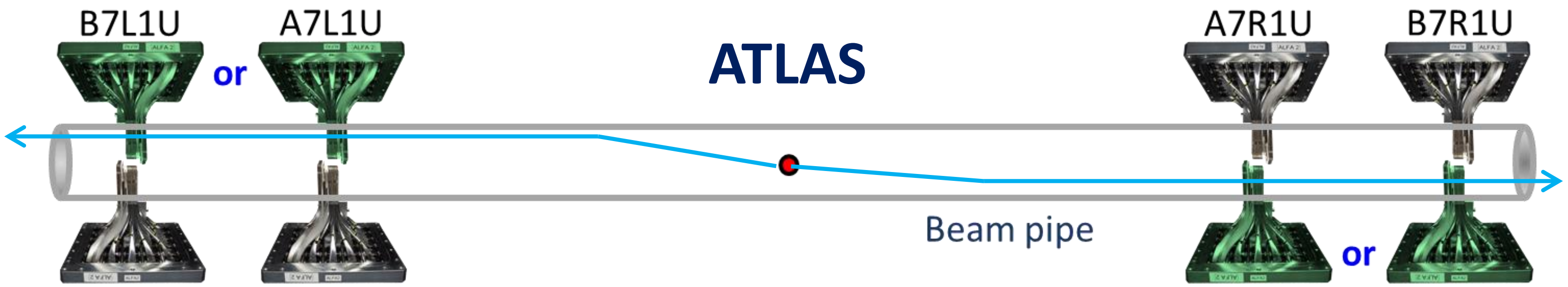


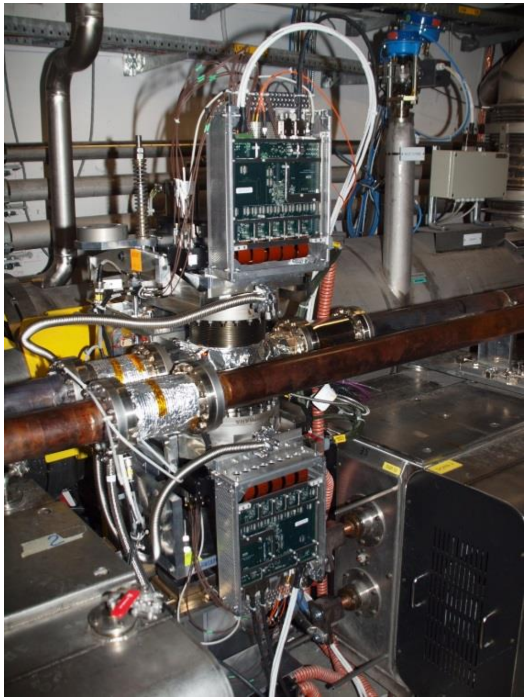
Photos S. Jakobsen

Outline of the talk:

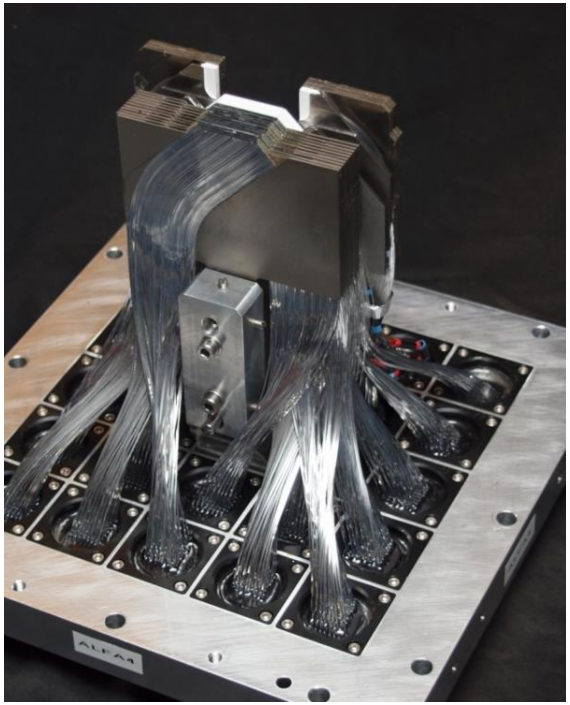
- Reminder about detector & physics
- 6 days of $\beta^* = 90$m running
- Physics prospects

The ALFA detector





- 2 x 2 stations
  ~ 240 m from ATLAS IP
- 8 fiber detectors with 2 x 10 layers of 0.5 mm quadratic fibers
- Movable in vertical direction
- Resolution ~ 35 µm



ALFA physics – elastics program

Measurement of luminosity and total cross section by elastic scattering at very low t

In dependence on t-range two options:

1. Only nuclear scattering and luminosity from ATLAS → σ_{tot}

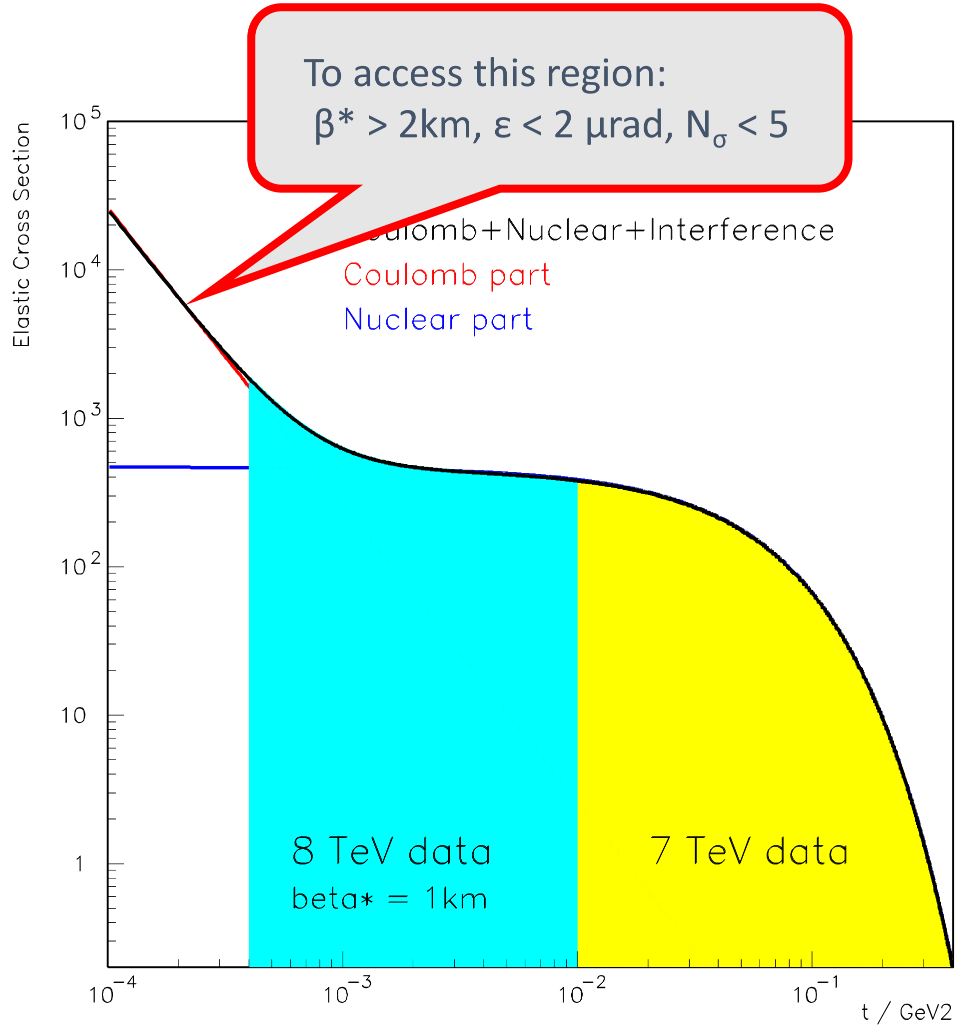
$$\frac{d\sigma}{dt} = \frac{1+\rho^2}{16\pi(\hbar c)^2}\sigma_{tot}^2 \exp(-Bt)$$

2. Coulomb + nuclear scattering: → Luminosity and σ_{tot}

$$\frac{dN}{dt} = L\pi|f_C + f_N|^2 \approx L\pi\left|-\frac{2\alpha}{|t|} + \frac{\sigma_{tot}}{4\pi}(i+\rho)e^{-b|t|/2}\right|^2$$

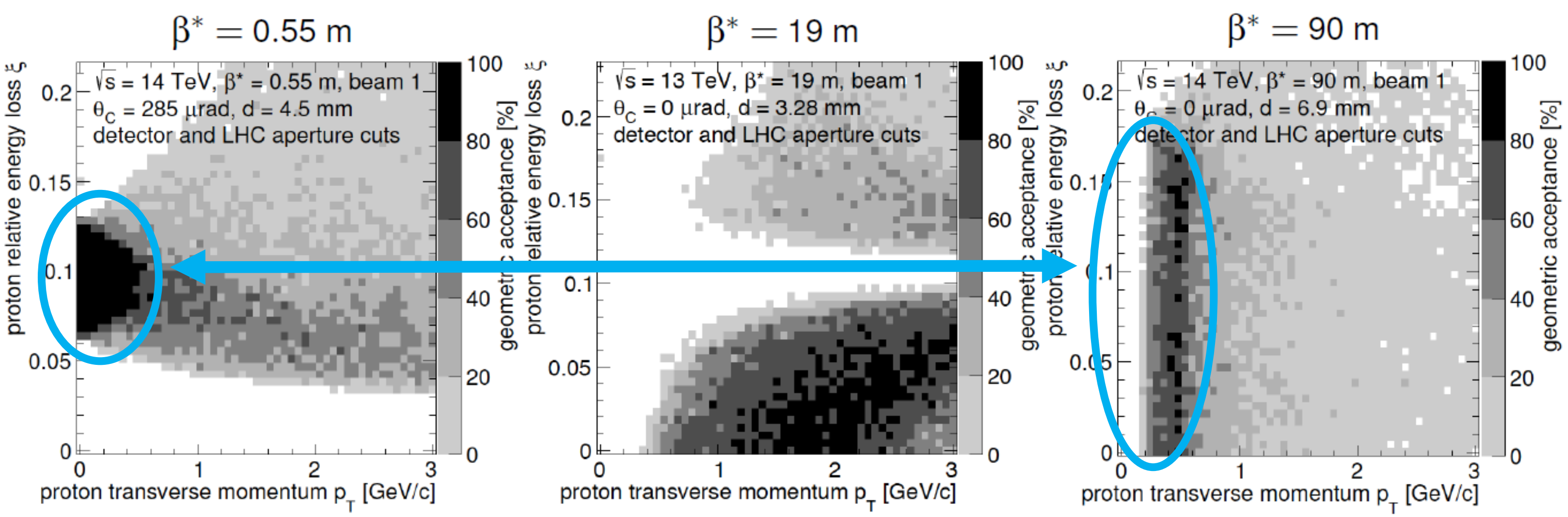
Key parameter: small t_{min} requires small emittance ε_N , close distance N_σ and large β*

$$t_{min} = m_p \quad p\frac{\varepsilon_N N_\sigma^2}{\beta *}$$



ALFA physics – diffraction

- Different beam optics allows access to different kinematic regions
- Many diffractive triggers ALFA + MBTS / LUCID / ID / calorimeters in the menu
- Contrary to standard β* = 0.55 m collision optics, β* = 90 m covers the full ξ-range



$(\xi \equiv 1 - E_{\mathrm{proton}}/E_{\mathrm{beam}})$

Potential analysis topics:

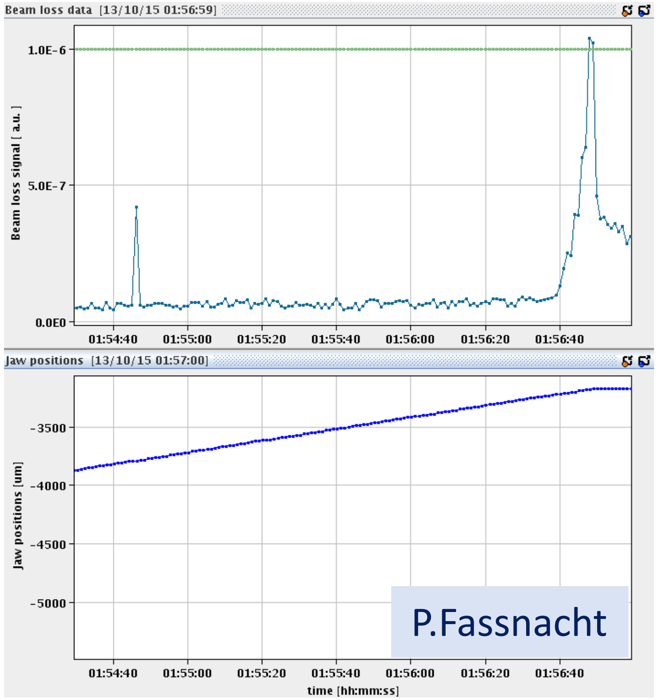
- Inclusive single diffraction: cross section, ξ / t – spectra
- Inclusive central production: ….
- Central exclusive production: double Pomeron / photon-Pomeron processes
- Hard diffraction with jets

6 days of β^*=90m running

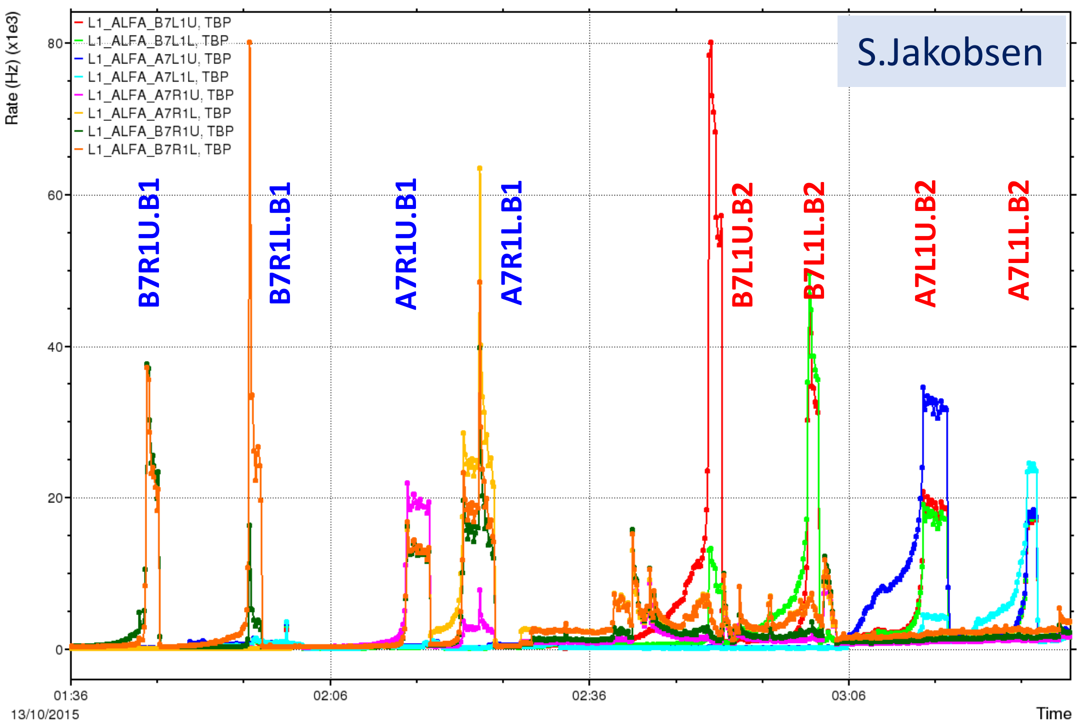
Day#1: beam based alignment

- Touch the beam edge with the Roman Pots to measure the center of the beam
- Necessary for machine protection, if detectors for physics are closest to the beam
- These positions violate the collimator hierarchy and are only allowed for low intensities

ALFA position and BLM signal



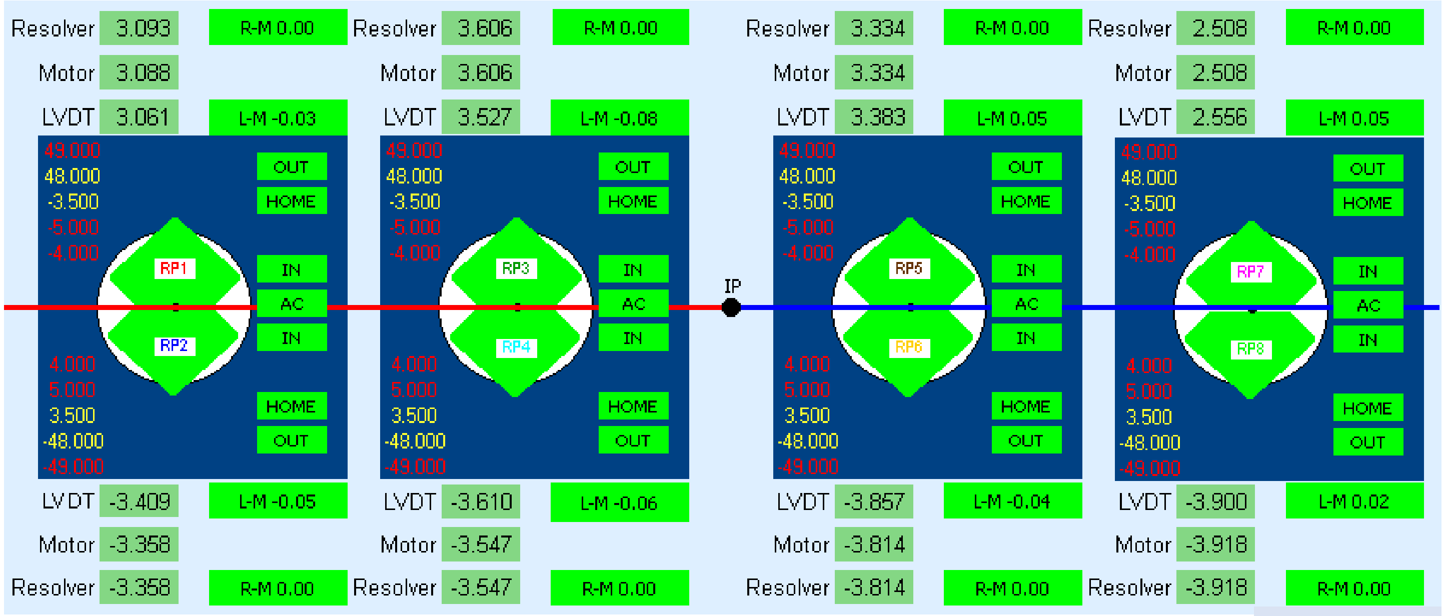
ALFA detector trigger rates during alignment



- All done after ~ 2.5 hours

Day#2: elastics part#1

- After the alignment the Roman Pots where moved to 4.5 $\sigma_{nominal}$
- But the background was too high, so the Roman Pots were moved out to 5.5 $\sigma_{nominal}$
- Detectors at 3 – 4 mm distance to the beam center, ~ 600 µm to the beam edge
- For luminosity cross check by vertex counting IBL was included in readout

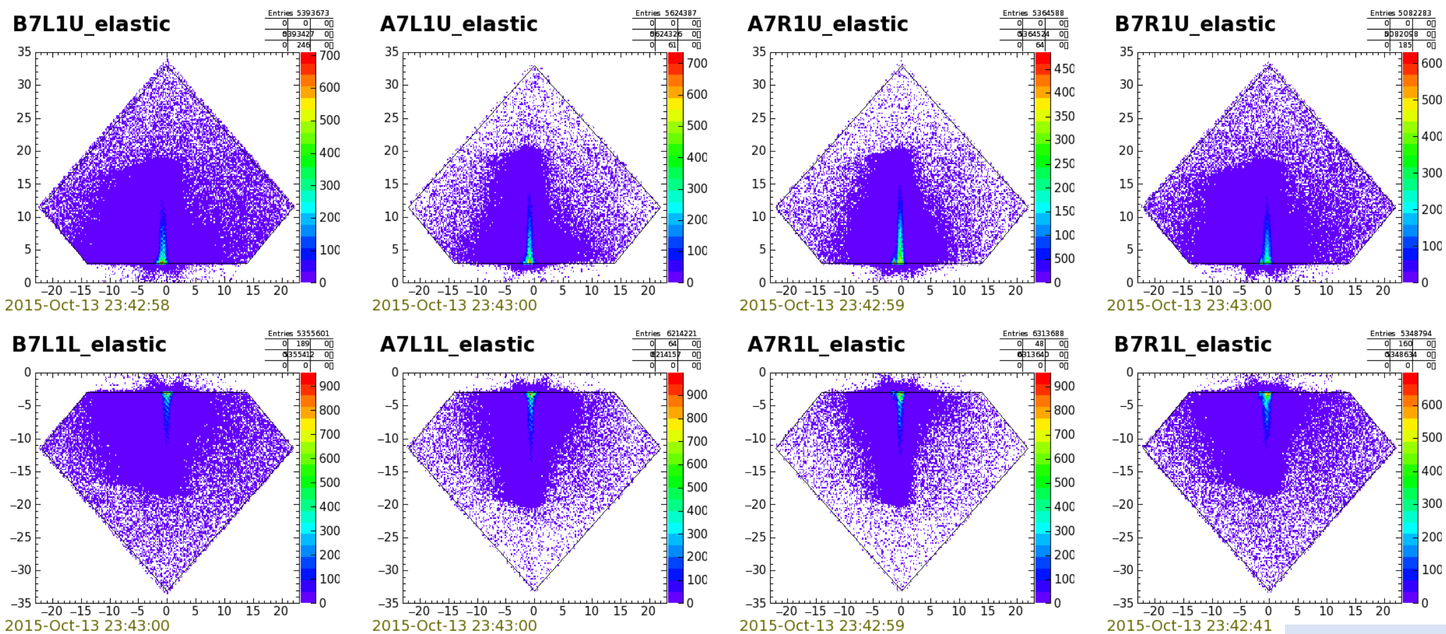


L.Seabra

- After about 2 hours beam was dumped by machine
- Collected: 17 million physics, 6.5 million elastic, 45 million calibration triggers
- Caveat: crossing angle 50 µrad not removed, alternative sample …

Day#2: elastics part#2

- Refill LHC with 3 bunches ~ 8E10 plus up to 10 pilot bunches ~ 1E10
- Move the Roman Pots again to 5.5 $\sigma_{nominal}$
- Follow data recording by farm processing for various groups of trigger items
- Now w/o IBL in readout to allow higher trigger and storage rates

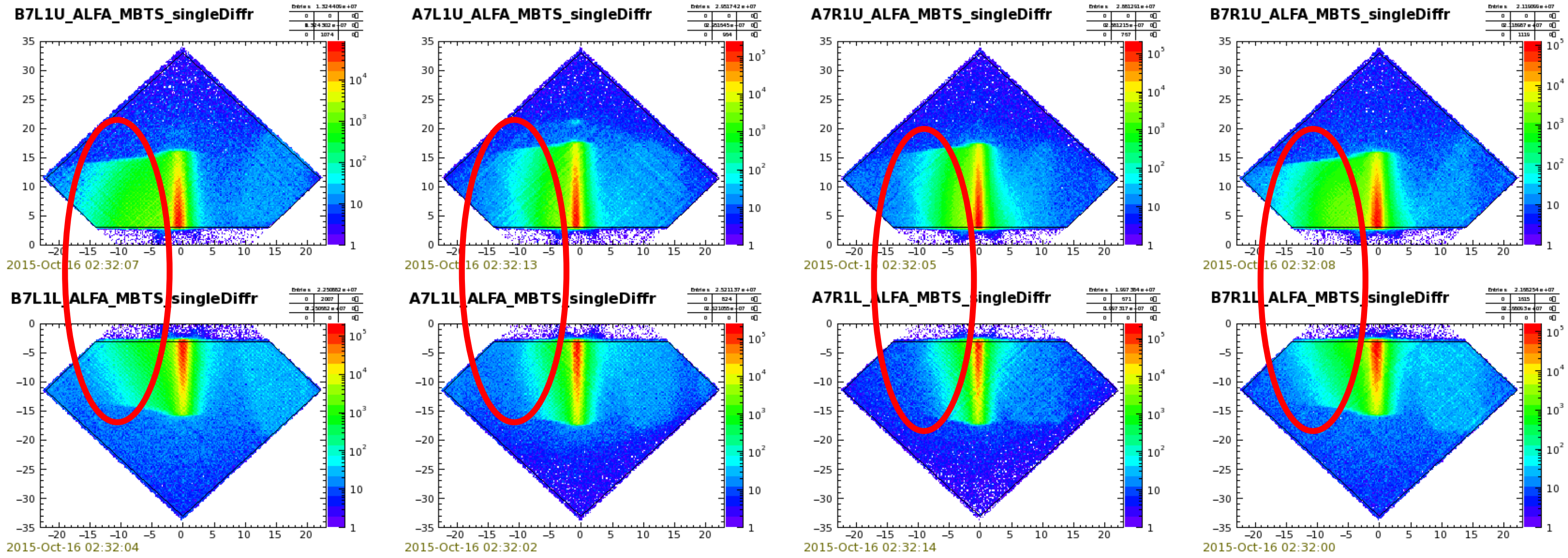


K.Korcyl

- After about 4.5 hours beam was dumped by operator !!!
- Collected: 40 million physics, 11 million elastic, 450 million calibration triggers
- Data w/o crossing angle for standard elastics analysis
- Qualification by loss map tests for Roman Pots at 10 σ successful, originally 12 σ

Day#3-6: diffraction

- Due to ALFA dead time min bunch spacing 100 nsec, allows max 700 bunches
- Unusual filling scheme, never before tested …
- Strategy for intensity ramp: 50 → 250 → 700 bunches
- Move all Roman Pots to 10 $\sigma_{nominal}$ (5-7 mm)
- Example: Online plots for single diffractive events combining ALFA & MBTS



K.Korcyl

Integrating over all 7 fills:

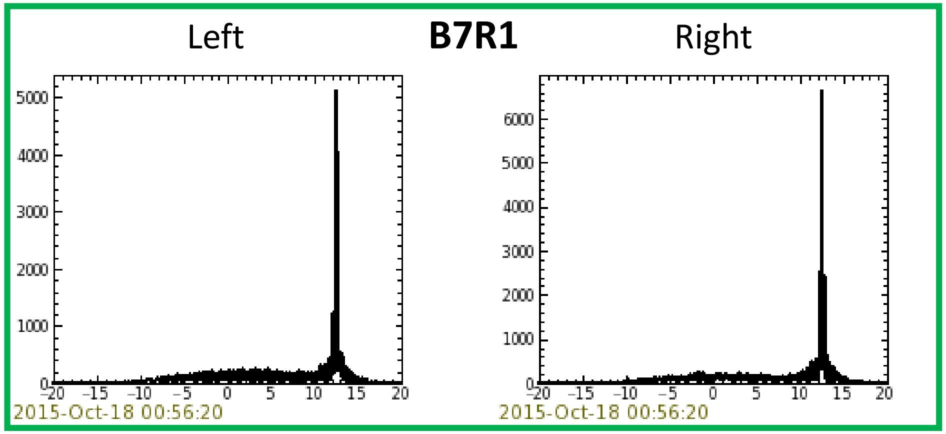
- LHC delivered: 735 nb-1
- ATLAS+ALFA in position recorded: 652 nb-1
- ATLAS+ALFA optimal: ~600 nb-1 (~82 % efficiency)

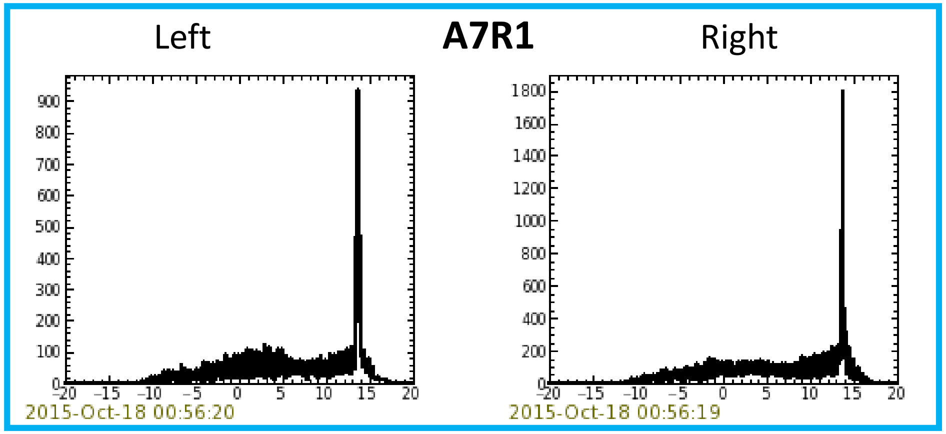
Online distance plots

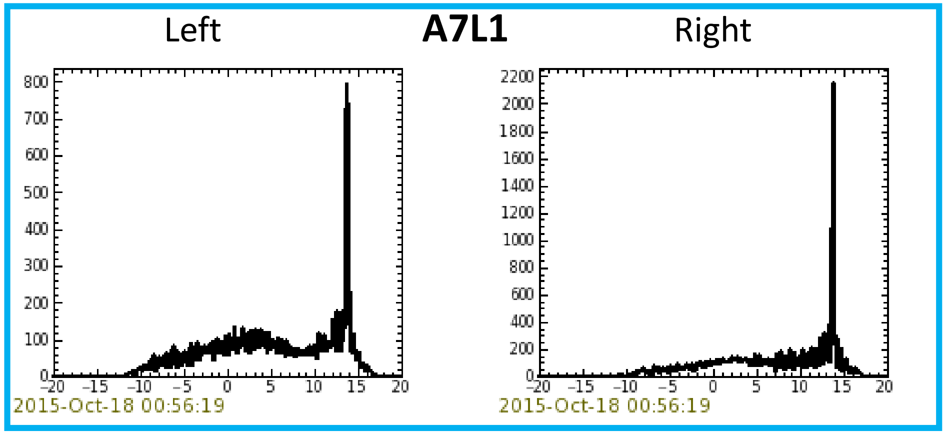
- The precise distance of upper and lower detectors is a key ingredient for the alignment
- Online plots could be used for a first estimates, during data taking it is a quality check
- Shown is the distance for the diffractive fill 4510, with Roman Pots at 10 $\sigma_{nominal}$

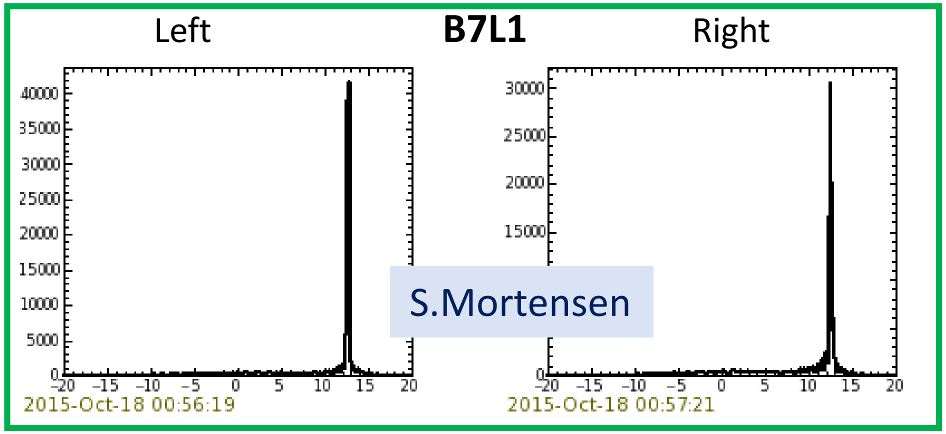
Outer stations

Inner stations







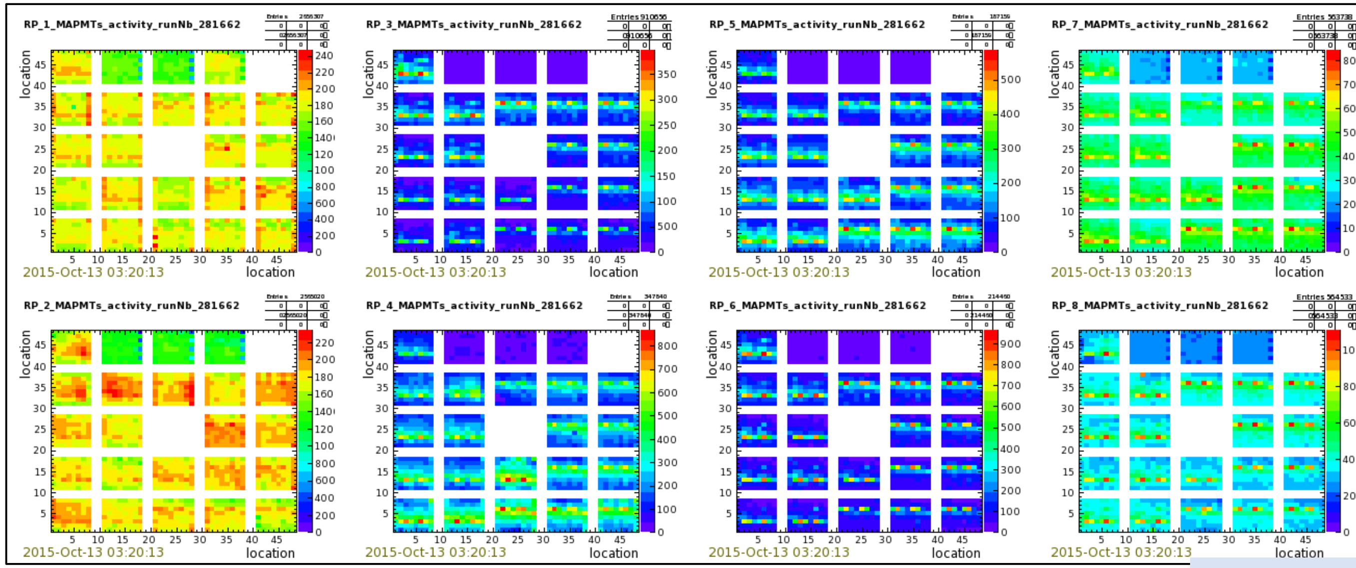


S.Mortensen

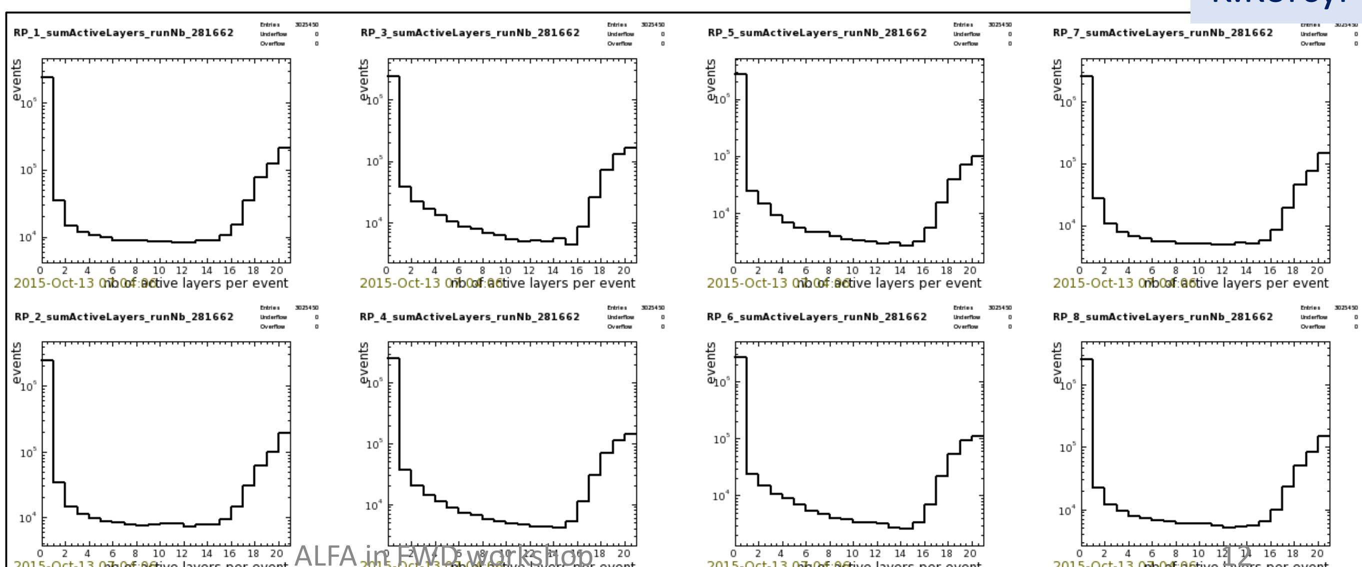
Data quality

In short: very good

- All MAPMTs alive (2holes hardware)
- Good tracking quality indicated by peak at 20 layers (peak at 0: other detector triggers)
- Failures: 5 single event upsets due to radiation (FE not rad-hard)
  - 2 PMF/layer lost
  - 2 trigger PMF lost
  - 1 motherboard lost



K.Korcyl

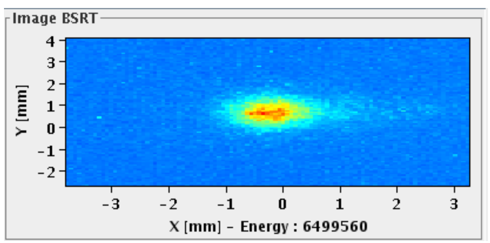


Emittance in elastic part#2

Emittance sets the overall scale of the t-resolution

Two types of feedback:

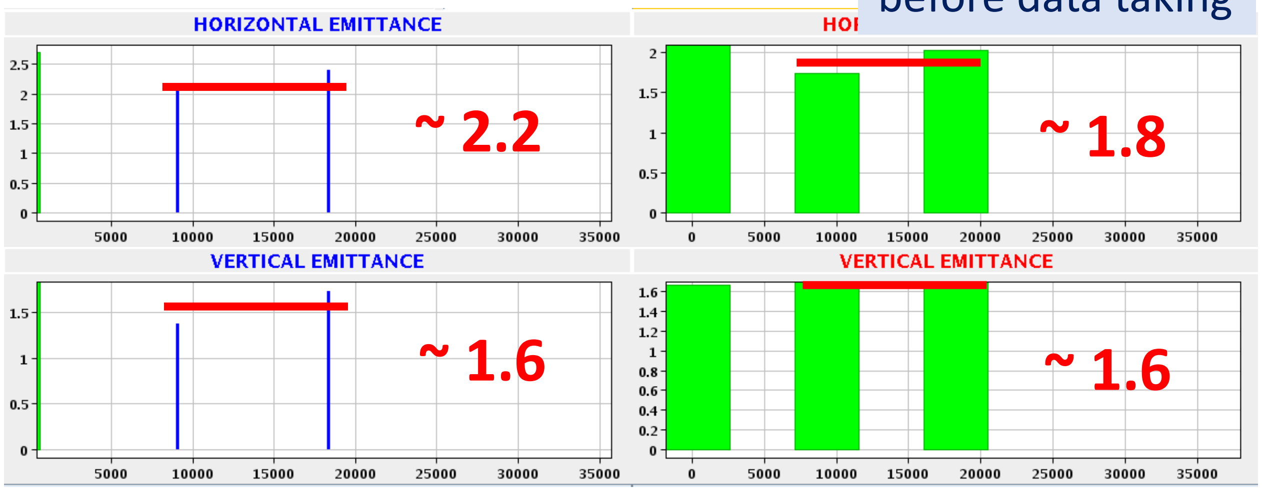
- wire scans
- synchrotron radiation
  = BSRT



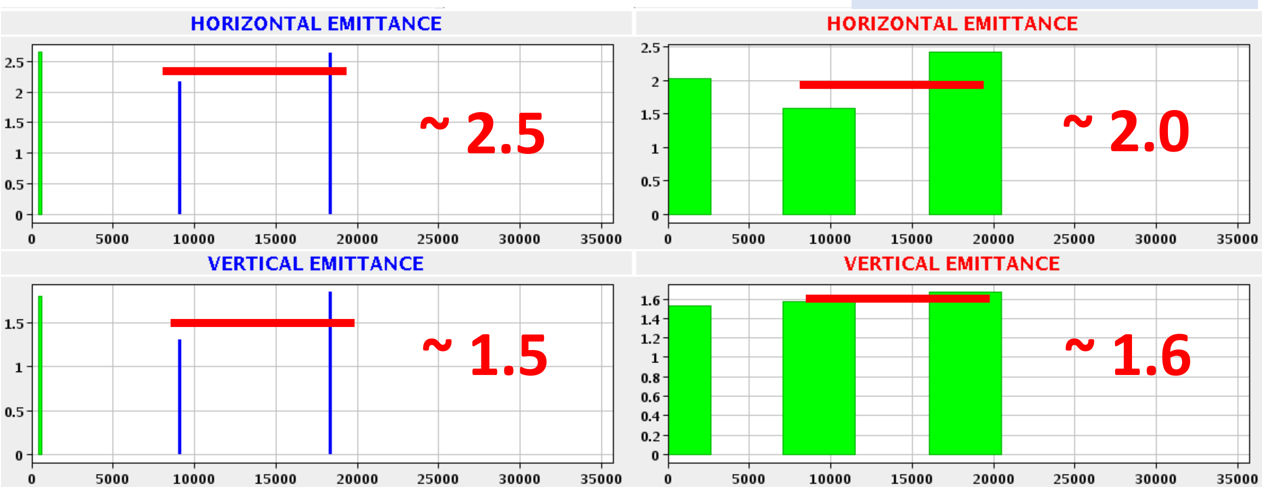
Many measurements done in all stages of the run

Typical values ~ 2 µrad, growth a few 0.1 µrad

before data taking

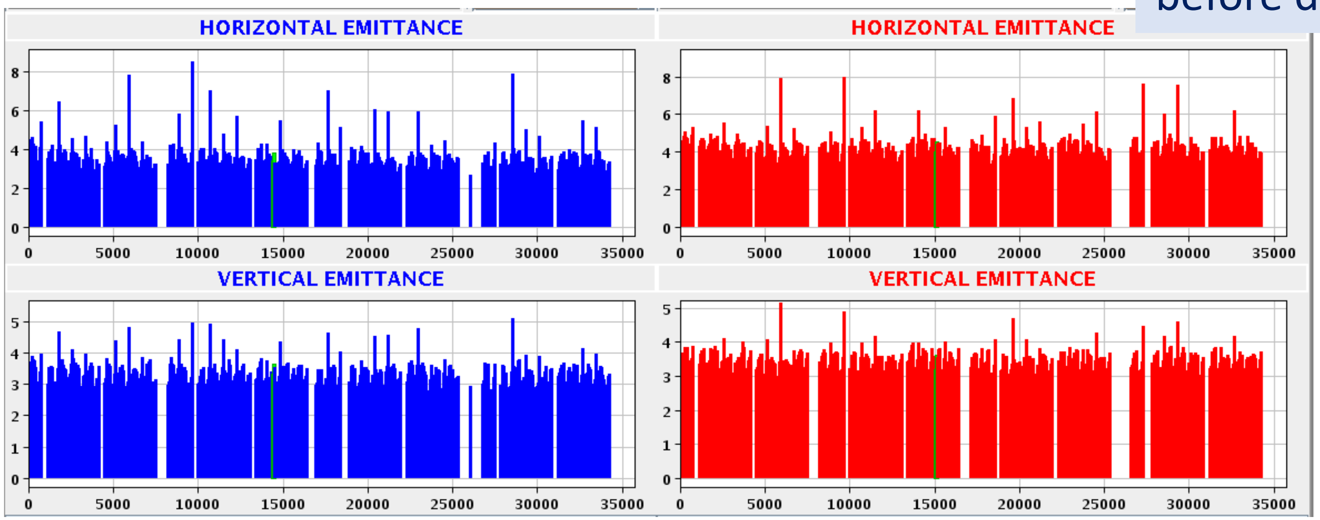


end of data taking

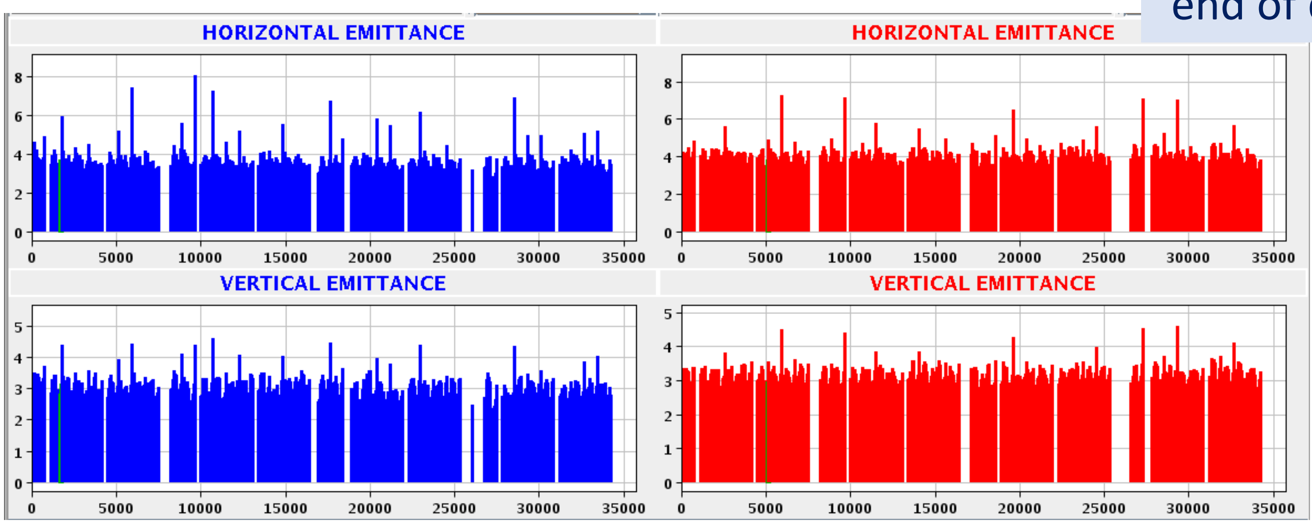


Emittance in diffractive fill#5

before data taking

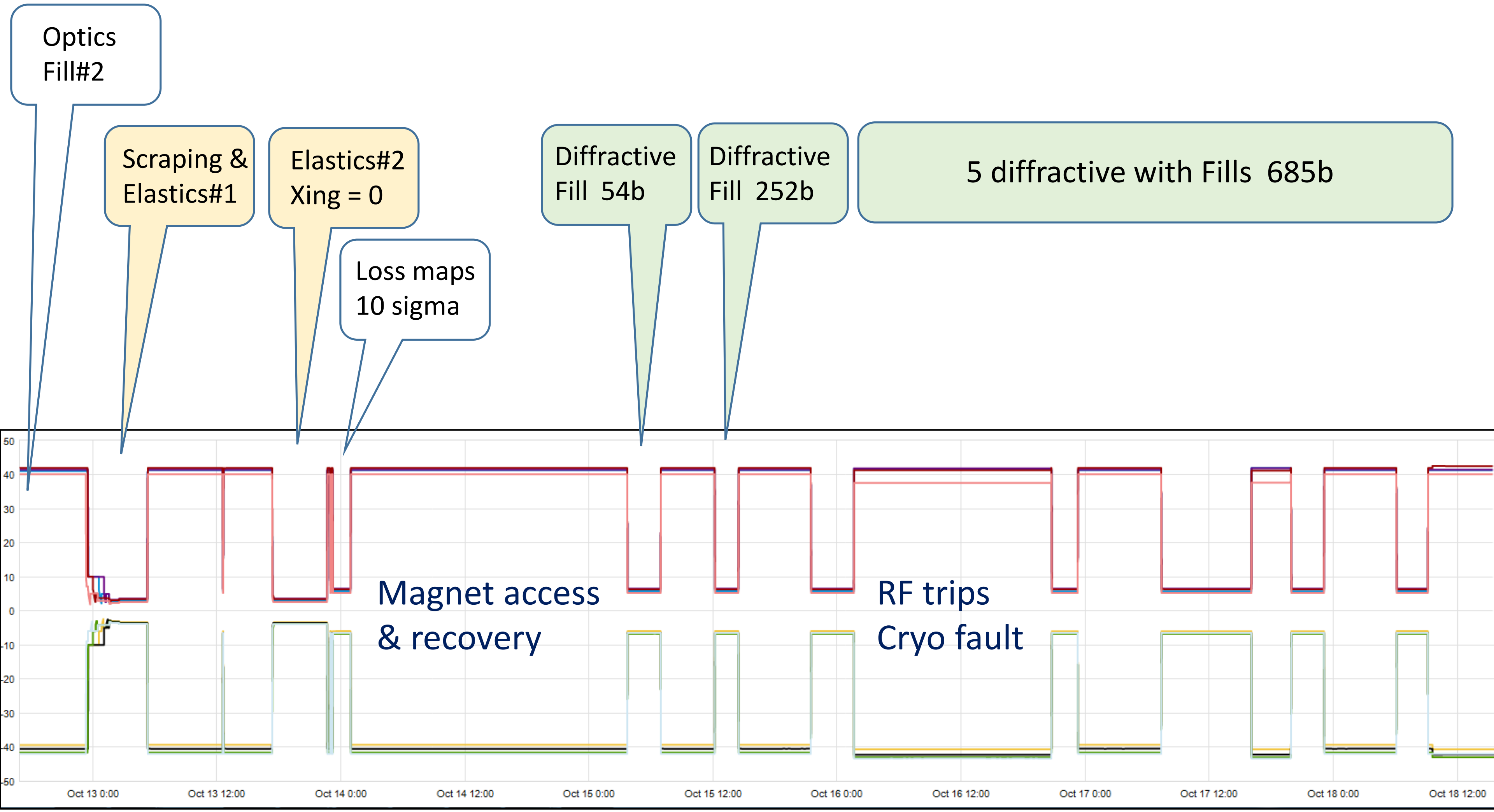


end of data taking



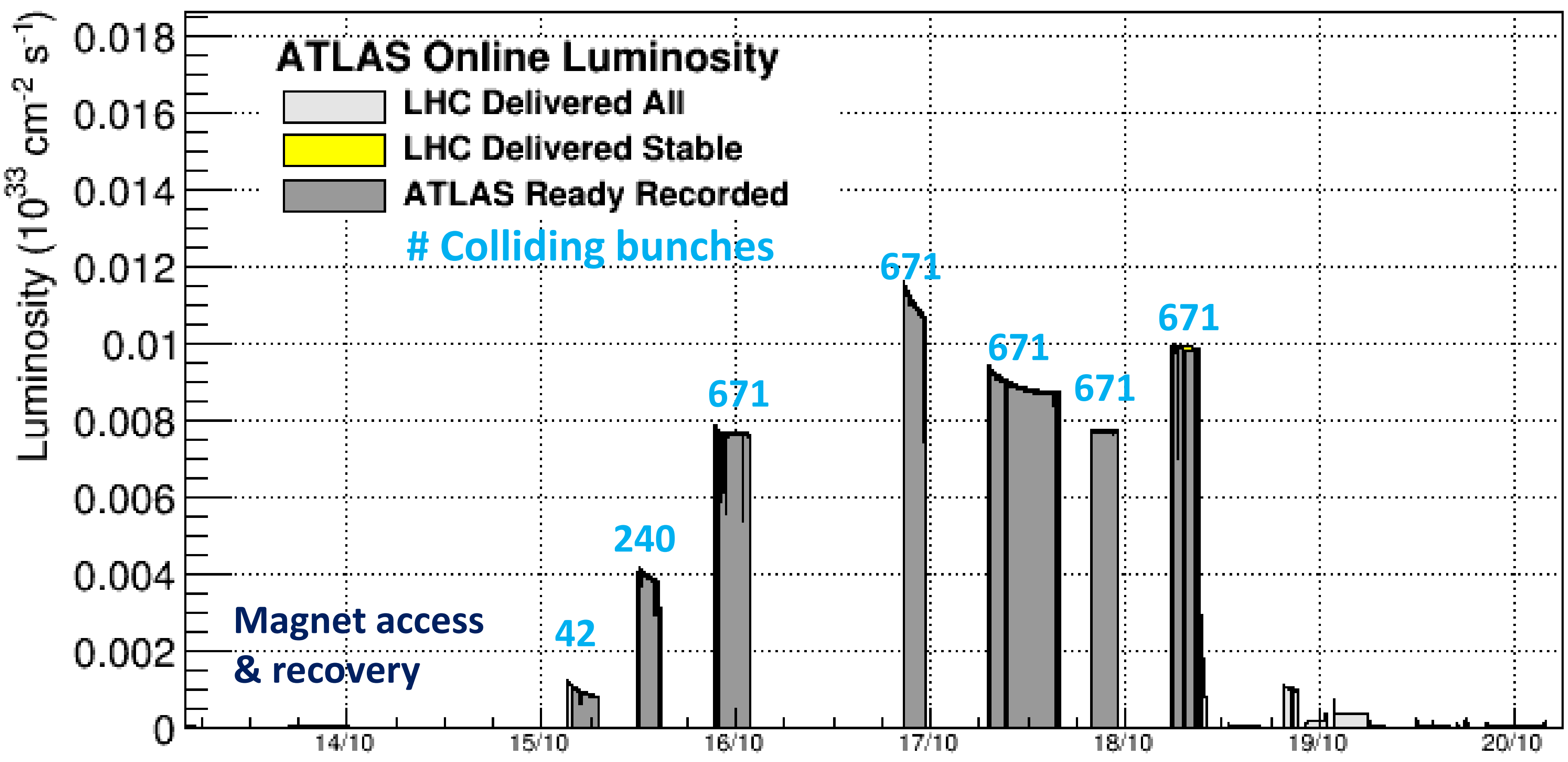
Typical values
3-4 μrad,
growth is small

Time line all 90m fills



Monday 8:00 → **Sunday 12:00**

Luminosity profile diffractive fills



- Typical duration 2-4 hours per fill, longest fill ~ 9 hours
- In total about 34 hours of data taking in a period of 6 days + 6 hours

Summary of good fills

Fill #	Bunches colliding	Stable*) beam	Peak lumi	Int. lumi [nb-1]	Physics goal	Dump
4489	2	1h55	3.0e28	202 µb-1	elastics	PC fault
4491	2	4h17	4.0e28	545 µb-1	elastics	OP dump
4495	42	3h32	1.1e30	11	diffraction	OP dump
4496	240	2h39	4.2e30	36	diffraction	OP dump
4499	671	4h12	7.7e30	115	diffraction	Cryo PLC
4505	671	2h40	1.2e31	103	diffraction	QPS
4509	671	8h47	9.4e30	280	diffraction	QPS
4510	671	3h15	7.8e30	88	diffraction	EE spurious
4511	671	3h33	1.0e31	122	diffraction	OP dump

*) for elastics "quiet beams", RPs close

Integrated luminosity with ATLAS ready:

- Elastic fills 747 µb-1
- Diffractive fills: 735 nb-1, ALFA IN 652 nb-1 (efficiency ~ 89%)

Physics prospects

Standard analysis 13 TeV

Elastic & total cross section via optical theorem:

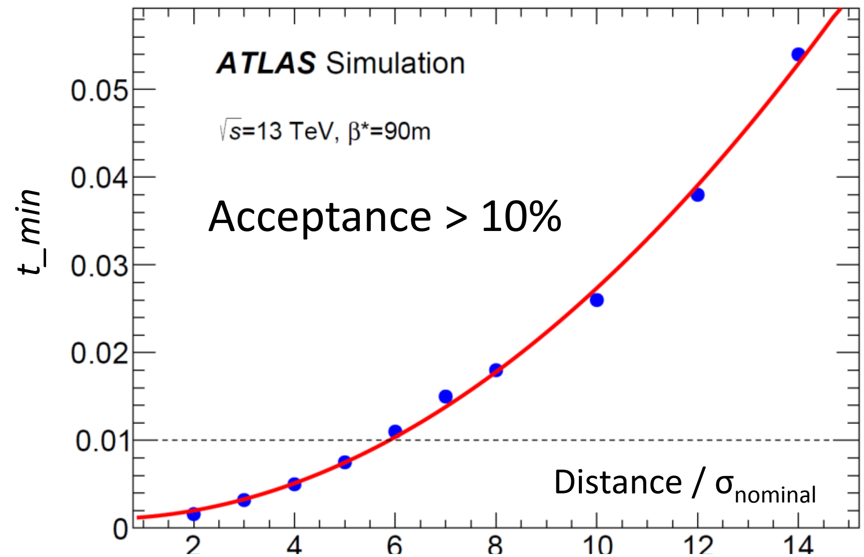
$$\sigma_{\text{tot}}^2 = \frac{16\pi}{1+\rho^2}\frac{1}{\mathcal{L}}\frac{dN}{dt}\bigg|_{t\to 0}$$

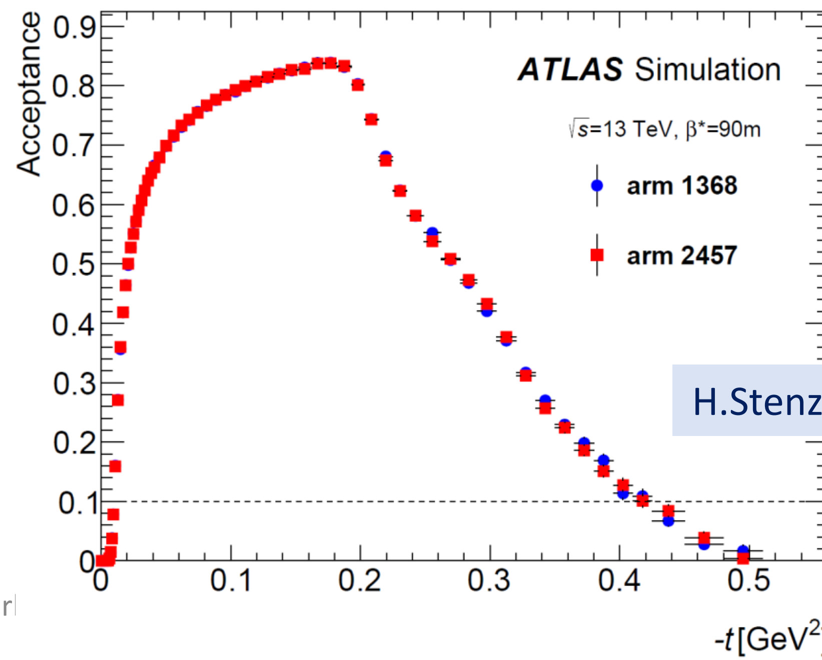
Conditions evolution Run1 → Run2:

- Distance 6.5/9.5 → 5.5 $\sigma_{nominal}$
- Emittance H/V 2-4/2 → 2-2.5/1.5 µrad
- At 5.5σ t_{min} ~ 0.01 GeV2 for acceptance > 10%, similar as for 7/8 TeV data

Precision:

- At 7TeV luminosity dominant contribution: $\Delta L/L = 2.4\%$ → $\Delta\sigma_{el}/\sigma_{el} = 2.5\%$, $\sigma_{tot} = 1.4\%$
- Luminosity for 13 TeV data pending, but probably again the dominant value …





Alternatives for σ_{tot}

1. **Adding elastic and inelastic cross sections** (ρ-independent method):

- Can be done with two independent measurements
- MBTS 13 TeV: σ_{inel} = 73.1 ± 0.9 (exp) ± 6.6 (lum) ± 3.8 (extr) mb (→ MBTS talk tomorrow B.D. Axen)
- An error estimate based on ALFA elastic result σ_{el}(7TeV) = 24.0 ± 0.6 mb and MBTS inelastic gives: **$\Delta\sigma_{tot}/\sigma_{tot}$ ~ 8%**
- In case of 2% luminosity error it will be reduced to: **$\Delta\sigma_{tot}/\sigma_{tot}$ ~ 5%**
- Dominant contribution is the uncertainty for extrapolation beyond ξ < 10E-6

2. **Combining elastic and inelastic rates** (luminosity-independent method):

$$\sigma_{\rm tot} = \frac{16\pi(\hbar c)^2}{1+\rho^2} \frac{{\rm d}N_{\rm el}/{\rm d}t|_{t=0}}{N_{\rm el}+N_{\rm inel}}$$

- All MBTS-triggers enabled to measure elastic and inelastic rate at the same time
- For 7 TeV the contributions from the optical point and the elastic rate are < 1%
- Neglecting these errors the dominant uncertainty is due to the inelastic rate ξ < 10E-6
- Using above quoted MBTS results one obtains: **$\Delta\sigma_{tot}/\sigma_{tot}$ = ~ 4%**

Bottom line: the luminosity-dependent method gives by far the most precise result, 1.4% for 7 TeV, but alternative approaches are useful as long as precise luminosity is unknown

Summary

Data taking:

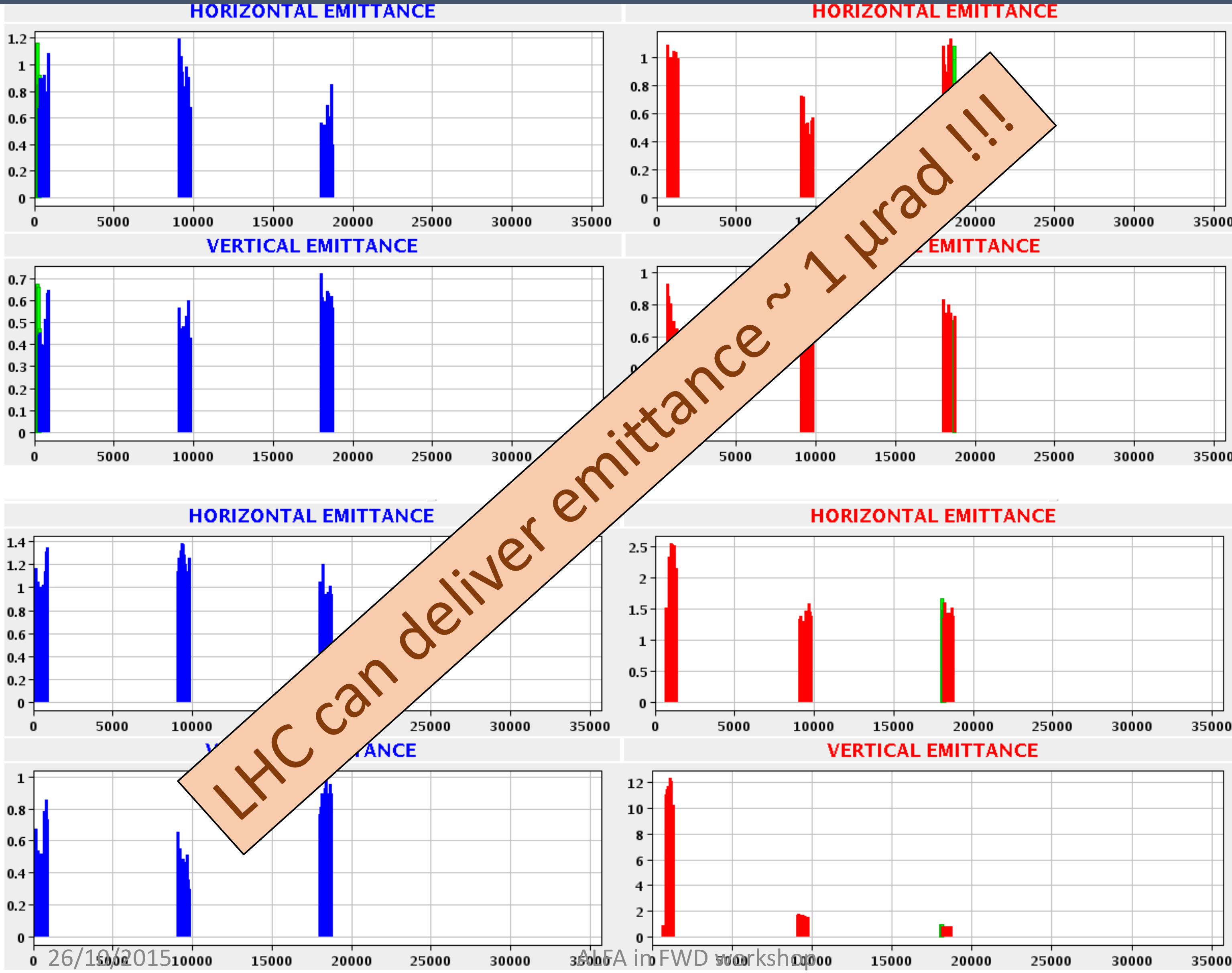
- ALFA/ATLAS had a very good 90m campaign w/o major hardware failures
- More luminosity collected compared to Run1:
  - elastics runs 7/8 TeV: 80/500 µb-1 → 13 TeV: 650µb-1
  - diffractive runs 7/8 TeV: 0.1/37nb-1 → 650 nb-1
- Also other parameters, distance and emittance, slightly better
- All the time shifter in CCC to react quickly on changing conditions

Physics prospects:

- Good chance to get t_{min} for fits of nuclear term around 0.01 GeV2, as for 7 TeV
- Start with analysis of 13 TeV data as soon as 8 TeV analysis finished
- In parallel a young investigator group take care for 8 TeV / β* = 1km data
- Diffractive analyses: we expect soon to finish exclusive pion production at 7/8 TeV
- For 13 TeV diffractive data the spectrum of analysis topics is much wider
- In YETS the magnet cables for Q4 will be installed to allow more phase space for optics to achieve β* > 2 km
- The plan for 2016 is commissioning and data taking with β* > 2 km

Backup slides

Emittance in diffractive fill#1/54b

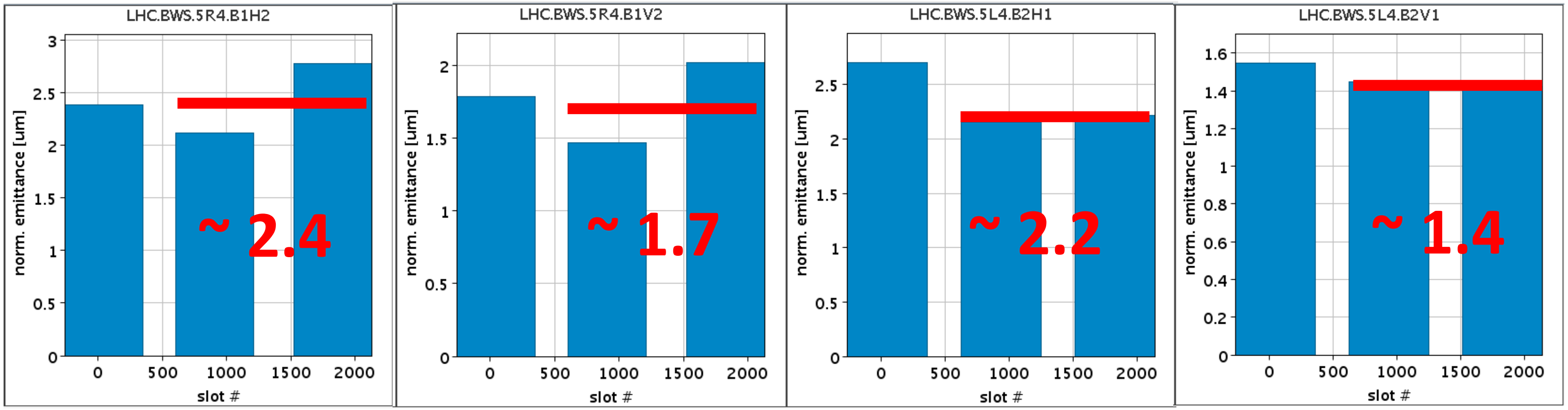


Before Data taking

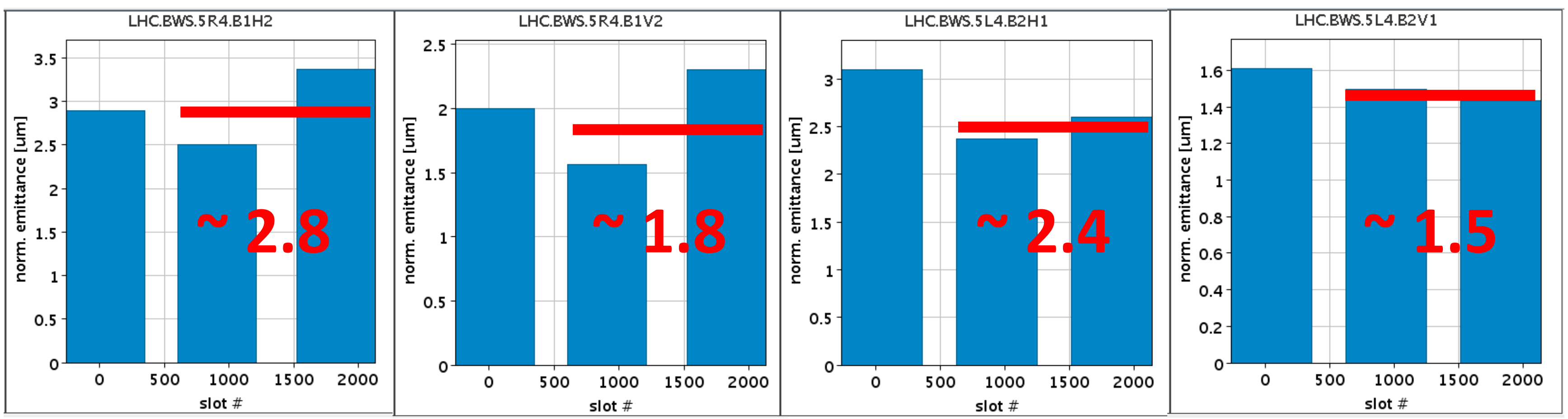
After Data taking

Emittance in elastics part#1

Wire scans just before physics data taking – beam1 , beam2



Wire scans just before end of physics data taking – beam1 , beam2



➔ Typical emittance ~ 2 µrad, growth after 2 hours ~ a few 0.1 µrad