Wire scanner optimization

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Student Session

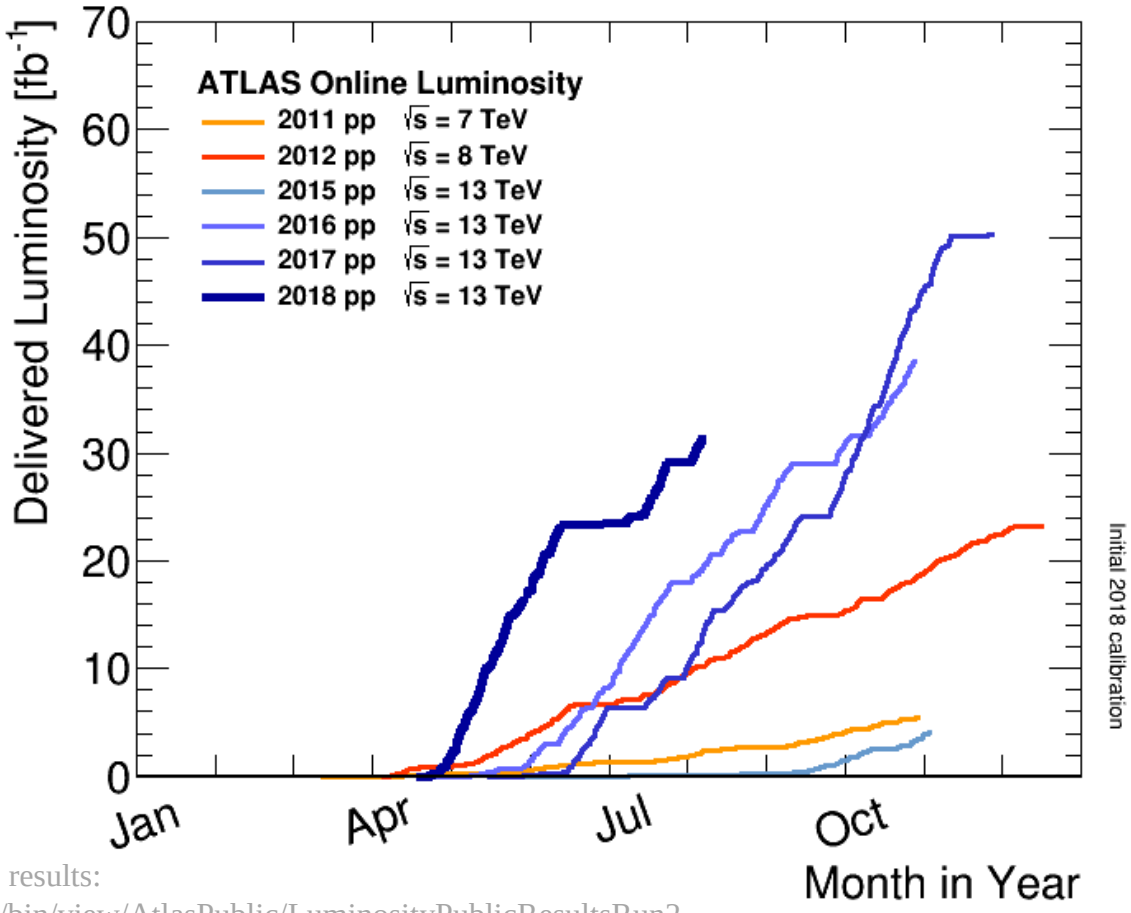
7.8.2018

Outline

- Motivation
- Emittance
- Wire scanner
- Beam profile measurements
- Conclusion

Motivation - HL-LHC upgrade

- The HL-LHC upgrade aims to increase the integrated luminosity by one order of magnitude (~350 fb^{-1}).



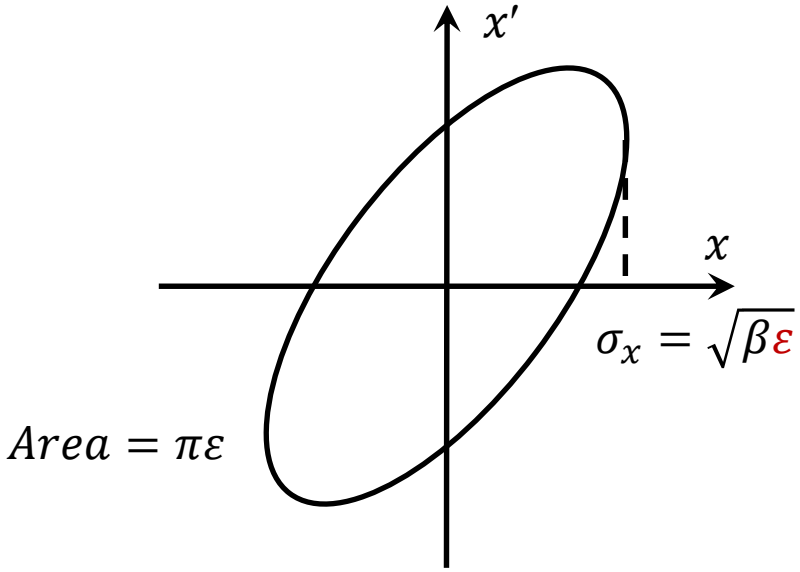
Atlas experiment – public results:
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LuminosityPublicResultsRun2

Motivation - HL-LHC upgrade

- For this the **PSB** will have to deliver two times the current brightness (B)

$$B = \frac{2I}{\pi^2 \varepsilon_x \varepsilon_y},$$

- where I is the beam intensity (number of particles) and $\varepsilon_{x,y}$ is the transverse emittance of the beam.



Motivation – HL-LHC injector upgrade

- The brightness of the LHC beam is defined in the **PSB**.

$$B = \frac{2I}{\pi^2 \varepsilon_x \varepsilon_y}$$

- Because the minimal emittance is set in the **PSB** and it can only grow after this.
- Therefore, emittance is a key parameter for retaining high brightness and it has to be carefully monitored to be able to identify eventual emittance blow-up.
- For the HL-LHC upgrade the maximum allowed emittance growth from PSB to PS is 5%, which imposes stringent constrains on the instrumentation performance.

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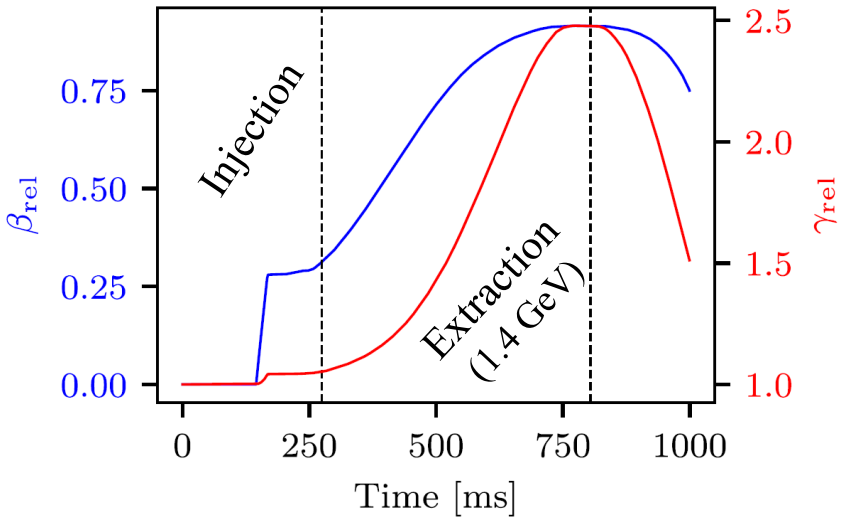
→ **Measurement optimization is needed!**

Emittance

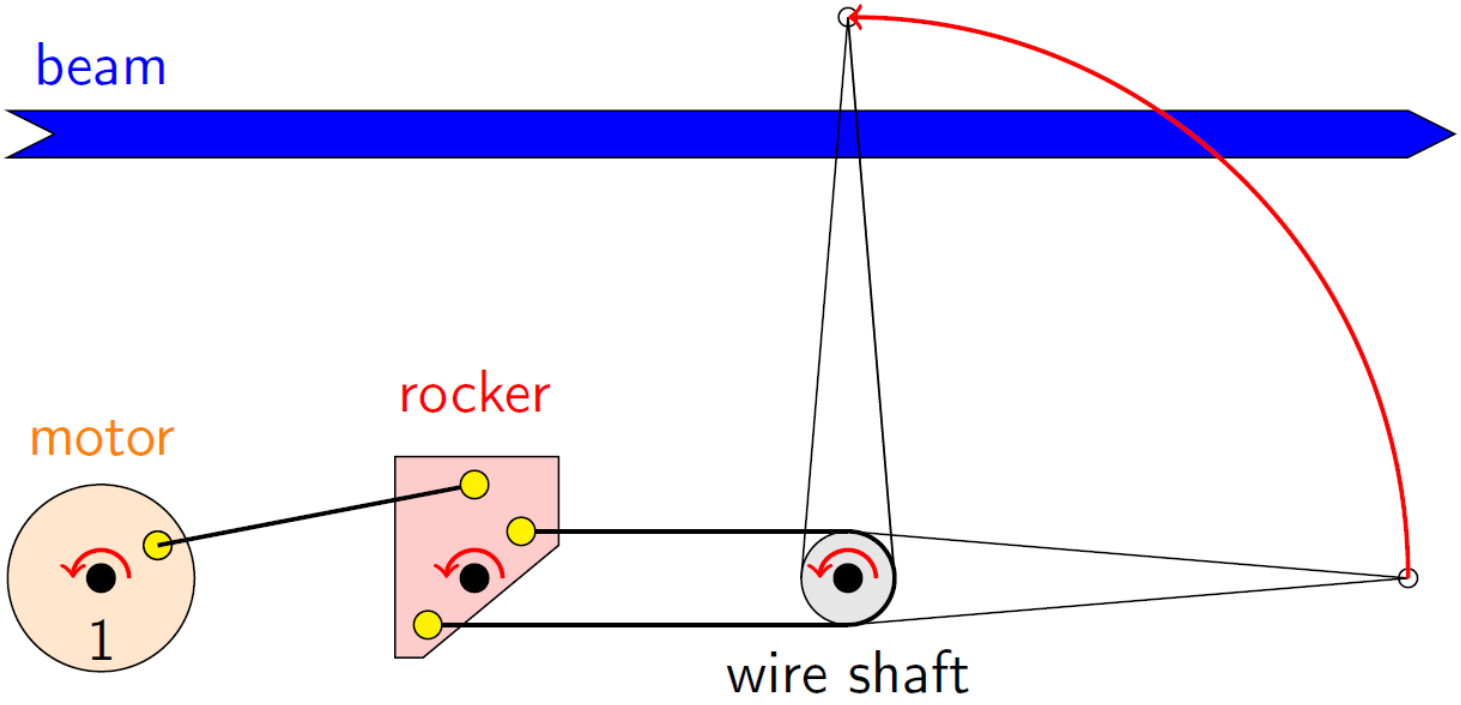
$$\varepsilon_{x,y} = \left(\frac{\sigma_{x,y}^2 - D_x^2 \delta^2}{\beta_{x,y}} \right) \beta_{rel} \gamma_{rel}$$

- **Observables:** $\sigma_{x,y}$ → Beam profile - Measured with **wire scanners**
  δ → Momentum spread ($\frac{\Delta p}{p} \approx 10^{-3}$) - Measured
- **Simulation:** D_x → Dispersion function
  $\beta_{x,y}$ → Beta function
  } Calculated with MAD-X*

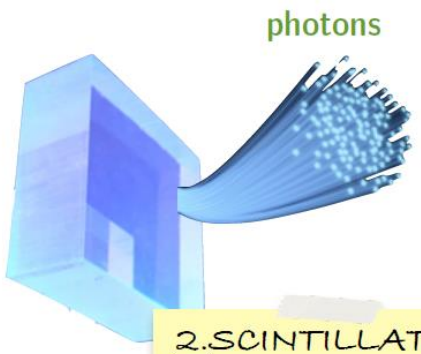


*Methodical Accelerator Design

Wire scanner - Principle

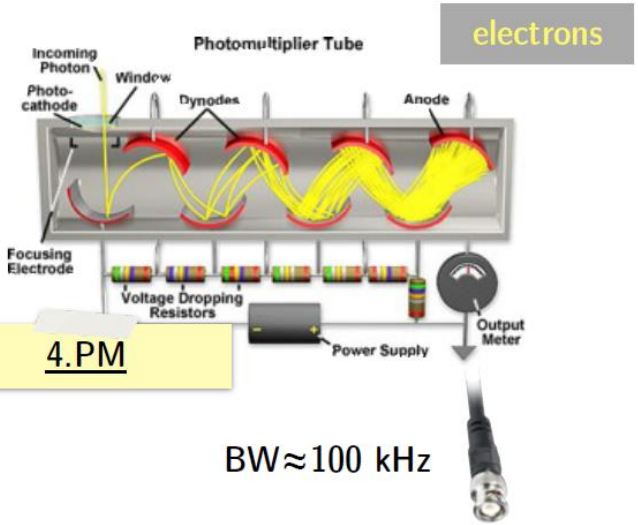


Wire scanner - Principle



2.SCINTILLATOR

3.FILTER

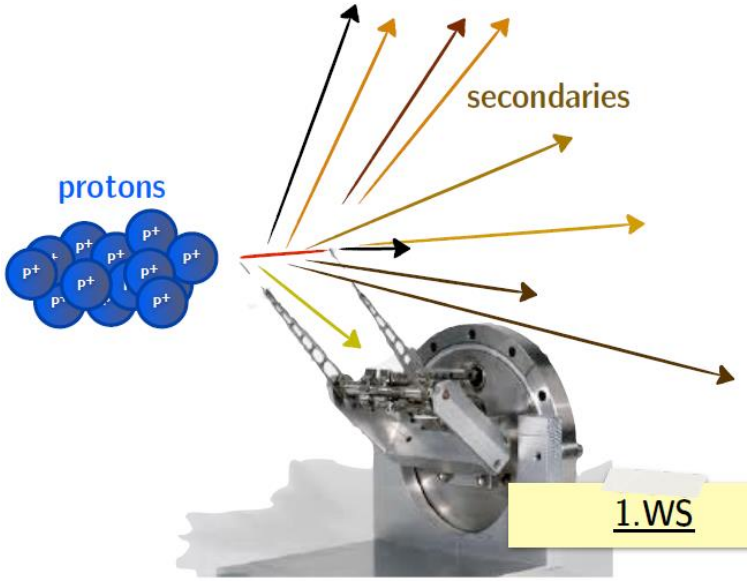


4.PM

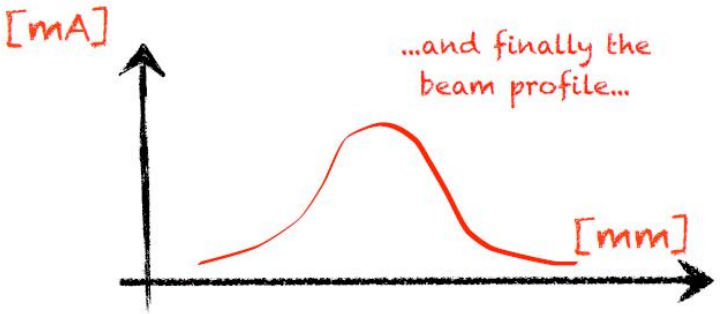
electrons

BW≈100 kHz

5.ADC+SERVER



1.WS



Wire scanner - Settings

Ring	Plane	Wire speed	Filter	Photomult-iplier gain
• 1 • 2 • 3 • 4	• Horizontal • Vertical	• 10 m/s • 15 m/s	• 0% x 2 • 0.2% • 0.5% • 2% • 5% • 20% • 100%	• 0% - 1000%

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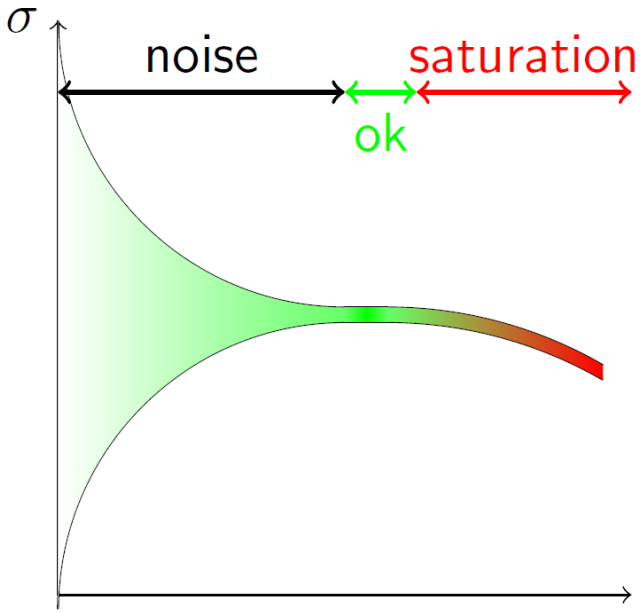
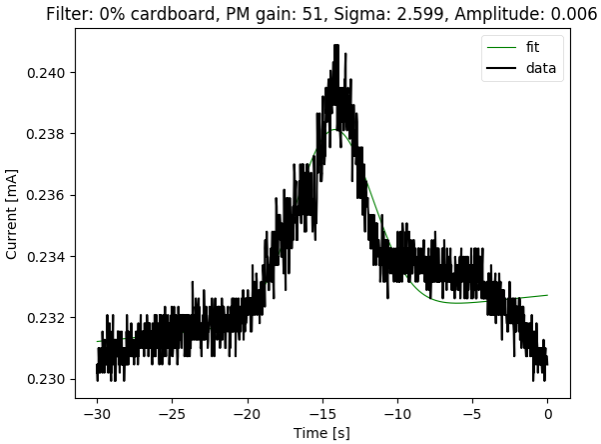
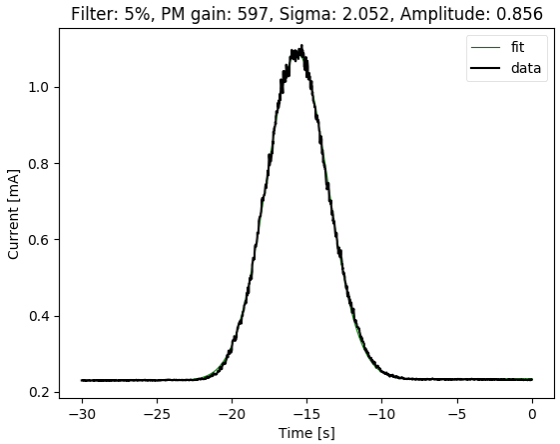
1 × 1 × 2 × 8 × 20

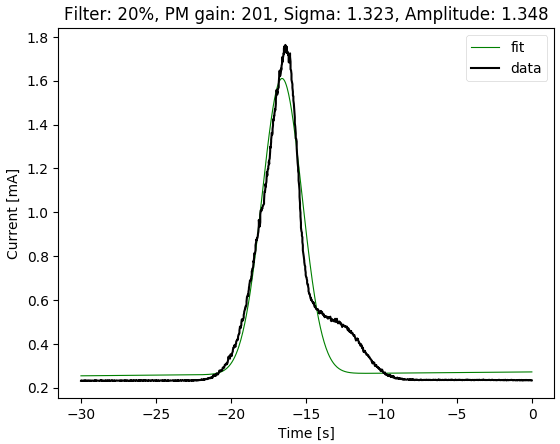
= 320 measurements, 1 measurement ~ 90 sec => 8 hours

Beam profile measurements - Saturation



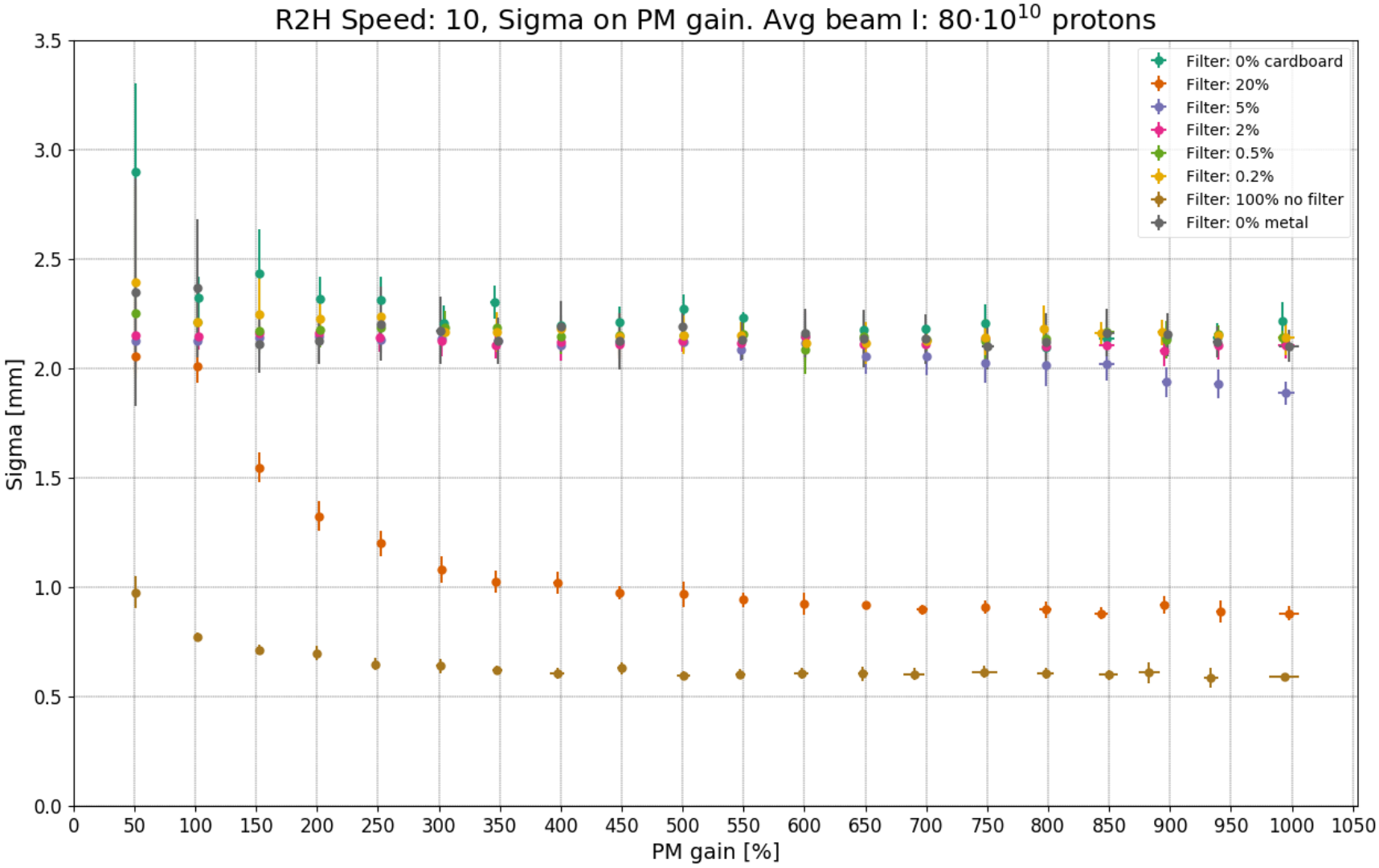




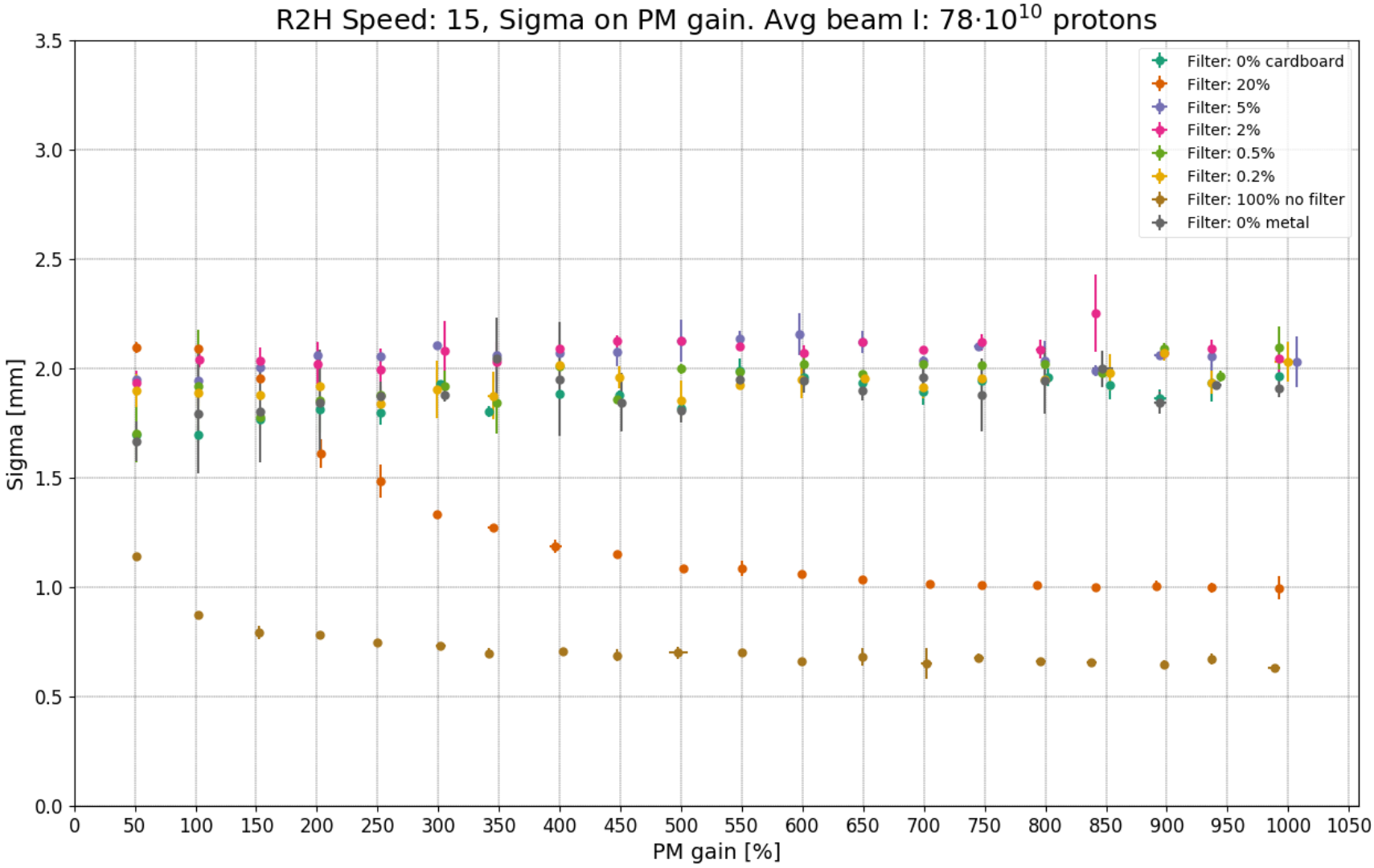


G. Sterbini, A. Guerrero, S. Gilardoni - An overview of the beam-based measurements using the PS wire scanners

Beam profile measurements



Beam profile measurements



Beam profile measurements

- Empirical formula describing intensity of the beam measured by the WS

Gain

$$I_{rec} = k(E_{kin}) \times V^7 \times TX_{filter} \times \frac{1}{v_{WS}} \times I_{beam}$$

I_{rec} - Beam intensity seen by the WS

$k(E_{kin})$ - Empirical parameter dependent on kinetic energy of the beam

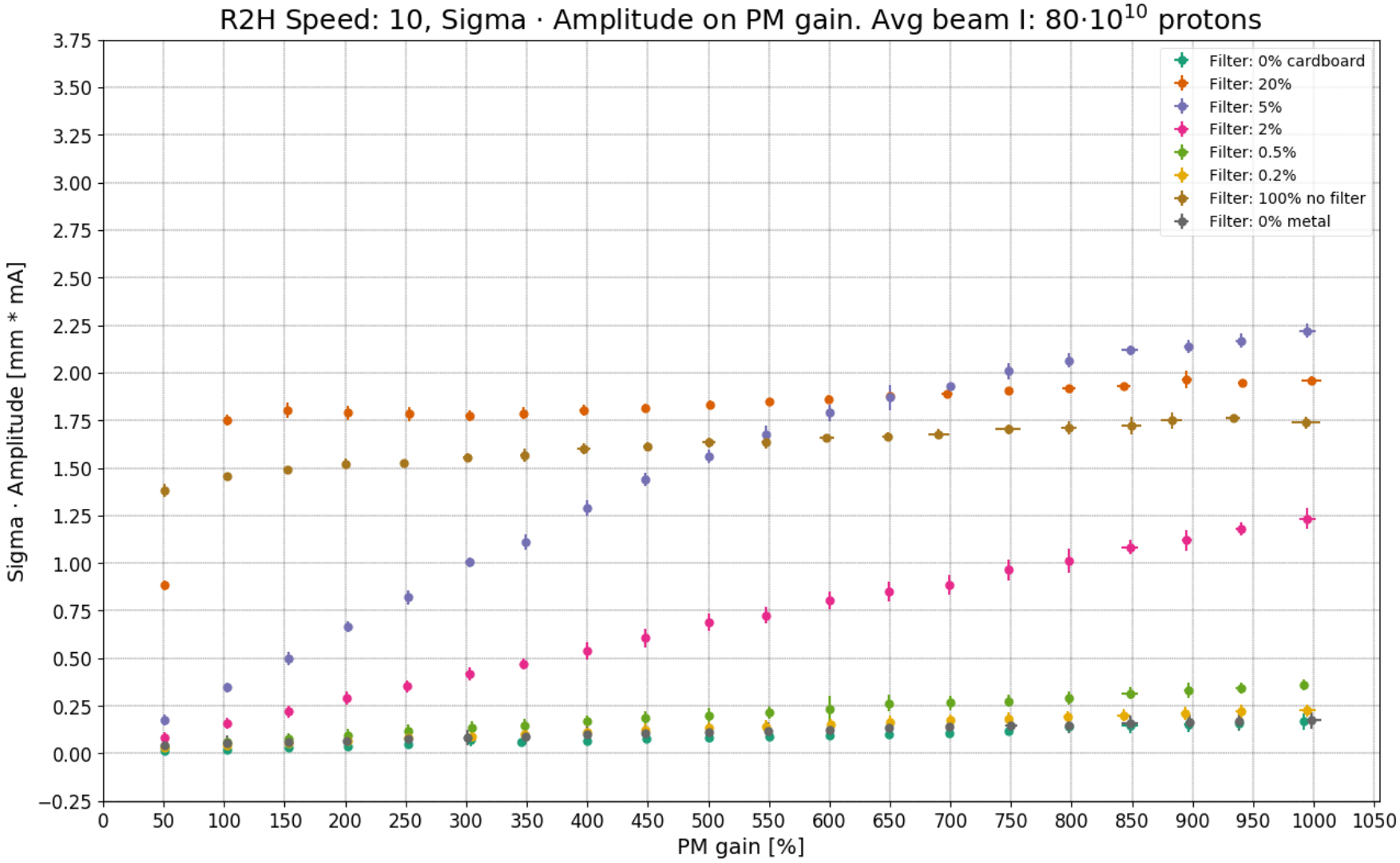
V^7 - Photomultiplier voltage

TX_{filter} - Transmittance of the filter

v_{WS} - Wire speed

I_{beam} - Beam intensity

Beam profile measurements



Conclusion

- Beam emittance is a crucial parameter of an accelerator to evaluate the performance of the machine and to understand beam dynamics. This is in particular important for the HL-LHC upgrade.
- Wire scanner settings have to be chosen carefully to obtain correct results.
- First series of measurements has been presented.
  - Observed behavior is in agreement with previous studies.
- In the following 6 weeks:
  - Optimal parameters for operation will be proposed.
  - Parameters for the empirical formula will be extracted from a fit.
  - More data will be taken.
  - Dependence on other variables will be studied.
  - Measurement will be repeated for different beam intensity.

Thank you for your attention!

Motivation – HL-LHC injector upgrade

$$B = \frac{2I}{\pi^2 \varepsilon_x \varepsilon_y}$$

- With beam intensity (I) increasing to achieve the required brightness (B), the space charge (repulsive force between protons) will also increase, causing the transvers emittance ($\varepsilon_{x,y}$) to rise as well.

$$Space\ charge \propto \frac{I}{E}$$

- This effect is dominant for low energy machines.
- In order to prevent it, the Linac4 will deliver protons with energy of 160 MeV to the **PSB** instead of the 50 MeV from Linac2.

Beam profile measurements