
CERN

2018 LHC Fluorescence tests

S. Mazzoni

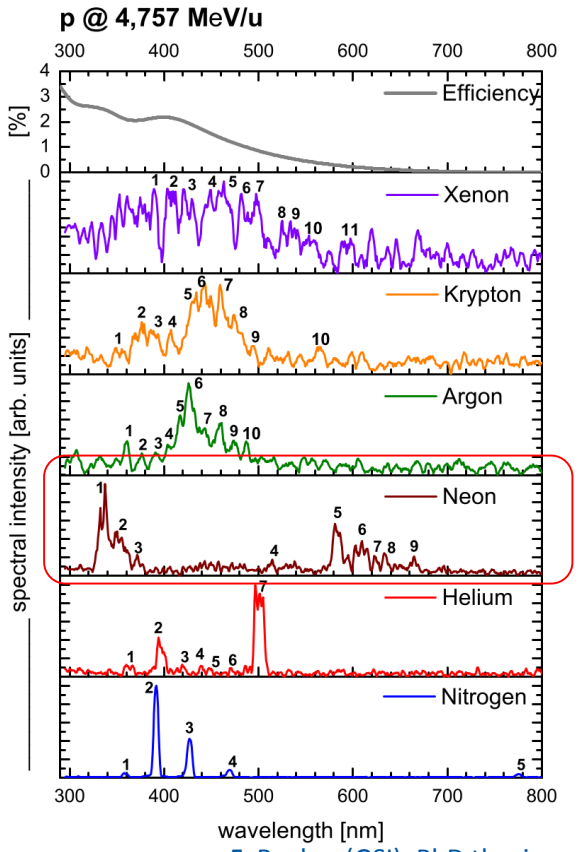
Beam Gas Curtain collaboration meeting at CERN, 27-28 November 2018

Fluorescence data (Ne)

- Data for Ne is scarce. Emission occurs between 300-400 nm (Ne^+) and 580-700 nm (neutral).
- Strongest (neutral) line 585.4 nm.
  Fluorescence by direct excitation (negligible cascading, no optical excitation), cross section based on $2p_1$ level excitation (Bretagne et al, J. Phys. D 1986, Puech & Mizzi, J. Phys. D 1991).
- Short life time: approx. 10 ns
- Data for electron impact up to 1 keV & protons up to 1 MeV. Extrapolated for 7 TeV protons

$$N_{ph} = N_p \sigma \rho_{Ne} \frac{\Omega}{4\pi} = 0.2 \text{ ph/bunch s cm}$$

LOW LIGHT YIELD!



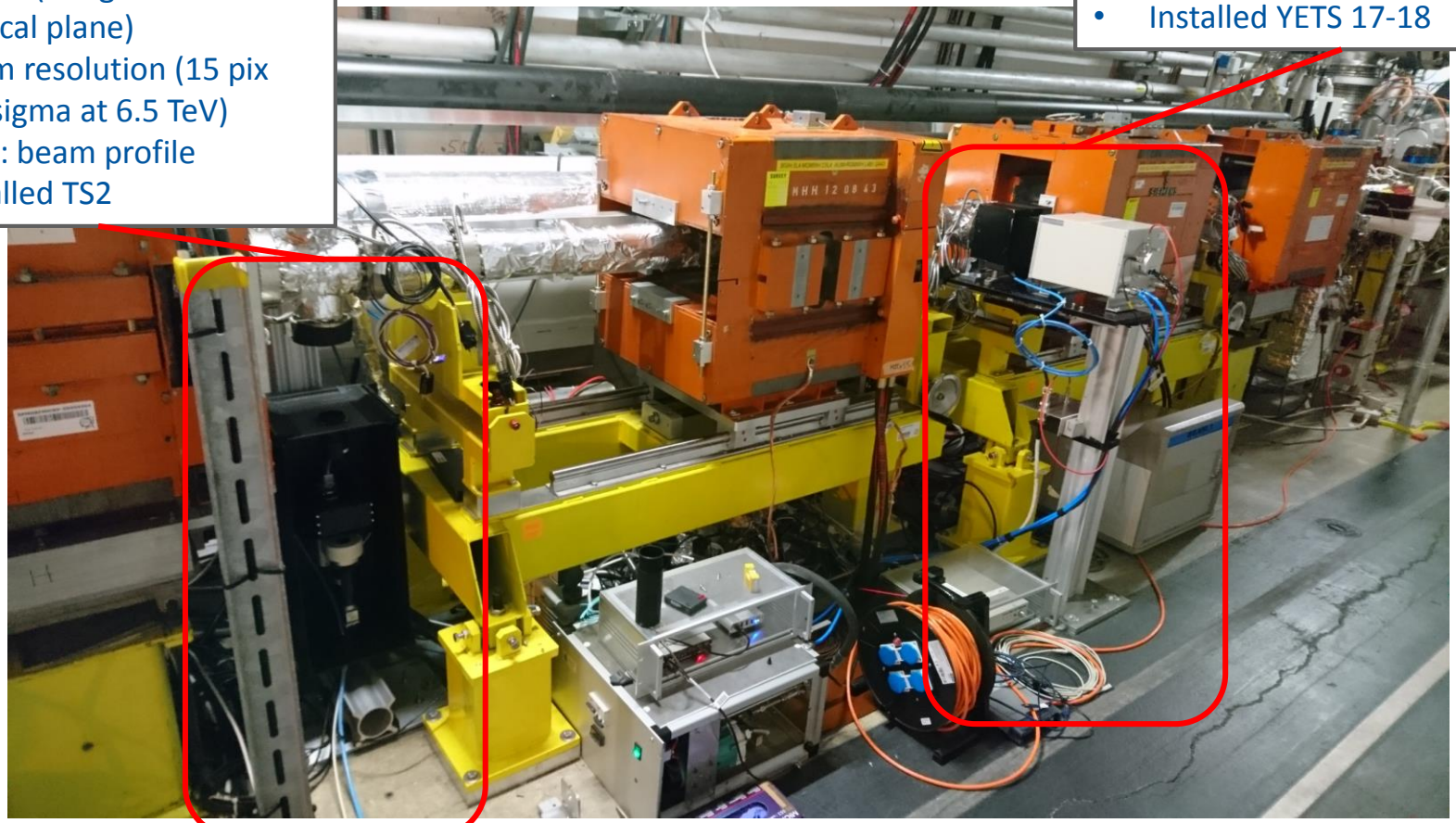
F. Becker (GSI), PhD thesis

N_{ph}	photons per unit length & time
N_p	10^{11} x 11400 (1 s int time)
σ	**4.7 x 10^{-22} cm^2**
ρ_{Ne}	7.8 x 10^8 cm^{-3} @ 3x10^{-8} mbar
Ω	7 x 10^{-3} Sr (camera)

Overview

- Intensified camera
- Image of horizontal beam profile (integrated over vertical plane)
- 20um resolution (15 pix per sigma at 6.5 TeV)
- Goal: beam profile
- Installed TS2

- MCP-PMT photon counting
- Time resolved measurement, 50 ps resolution over full LHC turn
- Goal: measurement of cross section and (exponential) time constant of fluorescence
- Installed YETS 17-18



Overview

Date	Fill #	#b	Device	Int. time [s]	comments
25/4	6612	603	PMT	?	First injection. Test
7/5	6650	2556	PMT	?	Again system test
16-17/5	6693	1887	PMT	360	6.5 TeV data plus BG data (no gas, block filter)
27/6	6854	1227	Camera	2.7	First test with camera. GaAsP photocathode.
6/7	6891	1452	Camera	3	6.5 TeV, BG data (no gas)
10/7	6909	2556	Camera	9 (585nm), 3 (340 nm)	6.5 TeV data, 585 and 340 nm.
27/9			Camera	-	System test after TS2. New camera (multialkali photocathode), translation stage
28/9	7232	2556	Camera	133 (585 nm), 200 (BB)	450 GeV data
17/10	7310	2556	Camera	420 (585 nm)	450 GeV data. Also 6.5 TeV data with 340 nm filter (800 s int time)
18/10	7315	2556	Camera	600	450 GeV data, 585 nm filter
19/10	7319	2566	Camera	-	Gas pressure increased to $4x10^{-7}$ mbar, beam dump
16/11	7448	648	Camera	5	Ion run. 6.3 TeV data, 585 nm filter. BG data (no gas)
20/11	7457	648	Camera	38	Ion run. 6.3 TeV data, 585 nm filter

PMT

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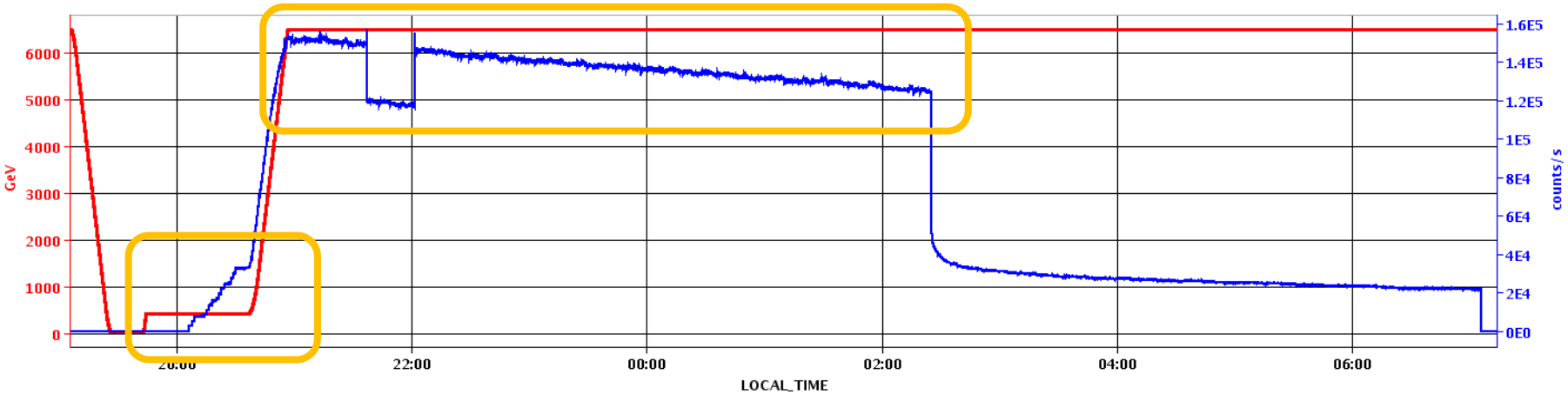
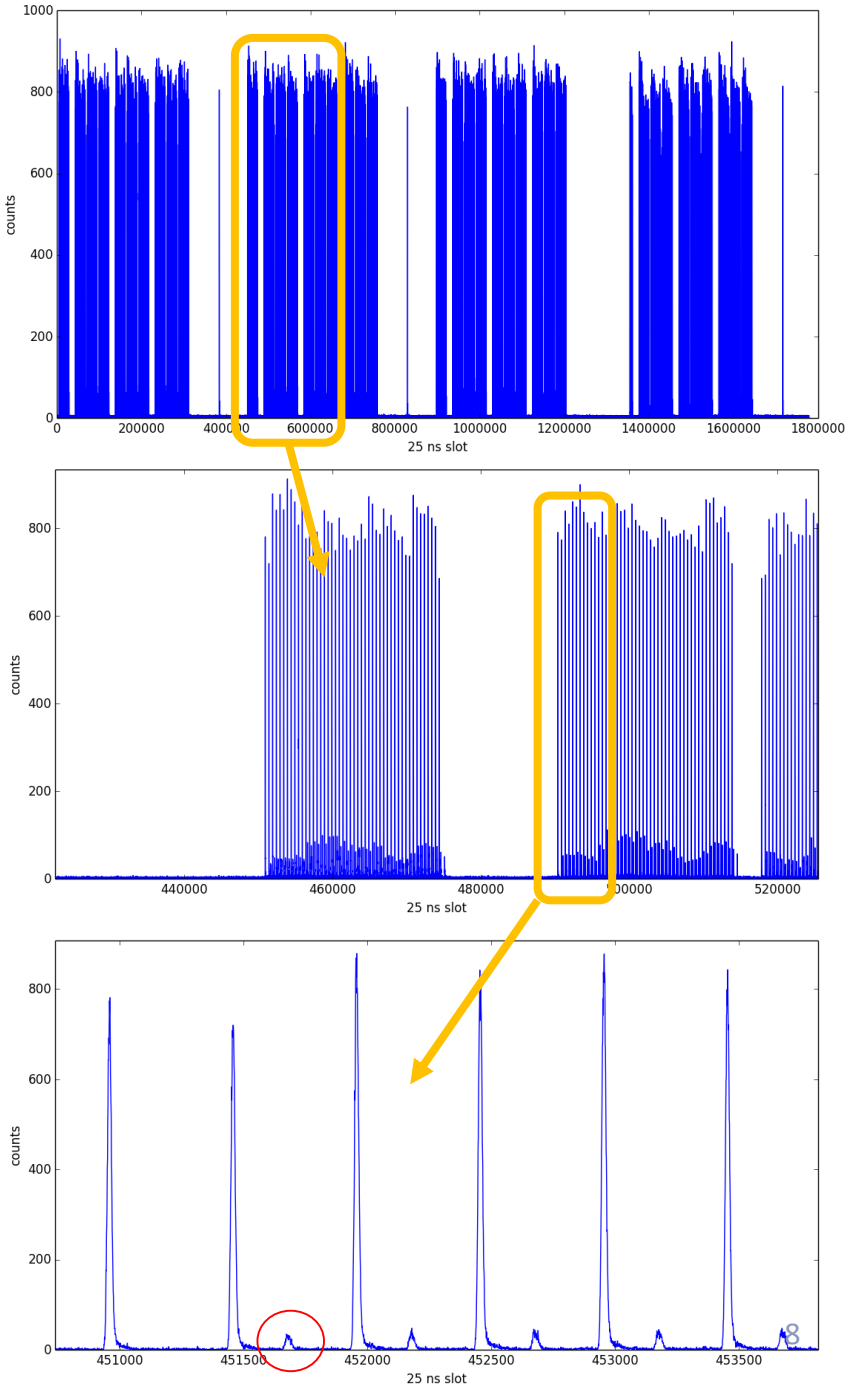
PMT results



- 1887 bunches (physics), 2.05x10^{14} protons (B1)
- Data acquired at injection energy: background (block filter) and signal (585 nm filter)
- Same at high energy (BG data around 22:00 hrs)
- At a glance:
  - Expected cps from fluorescence @ 585 nm: 5-10
  - BG (losses) cps: 1.2x10^{5}
  - Signal cps: 1.5x10^{5}

PMT Data analysis

- Principle: use temporal data integrated over 300 s. Sum over 25 ns slots
- MCP-PMT has “negligible” afterpulsing, but enough to effect analysis > only “clean” slots used. This considerably reduces statistics (42 bunches used in a physics fill)



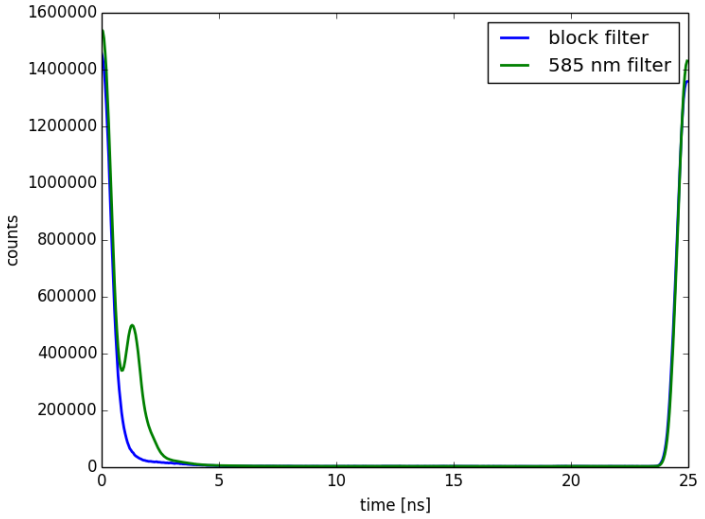
LDM SW (M. Palm, S. Bart)

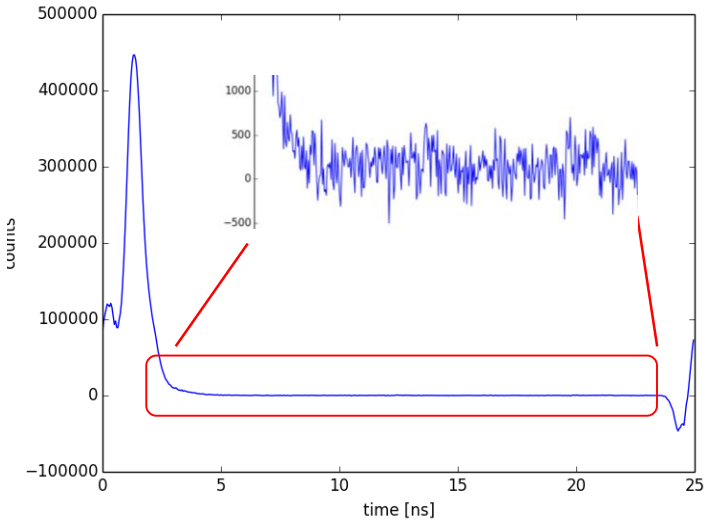
PMT data analysis

- Overlap of 42 bunches, 300 s integration time.
- Expected fluorescence counts: 1500-1800 distributed over an exponential with tau = 10 ns
- Signal rms noise is however around 100 counts per 50 ps bin!

POOR S/N

TRY IMAGING





Protons @ 450 GeV

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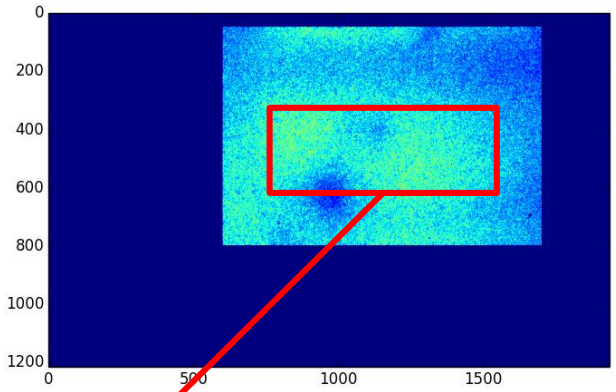
Protons @ 450 GeV

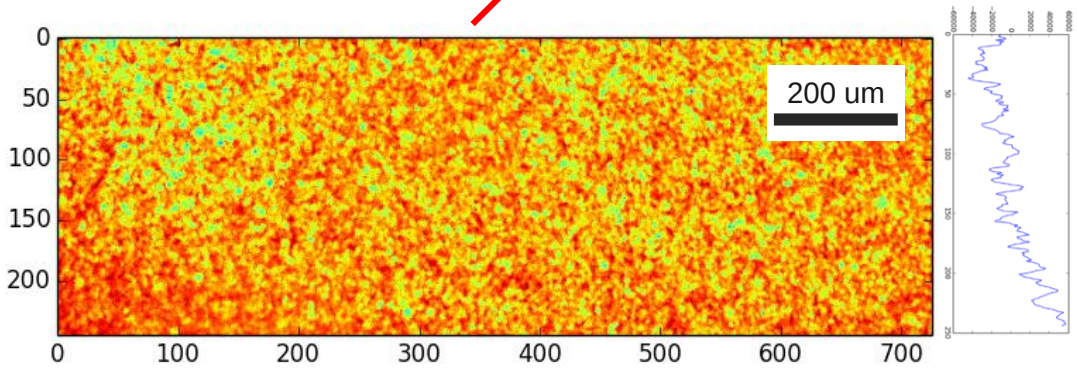
- 1400 s total integration time over 4 injections
- 480 s integration time background data (no gas)
- Photon counting:

$$I(x,y) = \sum_i S_i(x,y) - n \sum_i BG_i(x,y)$$

Where S_i is 2D map of photons on a signal image, BG_i a background image, n is an adjustable constant

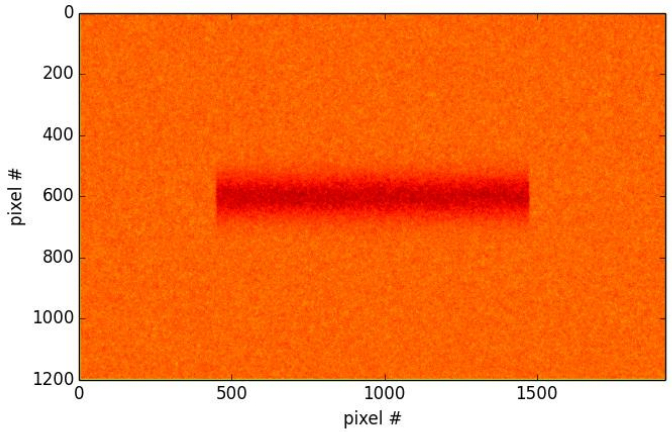
- Signal: expected 40 counts per image
- BG: measured approx. 2000 counts per image
- <u>No signal detected</u>





Protons @ 450 GeV

- Simulation, same S/N ratio:
  - N= 1.1E+05 counts on a Gaussian line with s = 1 mm (1400 s integration at injection)
  - 140*N counts randomly distributed (2000/40, normalized over different ROIs)
  - Signal clearly visible



- Simulation, find upper limit for S/N

Work in progress !

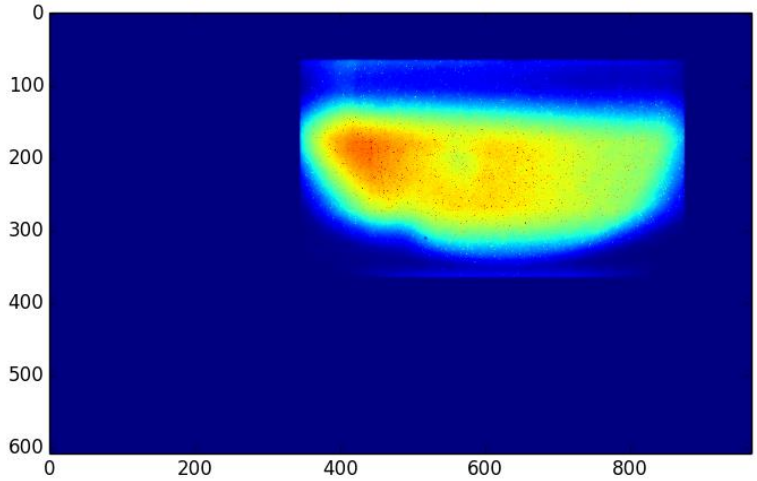
Ions @ 6.3 TeV

- Data acquisition during Pb ion run:
  - $Z^2 = 82^2 = 6724$ light yield Pb^+ vs p^+
  - p^+ intensity: 1E11 x 2556b = 2.5e14 p+ per fill
  - Pb^+ intensity: 1.2E8 x 600b = 7.2E10 Pb+ per fill

x2 light yield

- 7638 images, 5 ms exp time: 38.2 s integration time
- Photon counting
- SR background data not analysed yet
- No signal detected

PRELIMINARY



Noise: synchrotron radiation

- From PMT:
  - $2x10^4$ cps. However solid angle wrt camera is 1/30, QI is x5

$1.2x10^5$ cps on camera

- From ion run (26/11):

$1.7x10^5$ cps on camera

- Fluorescence signal (from expected cross section):

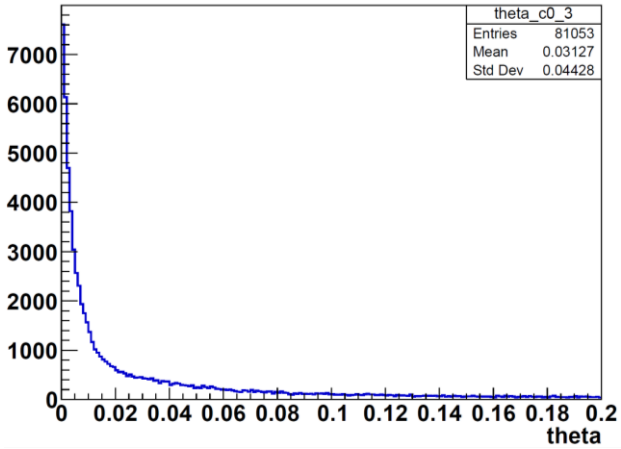
80 cps on camera

- Beam sigma: 300 um = 15 pixels (20 um/pixel)
- SR extends vertically over 300 pixels on image
- To have SR at 1σ: $\frac{N_{ph}}{15\sqrt{\pi}} e^{-1/2} = \frac{N_{SR}}{300} \Rightarrow N_{SR} = 500$

Need to reduce SR of factor 2-3x10²

Beam – gas interaction

- Cross section for p-Ne inelastic scattering:
  - 245 mb = 2.45 x 10^{-25} cm^2 @ 450 GeV
  - 297 mb = 2.97 x 10^{-25} cm^2 @ 7 TeV (= 0.5% of the 585.4 nm fluorescence one)
- .DAT files with 3.6 x 10^6 vertices

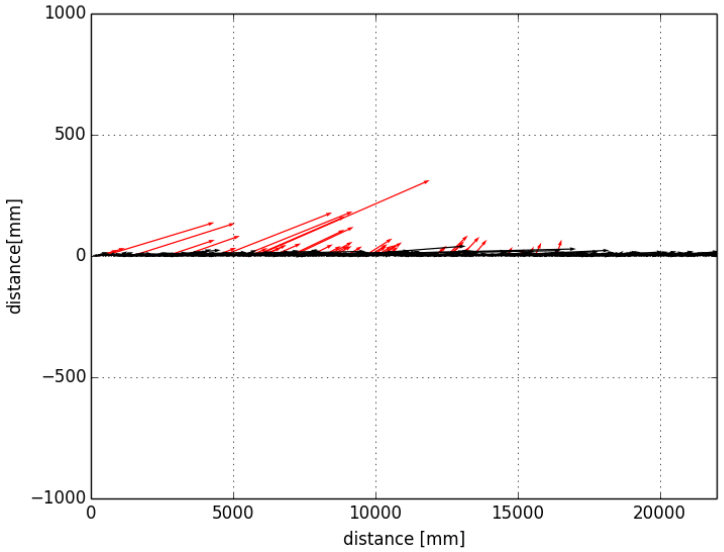


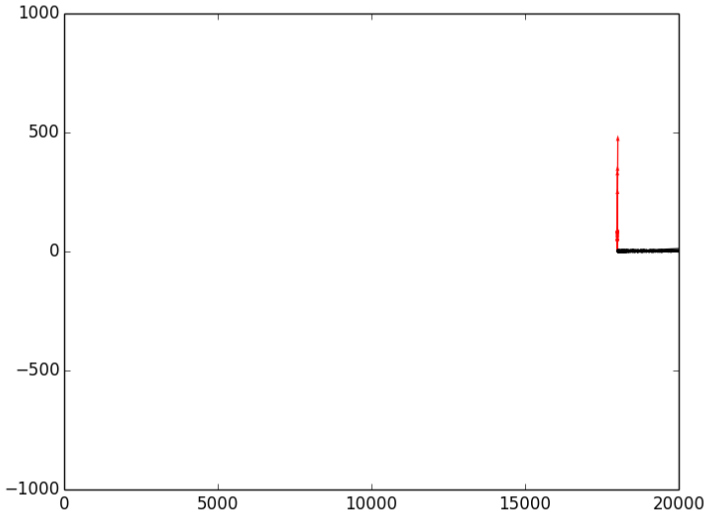
Thanks to BGV team: Benedikt, Robert, Sotiris!

Beam – gas interaction

- Monte carlo simulation with BGV vertex data (3.6×10^6 events):
  - Vertices randomly distributed in 22000 mm long, 80 mm dia tube
  - Sensor is a cube of 25mm side at z= 18000 mm, r = 600 mm
  - Counting vertices that cross the volume area:
- Present case: 1.4×10^{-5} hit probability
- BGC case ($18000<z<18001$): 5.3×10^{-6} hit probability

} 0.4 times per particle

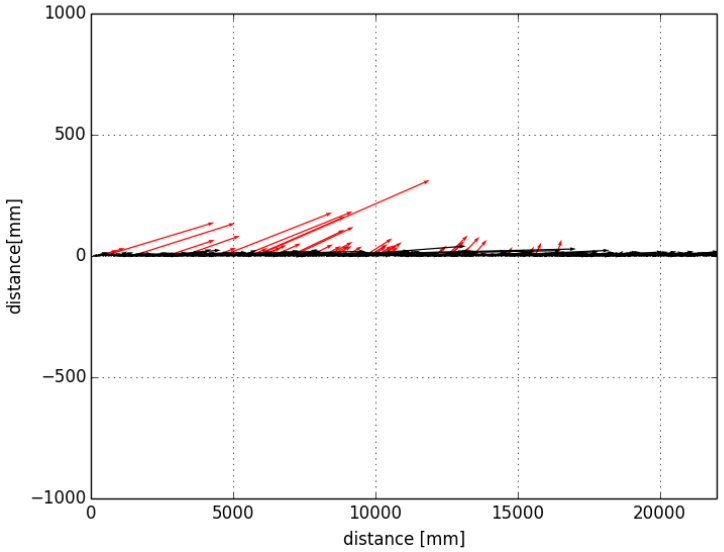


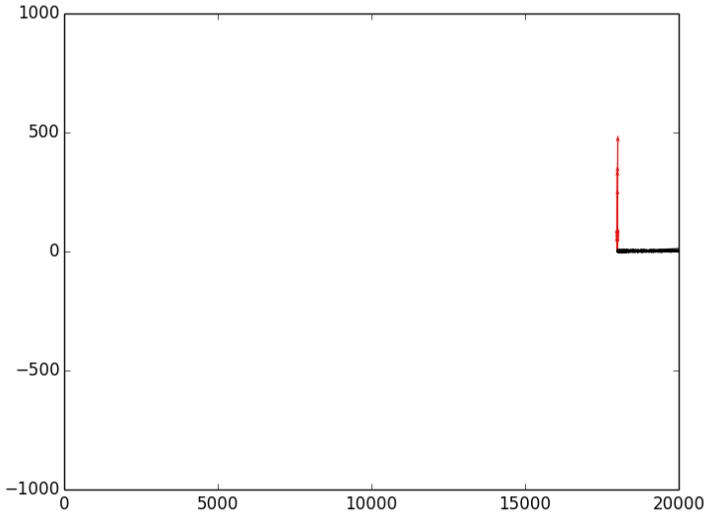


Beam – gas interaction

- Estimation of total number of gas particles for BGC vs present case ongoing
- ROUGH ESTIMATE:
  - Present 10^{-8} mbar over 10000 mm
  - BGC: 10^{-6} mbar over 1 mm

} 10^{-2} times BGV vs preset case



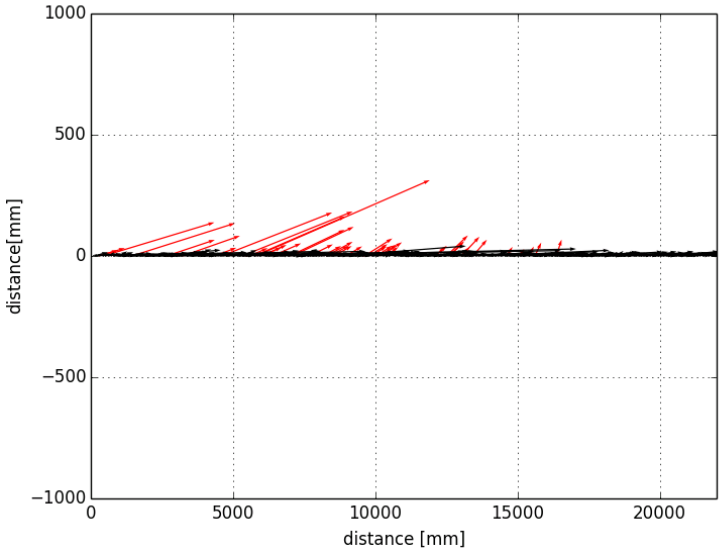


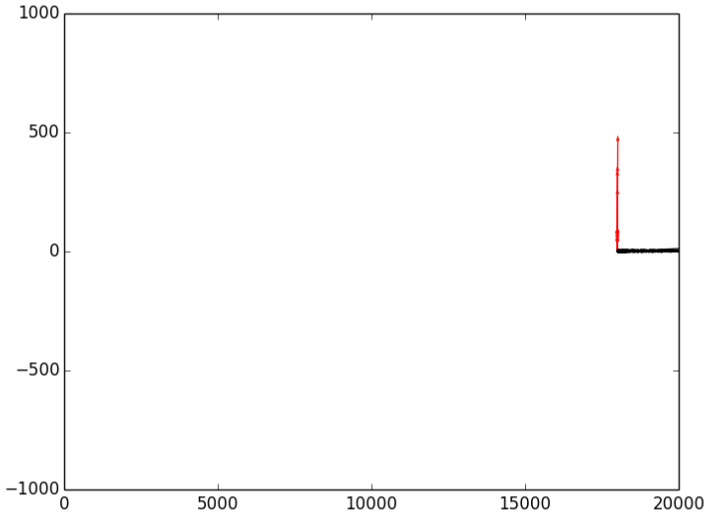
Beam – gas interaction

- Total number of detected losses BGC vs present case:

0.4 per particle x 10^{-2} particles = 4×10^{-3} losses

ROUGH ESTIMATE: order of 10-3 detected losses BGC vs present case





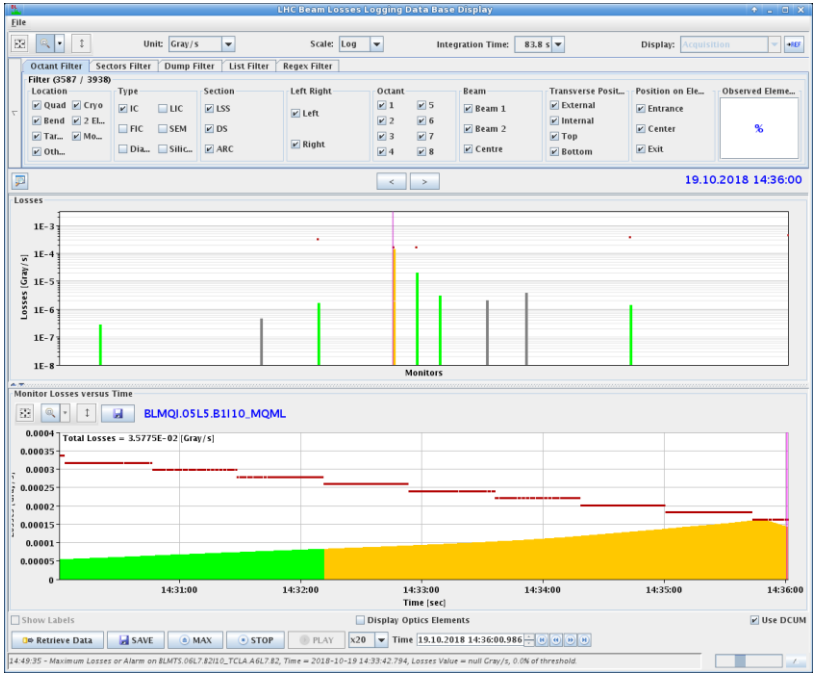
Conclusions

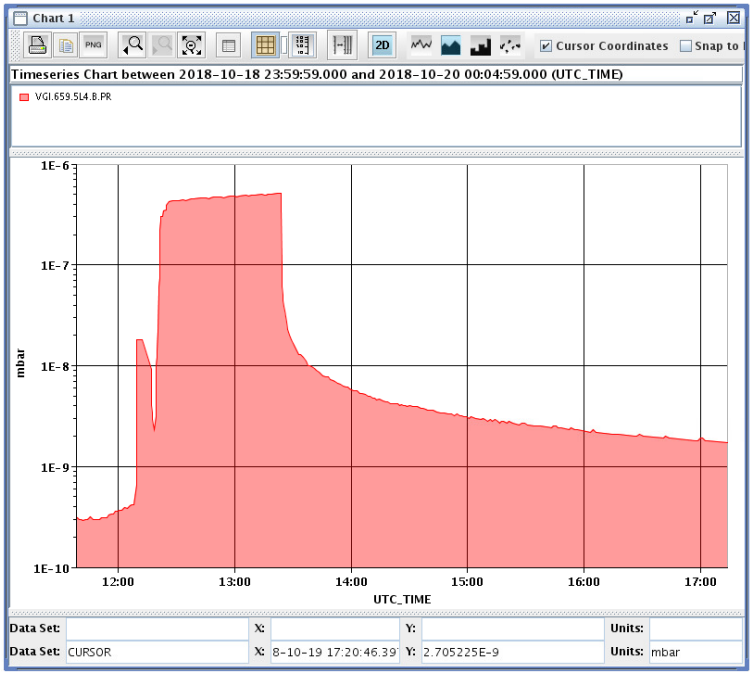
- No signal from p+ or ions at injection or high energy.
- Present work:
  - find upper limits for cross section
  - Estimate losses BGC vs present case
  - Estimate SR signal BGC vs present case
- Discussions with BGV team, ABP (R. Bruce)


CERN

Status

- On 19/10/2018, ‘manual’ injection of Ne at 4×10^{-7} mbar caused the LHC beam to dump due to losses on tertiary collimators of point 5 (20 s integration time).
- No significant losses on primary collimator (point 7)





Status

- Test injection with Pb ions performed on Tue 13/11. Nominal injection around 10^{-8} mbar.
- Low (<1%) losses in Pt. 4, almost not distinguishable losses in pt. 5.
- OK to continue injection during Pb run.