
CERN

Beam quality throughout the LHC injector chain

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What did we do?

- Measurements with several accelerators
- Processed the data
- Data compared and interpreted
- Lots of different people explaining things to us

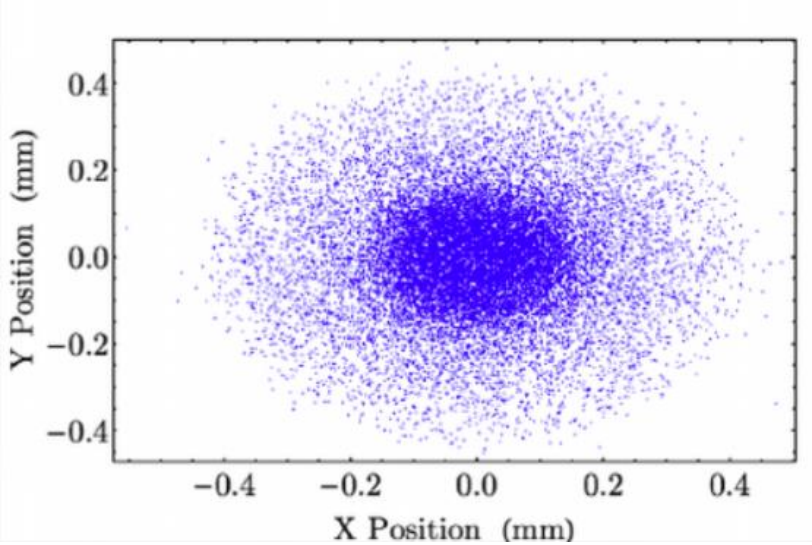
Our goal

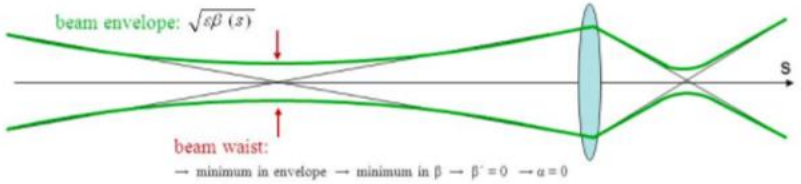
- Map if there is brightness loss of the LHC beam along the injector chain

- See how the wire scanner measurement affects the beam

Transverse emittance

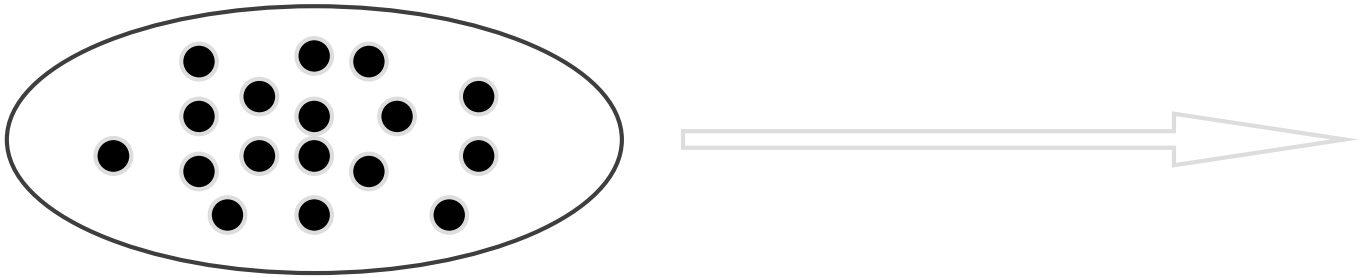
- Number that gives an indication of the transverse size and the angles
- Ideally: as small as possible
- Important for the brightness





Intensity

- Number of protons in a bunch
- Also important for brightness

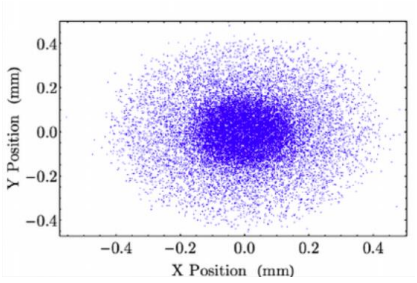


Brightness

$$\text{Brightness} = \frac{\text{No. of particles}}{\text{Area}}$$

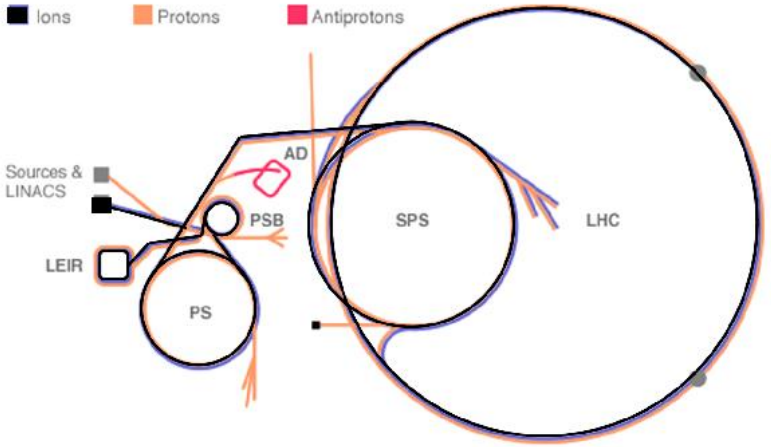
- Density of particles in transverse plane
- Brightness was calculated using measured data
- High brightness —> more collisions
- Brightness drops off throughout chain

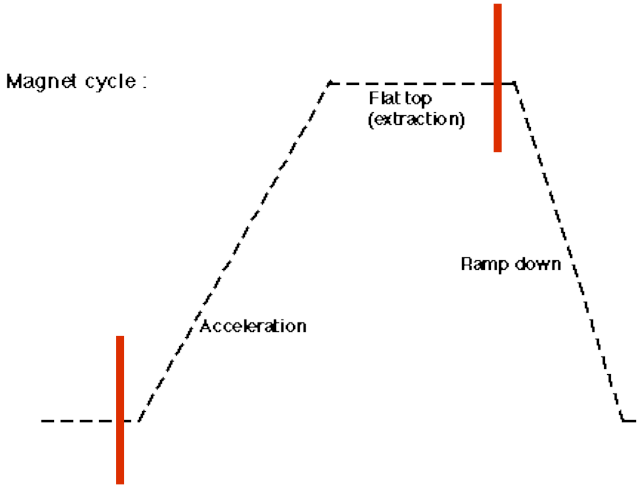
$$B_n = \frac{2I}{\pi^2 \epsilon_x \epsilon_y}$$



Collecting data

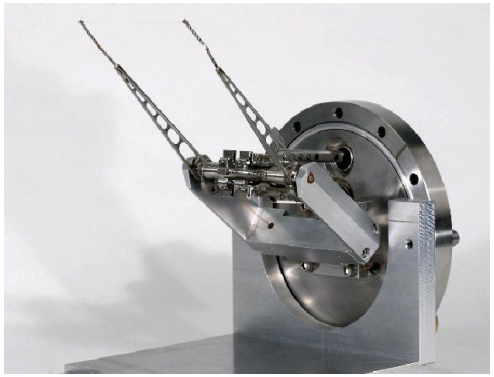
- Measurements at various moments in different accelerators
- Booster, PS, SPS, (LHC)
- Injection and extraction

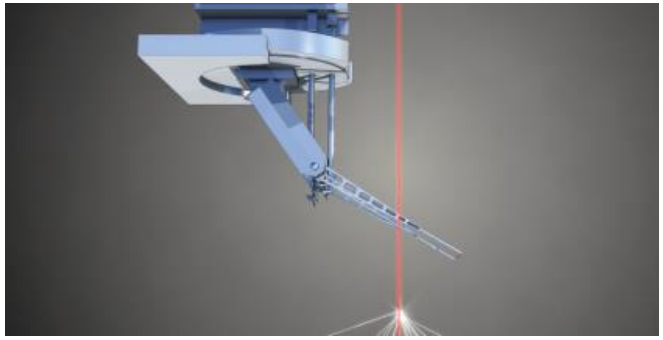




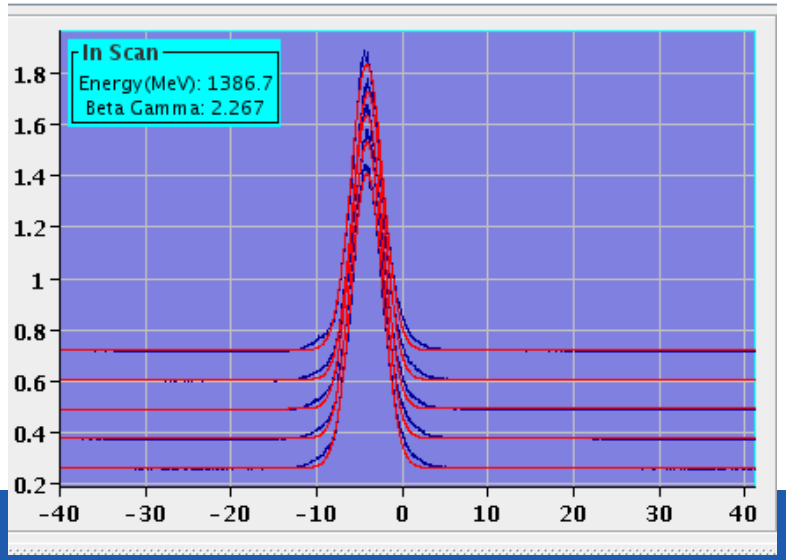
Wirescanner

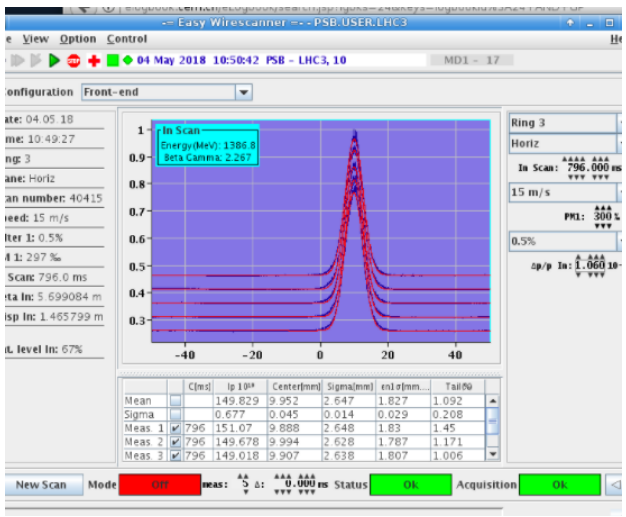
- Measure beam profile and beam sigma in transverse plane
- Separate horizontally and vertically
- Application gives intensity and emittance

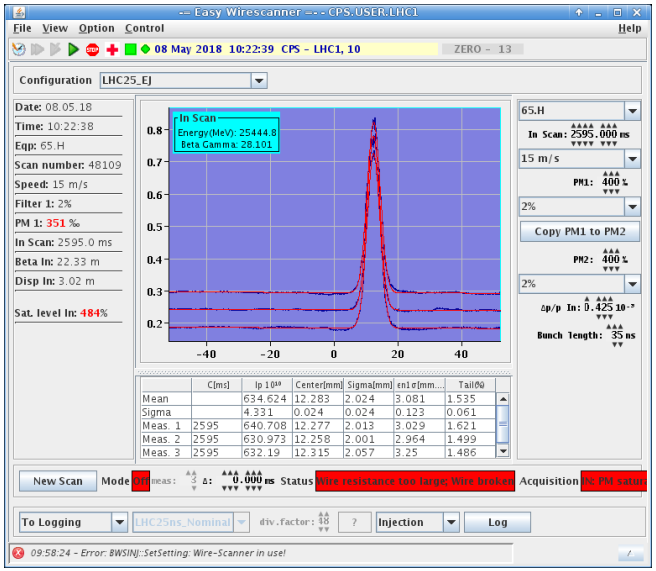


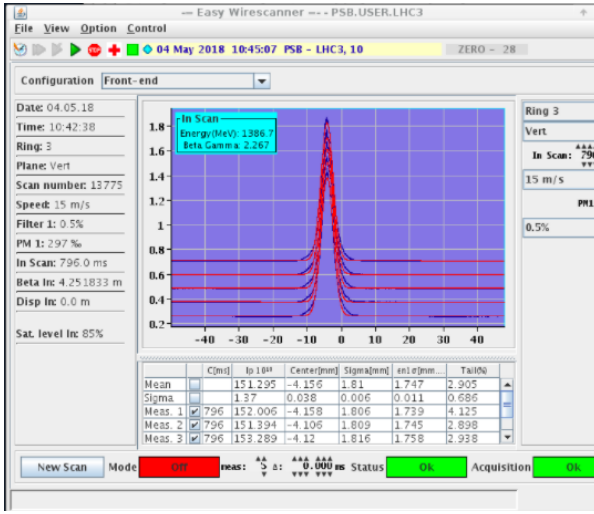


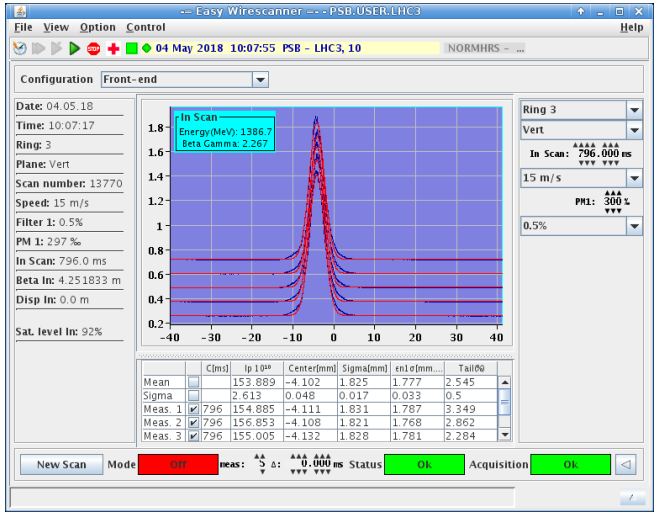
	C[ms]	Ip 10^{10}	Center[mm]	Sigma[mm	$\epsilon n1\sigma$[mm...	Tail@
Mean		652.168	-0.073	3.253	2.03	1.564
Sigma		1.412	0.024	0.043	0.053	0.194
Meas. 1	185	651.661	-0.041	3.193	1.956	1.818
Meas. 2	185	654.094	-0.081	3.292	2.079	1.525
Meas. 3	185	650.748	-0.098	3.272	2.054	1.348

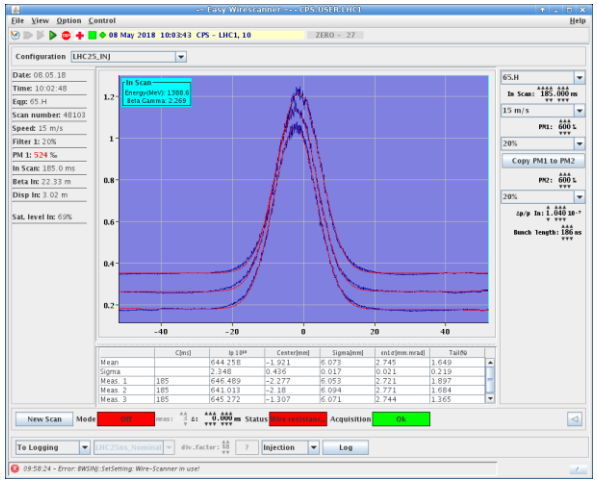


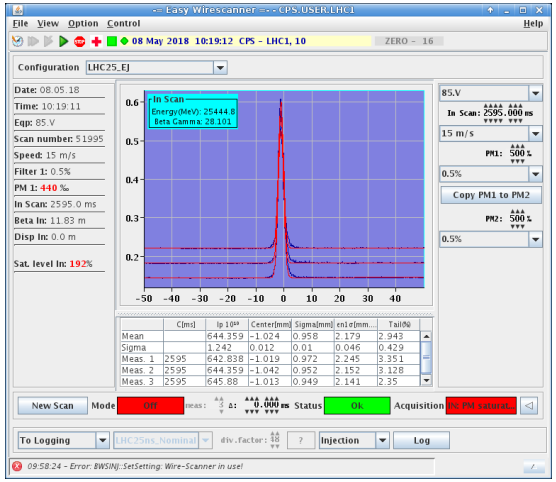

-- Easy Wirescanner -- - PSB.USER.LHC3
04 May 2018 10:50:42 PSB - LHC3, 10
MD1 - 17
Configuration Front-end
In Scan
Energy(MeV): 1386.8
Beta Gamma: 2.267
Ring 3
Horiz
In Scan: 796.000 ms
15 m/s
PM1: 300 %
0.5%
Mean 149.829 9.952 2.647 1.827 1.092
Sigma 0.677 0.045 0.014 0.029 0.208
Meas. 1 796 151.07 9.888 2.648 1.83 1.45
Meas. 2 796 149.678 9.994 2.628 1.787 1.171
Meas. 3 796 149.018 9.907 2.638 1.807 1.006
New Scan
Mode Off
Status Ok
Acquisition Ok


-- Easy Wirescanner -- - CPS.USER.LHC1
File View Option Control Help
08 May 2018 10:22:39 CPS - LHC1, 10
ZERO - 13
Configuration LHC25_EJ
Date: 08.05.18
Time: 10:22:38
Eqp: 65.H
Scan number: 48109
Speed: 15 m/s
Filter 1: 2%
PM 1: 351 ‰
In Scan: 2595.0 ms
Beta In: 22.33 m
Disp In: 3.02 m
Sat. level In: 484%
In Scan
Energy(MeV): 25444.8
Beta Gamma: 28.101
65.H
In Scan: 2595.000 ms
15 m/s
PM1: 400 %
2%
Copy PM1 to PM2
PM2: 400 %
2%
Δp/p In: 0.425 10⁻³
Bunch length: 35 ns
Mean 634.624 12.283 2.024 3.081 1.535
Sigma 4.331 0.024 0.024 0.123 0.061
Meas. 1 2595 640.708 12.277 2.013 3.029 1.621
Meas. 2 2595 630.973 12.258 2.001 2.964 1.499
Meas. 3 2595 632.19 12.315 2.057 3.25 1.486
New Scan
Mode Off
Status Wire resistance too large Wire broken
Acquisition PC PM saturated
To Logging
LHC25ns_Nominal
Injection
Log
09:58:24 - Error: BWSINJ::SetSetting: Wire-Scanner in use!

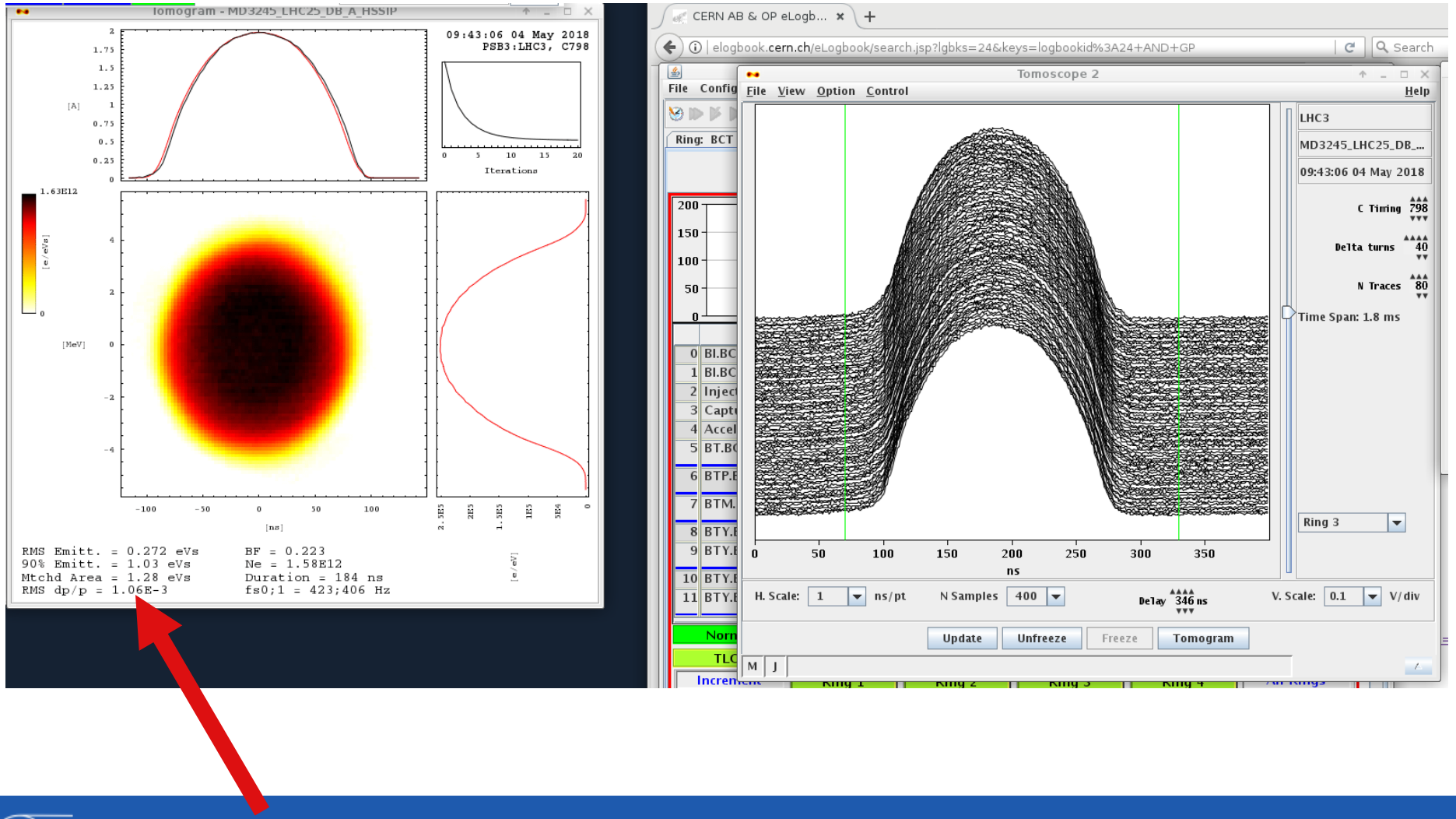

-- Easy Wirescanner -- - PSB.USER.LHC3
File View Option Control
04 May 2018 10:45:07 PSB - LHC3, 10
ZERO - 28
Configuration Front-end
Date: 04.05.18
Time: 10:42:38
Ring: 3
Plane: Vert
Scan number: 13775
Speed: 15 m/s
Filter 1: 0.5%
PM 1: 297 ‰
In Scan: 796.0 ms
Beta In: 4.251833 m
Disp In: 0.0 m
Sat. level In: 85%
In Scan
Energy(MeV): 1386.7
Beta Gamma: 2.267
Ring 3
Vert
15 m/s
0.5%
Mean 151.295 -4.156 1.81 1.747 2.905
Sigma 1.37 0.038 0.006 0.011 0.686
Meas. 1 796 152.006 -4.158 1.806 1.739 4.125
Meas. 2 796 151.394 -4.106 1.809 1.745 2.898
Meas. 3 796 153.289 -4.12 1.816 1.758 2.938
New Scan
Mode Off
Status Ok
Acquisition Ok


-- Easy Wirescanner -- - PSB.USER.LHC3
File View Option Control Help
04 May 2018 10:07:55 PSB - LHC3, 10
NORMHRS - ...
Configuration Front-end
Date: 04.05.18
Time: 10:07:17
Ring: 3
Plane: Vert
Scan number: 13770
Speed: 15 m/s
Filter 1: 0.5%
PM 1: 297 ‰
In Scan: 796.0 ms
Beta In: 4.251833 m
Disp In: 0.0 m
Sat. level In: 92%
In Scan
Energy(MeV): 1386.7
Beta Gamma: 2.267
Ring 3
Vert
In Scan: 796.000 ms
15 m/s
PM1: 300 %
0.5%
Mean 153.889 -4.102 1.825 1.777 2.545
Sigma 2.613 0.048 0.017 0.033 0.5
Meas. 1 796 154.885 -4.111 1.831 1.787 3.349
Meas. 2 796 156.853 -4.108 1.821 1.768 2.862
Meas. 3 796 155.005 -4.132 1.828 1.781 2.284
New Scan
Mode Off
Status Ok
Acquisition Ok



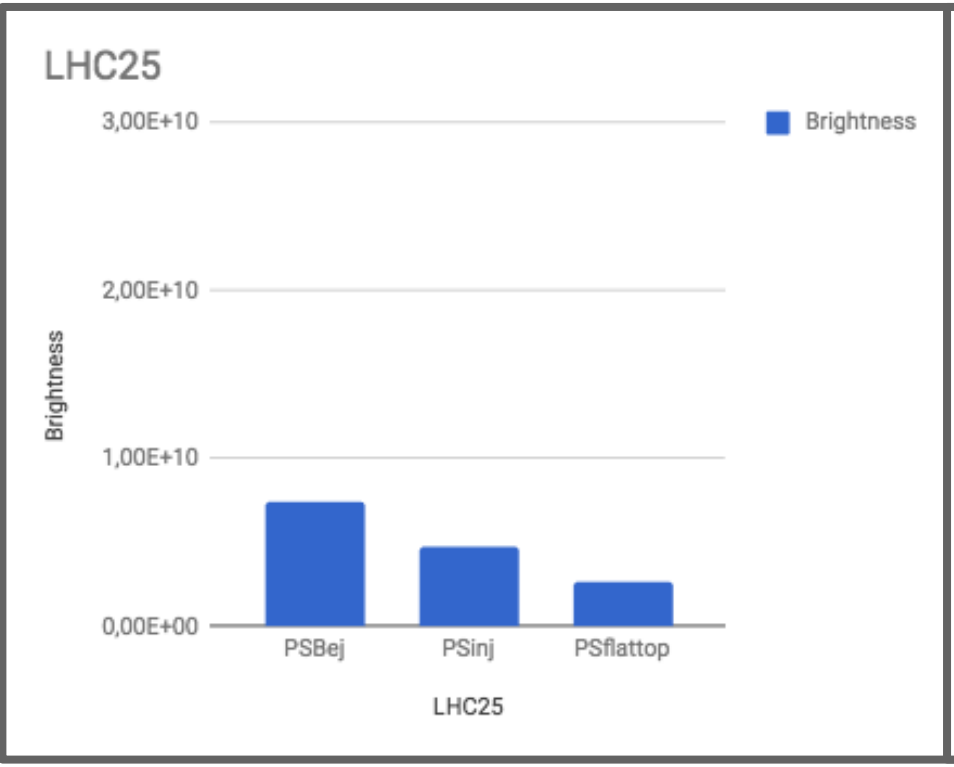

-- Easy Wirescanner -- - CPS.USER.LHC1
File View Option Control Help
08 May 2018 10:19:12 CPS - LHC1, 10
ZERO - 16
Configuration LHC25_EJ
Date: 08.05.18
Time: 10:19:11
Eqp: 85.V
Scan number: 51995
Speed: 15 m/s
Filter 1: 0.5%
PM 1: 440 ‰
In Scan: 2595.0 ms
Beta In: 11.83 m
Disp In: 0.0 m
Sat. level In: 192%
In Scan
Energy(MeV): 25444.8
Beta Gamma: 28.101
85.V
In Scan: 2595.000 ms
15 m/s
PM1: 500 %
0.5%
Copy PM1 to PM2
PM2: 500 %
0.5%
Mean 644.359 -1.024 0.958 2.179 2.943
Sigma 1.242 0.012 0.01 0.046 0.429
Meas. 1 2595 642.838 -1.019 0.972 2.245 3.351
Meas. 2 2595 644.359 -1.042 0.952 2.152 3.128
Meas. 3 2595 645.88 -1.013 0.949 2.141 2.35
New Scan
Mode Off
Status Ok
Acquisition PC PM saturated
To Logging
LHC25ns_Nominal
Injection
Log
09:58:24 - Error: BWSINJ::SetSetting: Wire-Scanner in use!

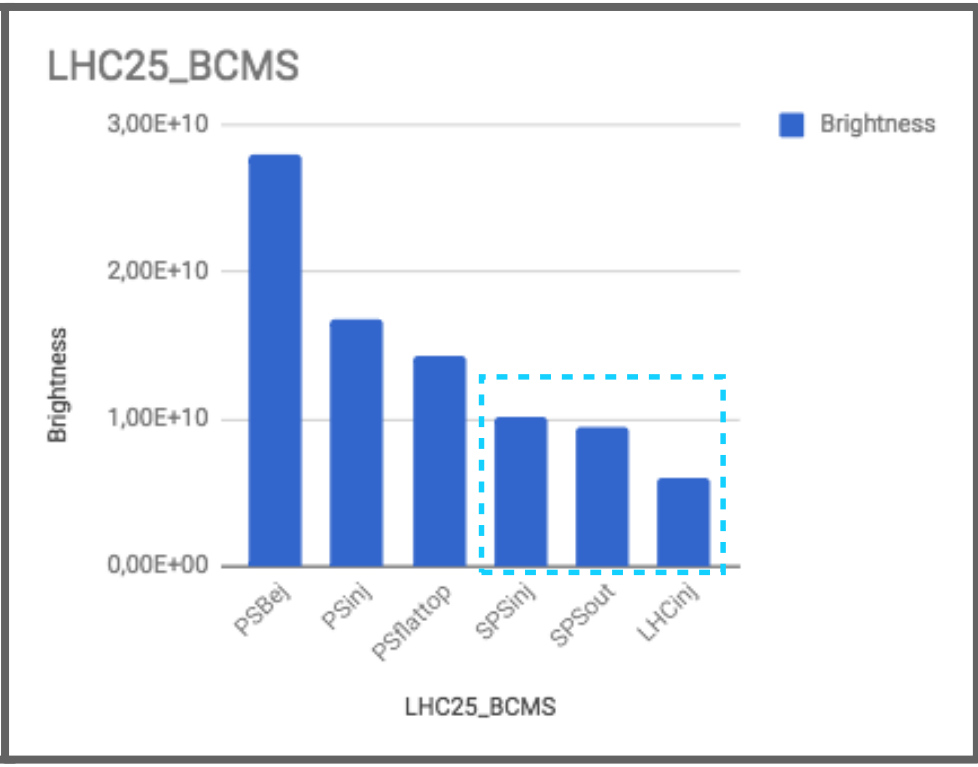
Tomogram


Tomogram - MD3245_LHC25_DB_A_HSSIP
09:43:06 04 May 2018
PSB3:LHC3, C798
Iterations
RMS Emitt. = 0.272 eVs
90% Emitt. = 1.03 eVs
Mtchd Area = 1.28 eVs
RMS dp/p = 1.06E-3
BF = 0.223
Ne = 1.58E12
Duration = 184 ns
fs0;1 = 423;406 Hz
CERN AB & OP eLogb...
elogbook.cern.ch/eLogbook/search.jsp?lgbks=24&keys=logbookid%3A24+AND+GP
Tomoscope 2
File View Option Control Help
LHC3
MD3245_LHC25_DB_...
09:43:06 04 May 2018
C Timing 798
Delta turns 40
N Traces 80
Time Span: 1.8 ms
Ring 3
H. Scale: 1 ns/pt
N Samples 400
Delay 346 ns
V. Scale: 0.1 V/div
Update
Unfreeze
Freeze
Tomogram

Results

$$B_n = \frac{2I}{\pi^2 \epsilon_x \epsilon_y}$$





LHC25 beam

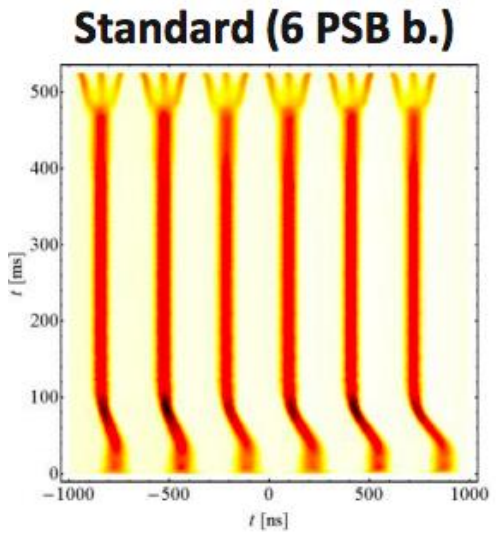
Previous beam used in LHC

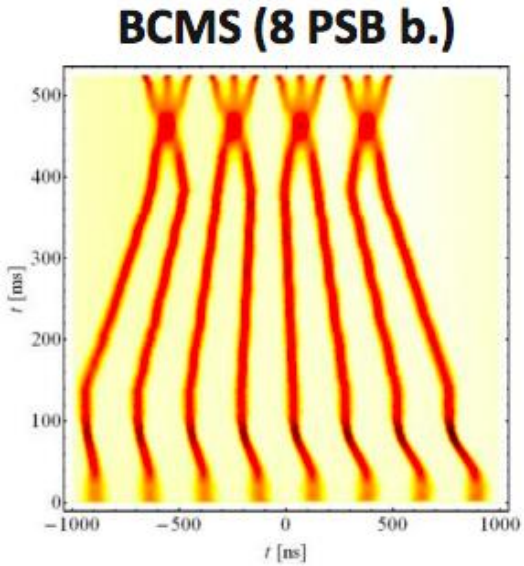
BCMS beam

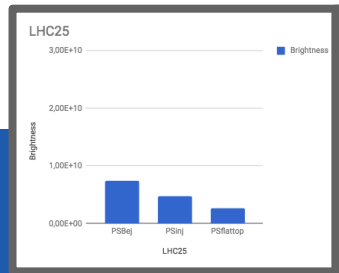
Current beam used in LHC

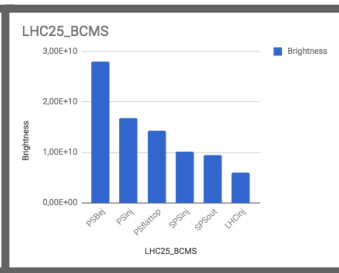
Different beams

- Difference in brightness
- Beams are prepared differently
- LHC25: bunches have lower intensity in the PSB
- Batch Compression Merging and Splitting



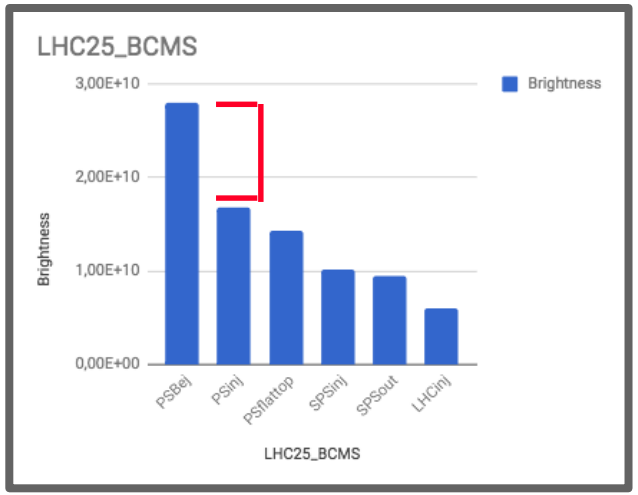






Loss of brightness between PSB and PS

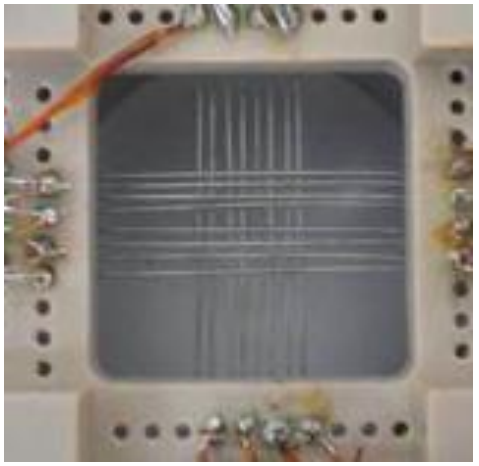
- Optics mismatch
  - Magnet settings of the machines do not match
- Beam oscillation —> emittance blow-up
- Upgrades during shutdown

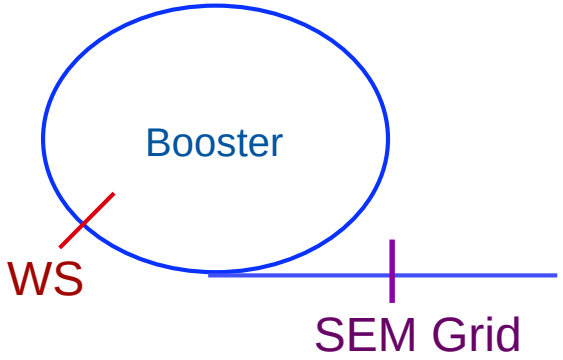


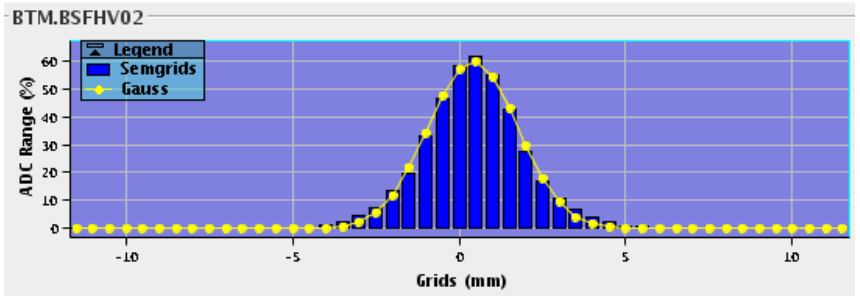
Part 2: The effect of the wire scanner on other measurements

SEM Grid

- Measures beam profile
- Application calculates emittance
- Measured before beam dump
- Horizontal and vertical separate

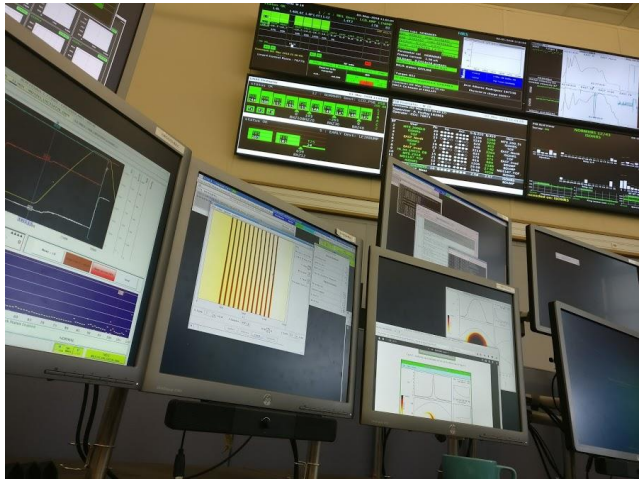






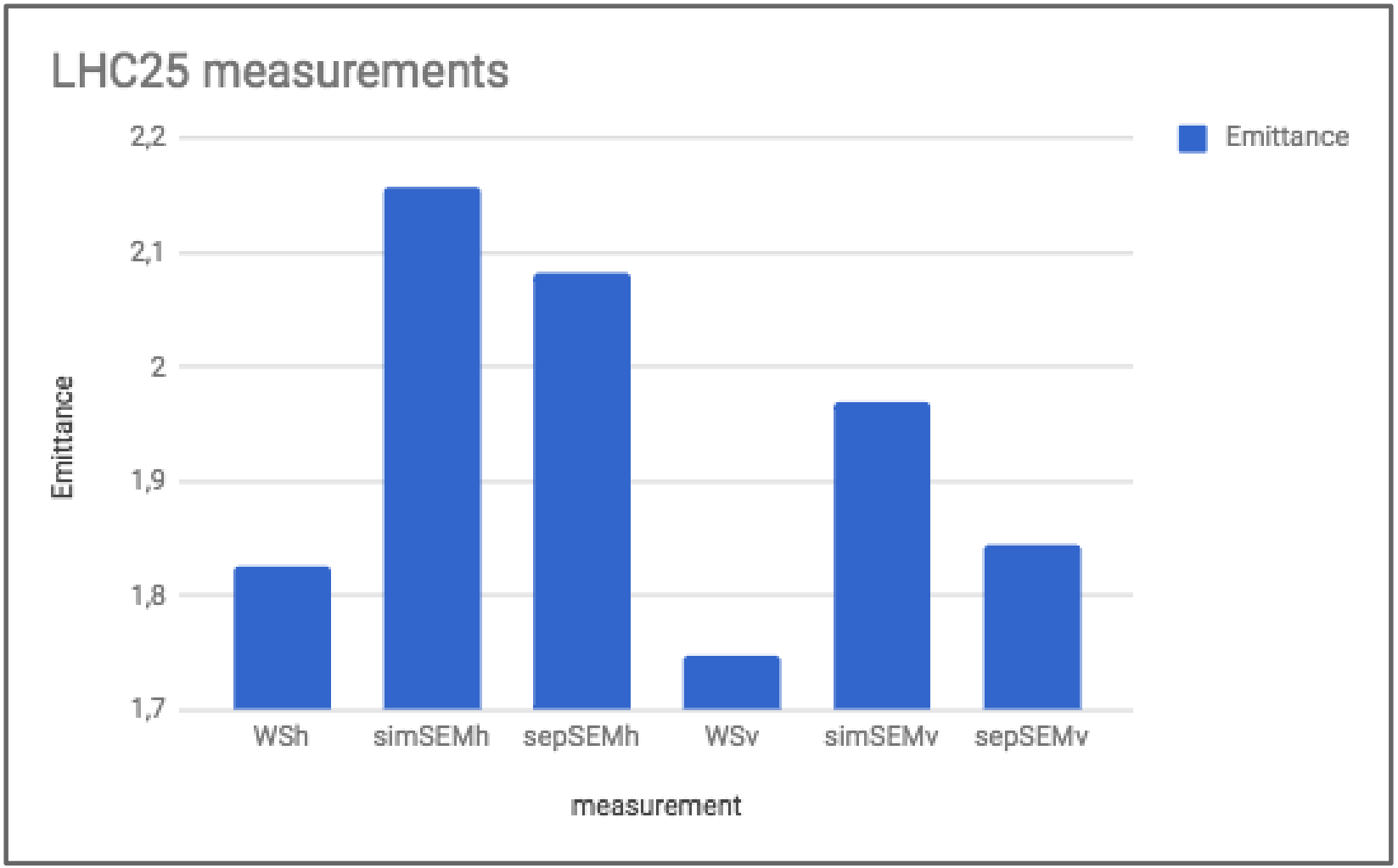
Collecting data

- 3 Different measuring moments:
  - Only wire scanner
  - Only SEM grid
  - Wire scanner and SEM grid simultaneously

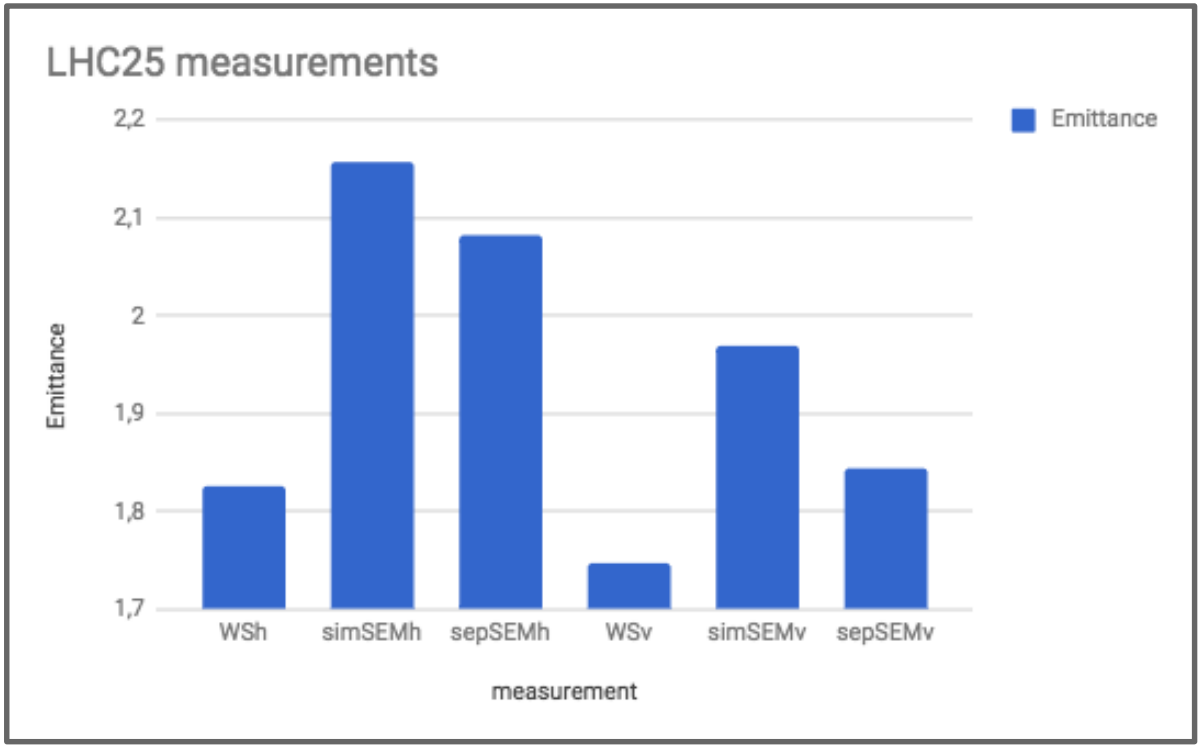


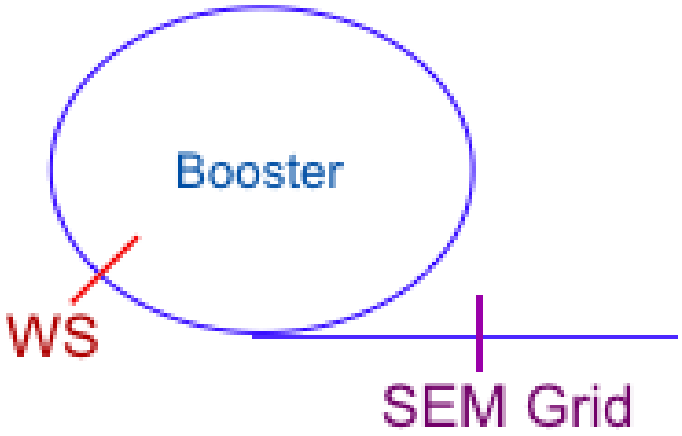
- Does the wire scanner affect the SEM grid measurement?

Results


LHC25 measurements
Emittance
2,2
2,1
2
1,9
1,8
1,7
Emittance
WSh
simSEMh
sepSEMh
WSv
simSEMv
sepSEMv
measurement

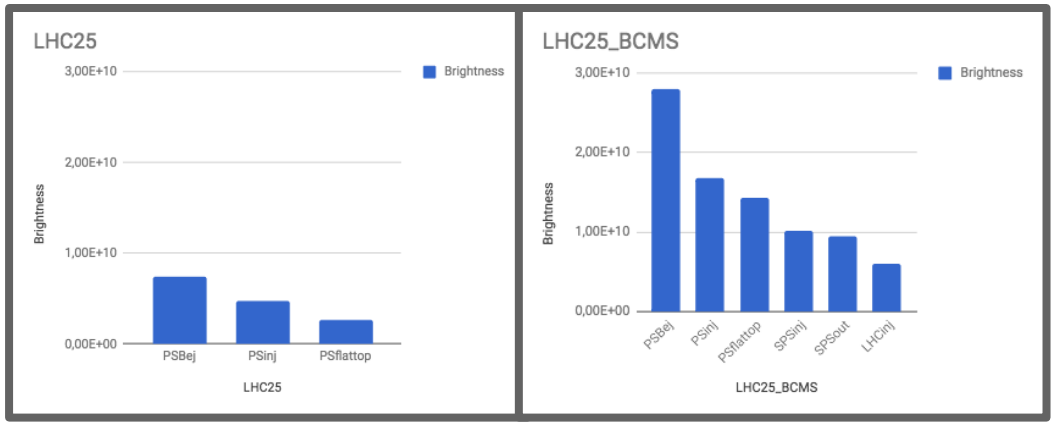
Results

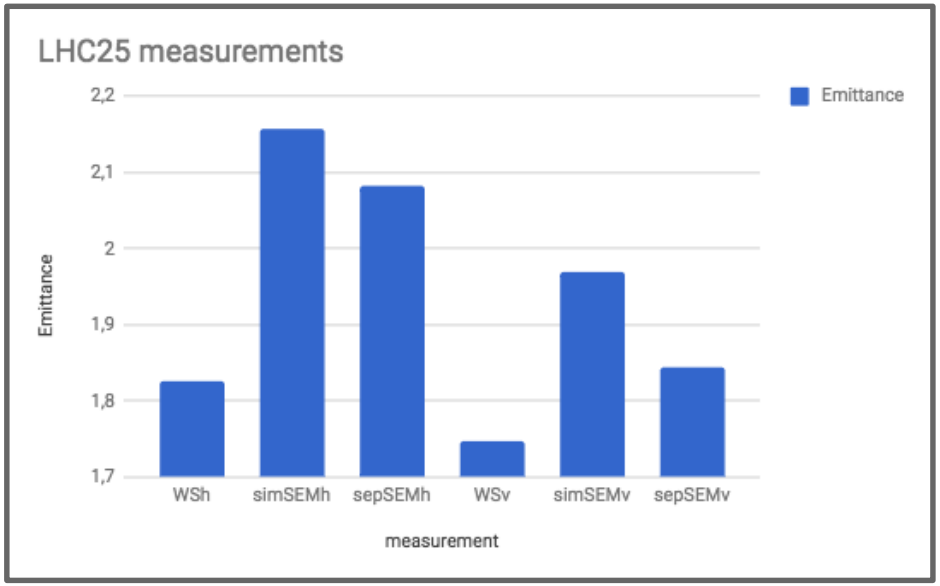

LHC25 measurements
Emittance
2,2
2,1
2
1,9
1,8
1,7
Emittance
WSh
simSEMh
sepSEMh
WSv
simSEMv
sepSEMv
measurement


Booster
WS
SEM Grid

Summary

- The BCMS beam is brighter than LHC25
- Significant loss of brightness between PSB and PS for BCMS
- Simultaneous WS/SEM measurements cause inaccuracy for SEM





Thank you