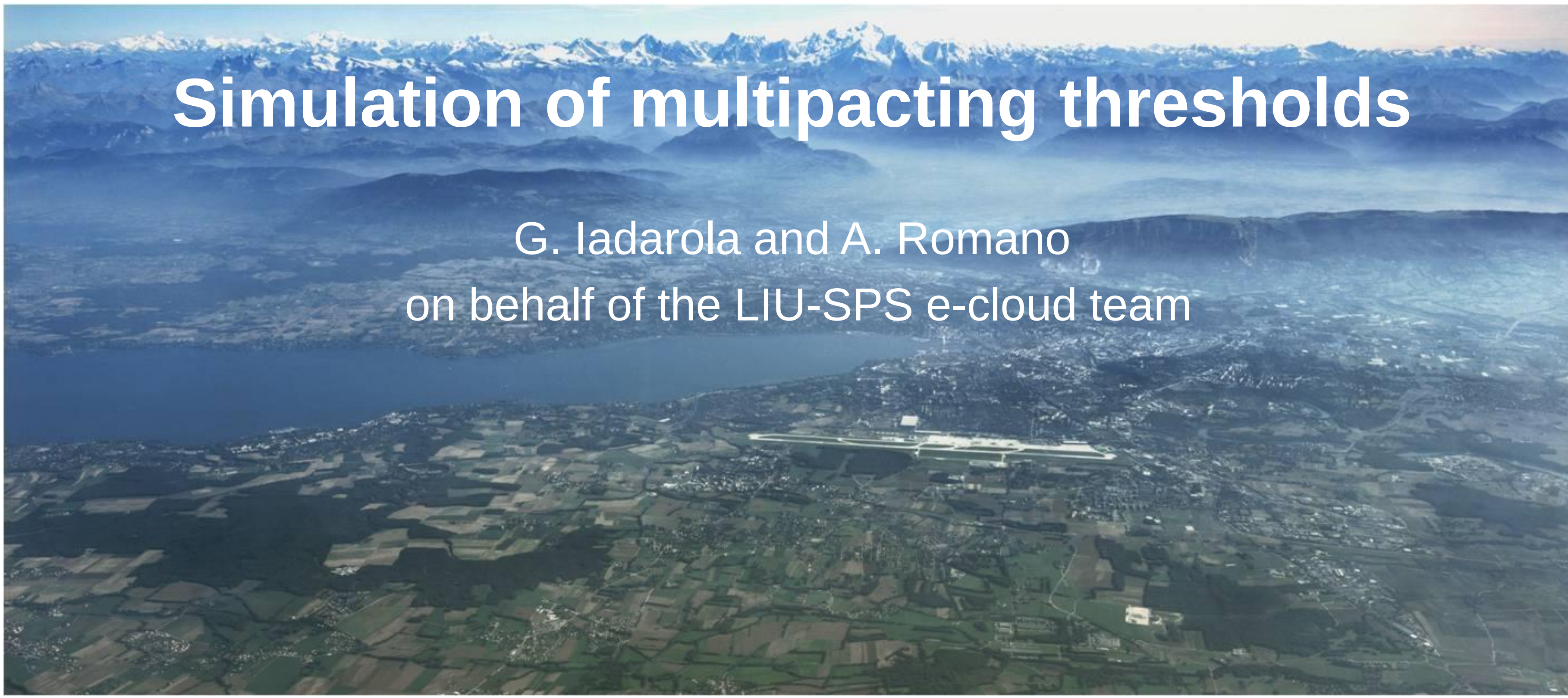
LHC Injectors Upgrade



Simulation of multipacting thresholds

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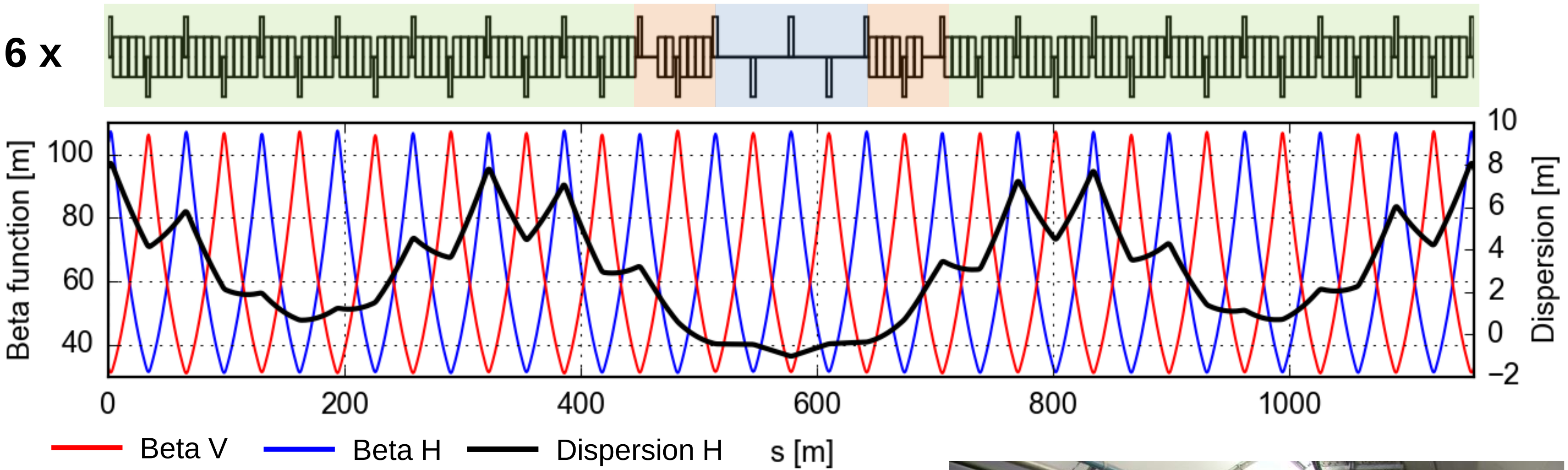
on behalf of the LIU-SPS e-cloud team

LIU SPS scrubbing review, 8 September, 2015

Introduction

- We **simulated the e-cloud formation** in the main components of the SPS machine using the **PyECLOUD code**
- Main goal of the studies is to identify the **multipacting threshold**, i.e. the value of the **Secondary Electron Yield** above which the e-cloud can develop in the chamber
  - …and electron distributions for beam dynamics simulation
- Simulations were carried out for the standard **25 ns beam** with intensity ranging **from 1 x 10^{11} ppb to 2 x 10^{11} ppb** at the SPS injection energy (26 GeV/c)

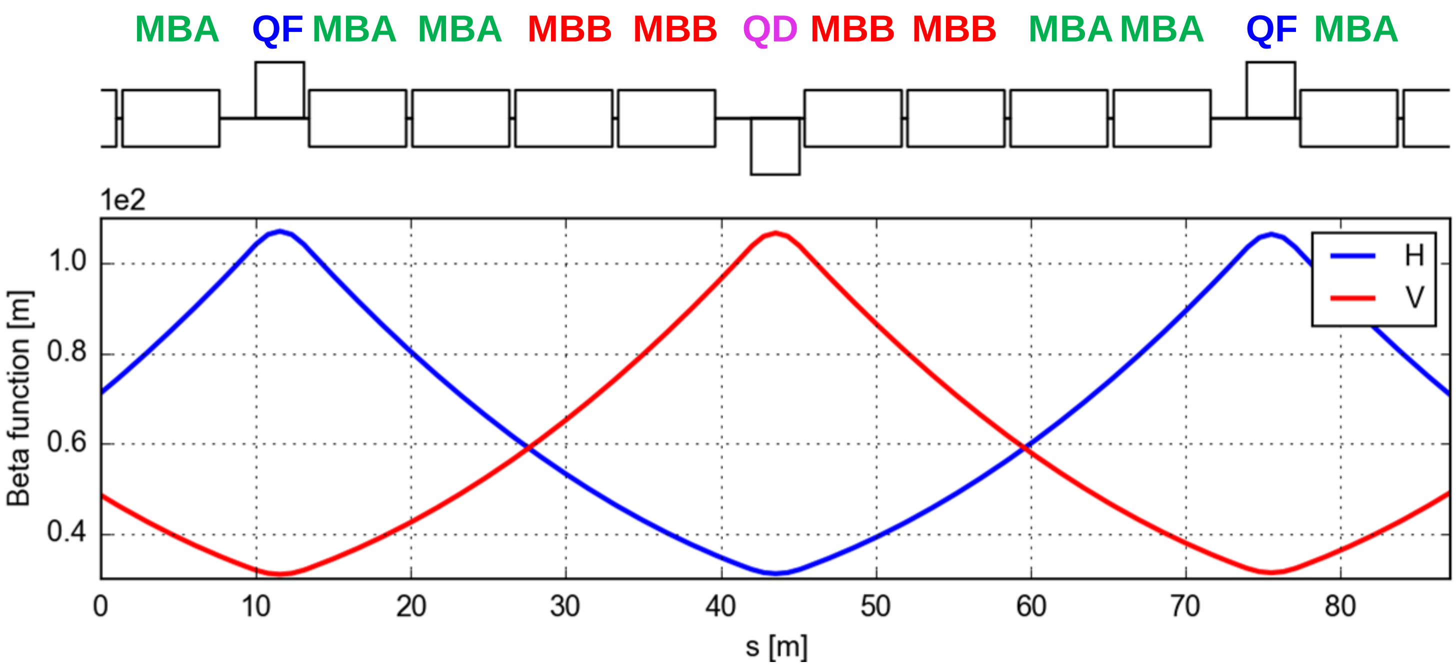
The SPS lattice

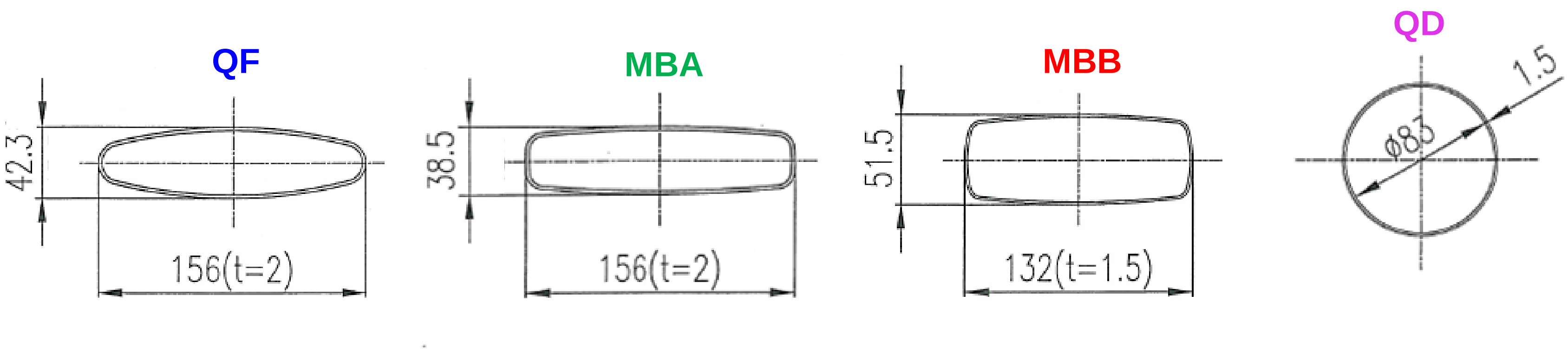


- **FODO lattice** with a **6-fold** symmetry
- **6 sextants** each made of:
  - 14 regular FODO cells (QF + QD + 8 dipoles)
  - 2 “Dispersion suppressor“ cells (regular cells with 2 missing dipoles)
  - 2 straight section cells (regular cells with no dipoles)

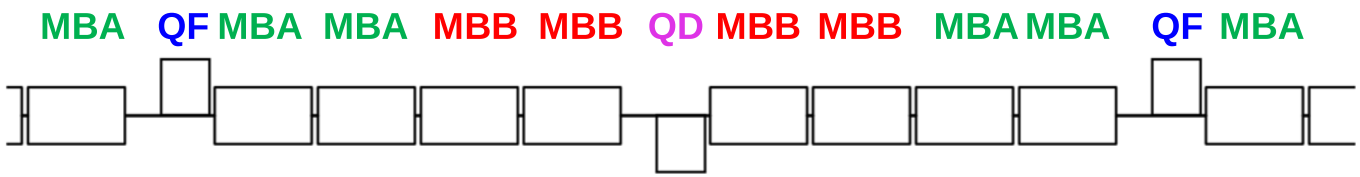
The SPS main magnets

- 4 kinds of main magnets with chambers following the envelope of the beam

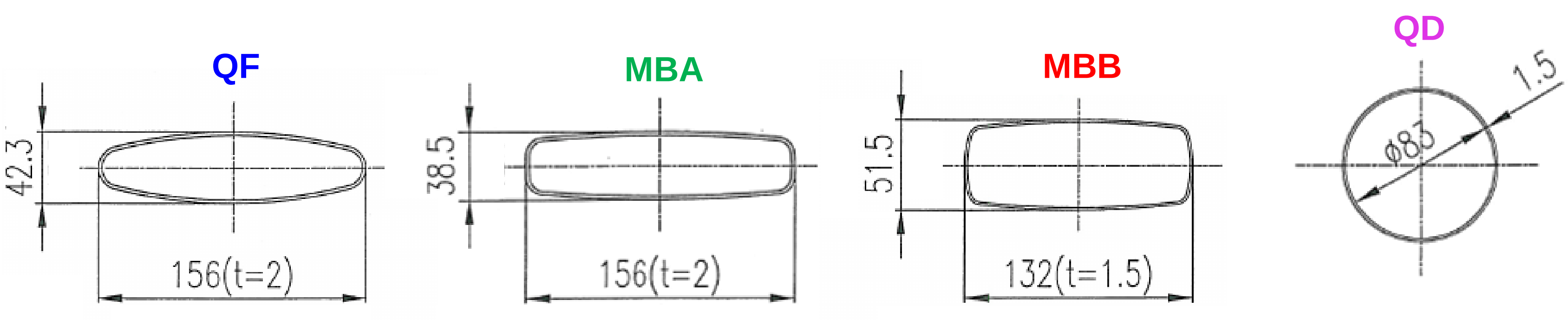




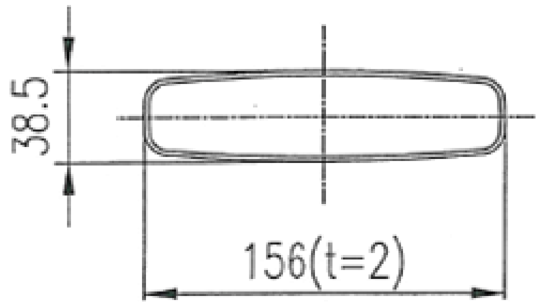
The SPS main magnets

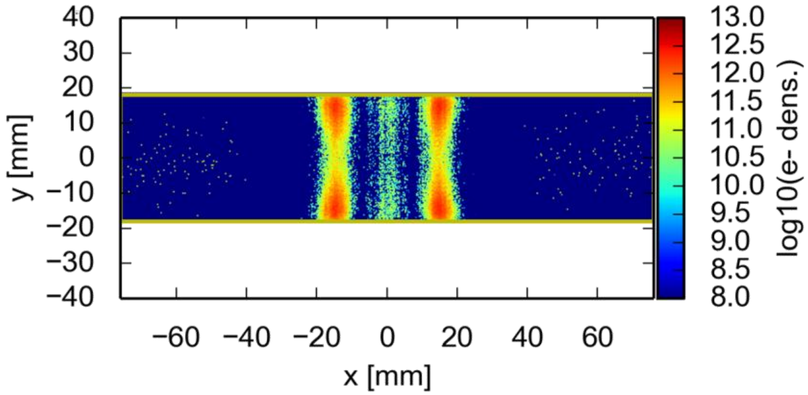


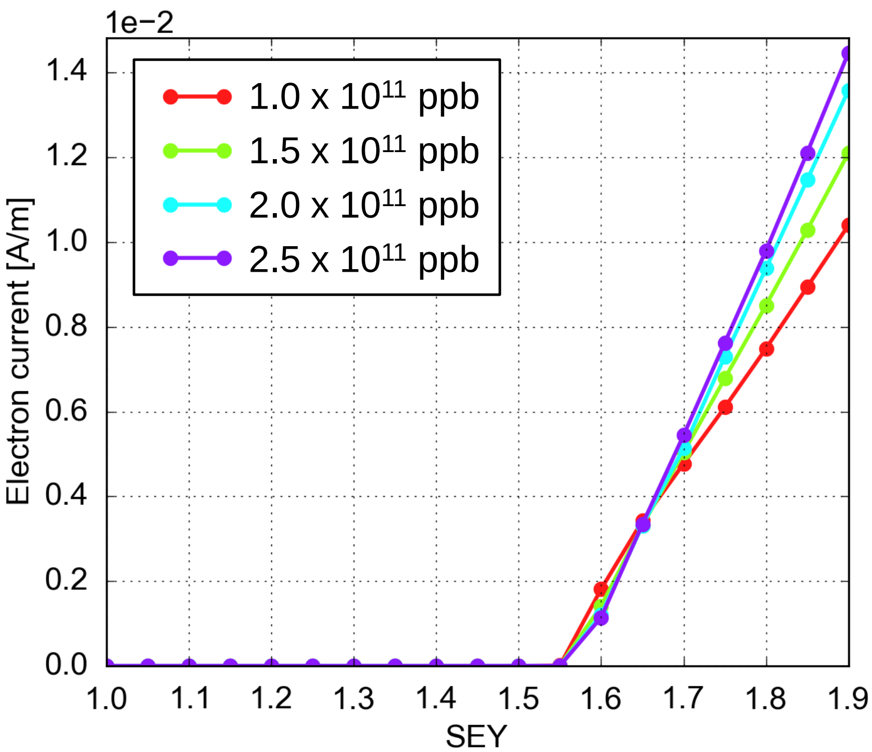
Machine element	Field	Length	N. installed	Fraction of the SPS length
MBA dipole magnet	0.12 T at 26 GeV/c 2.1 T at 450 GeV/c	6.3 m	360	32.8 %
MBB dipole magnet	0.12 T at 26 GeV/c 2.1 T at 450 GeV/c	6.3 m	384	35.0 %
QF quadrupole magnet	14.2 T/m at 450 GeV/c 0.82 T/m at 26 GeV/c	3.1 m	108	4.8 %
QD quadrupole magnet	14.2 T/m at 450 GeV/c 0.82 T/m at 26 GeV/c	3.1 m	108	4.8 %



Simulation results: MBA-type dipoles

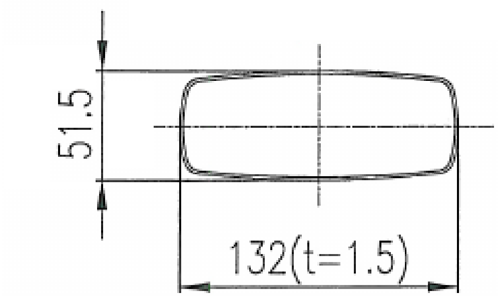


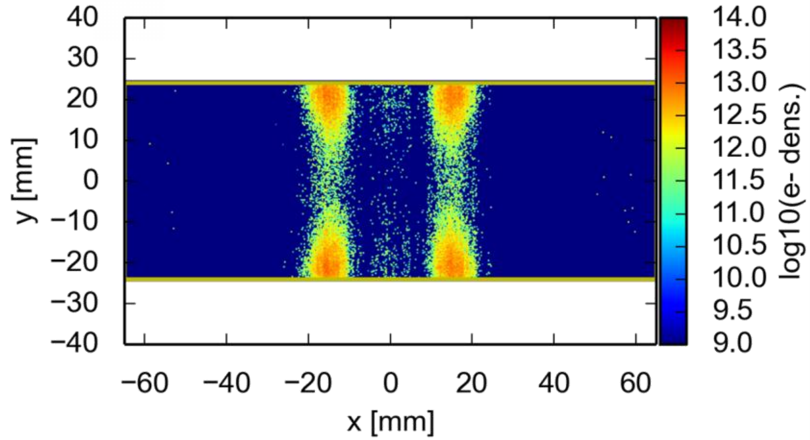


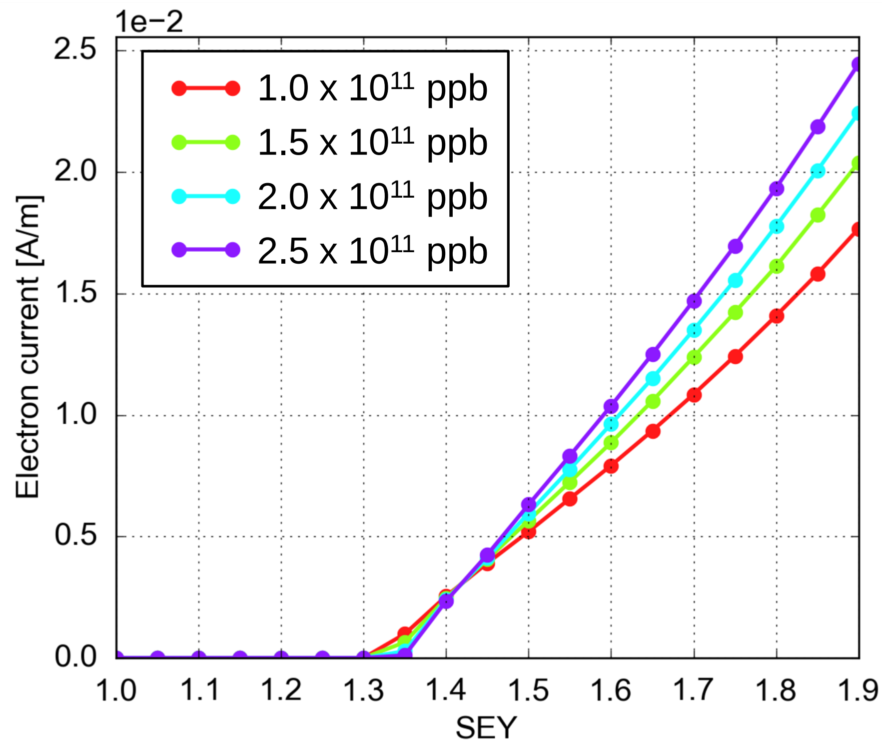


- Transverse distribution with two vertical stripes (typical of e-cloud in dipoles)
- Multipacting threshold at **SEY_{thr}=1.6**
- Dependence on bunch intensity is quite weak

Simulation results: MBB-type dipoles

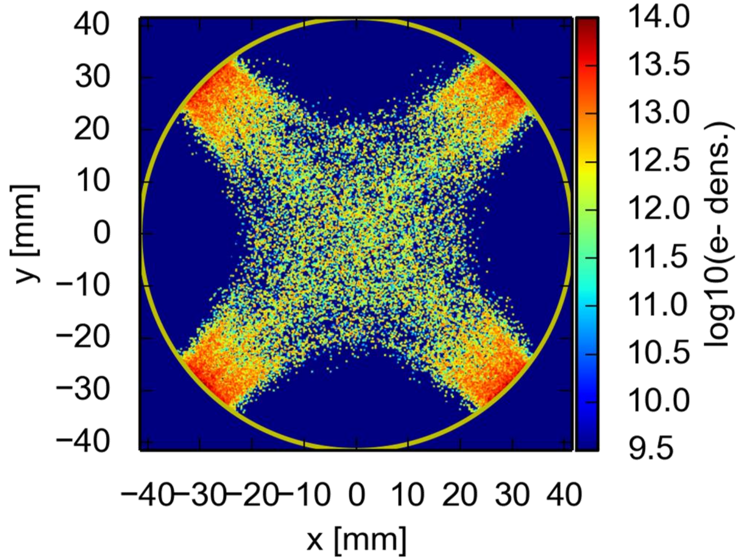


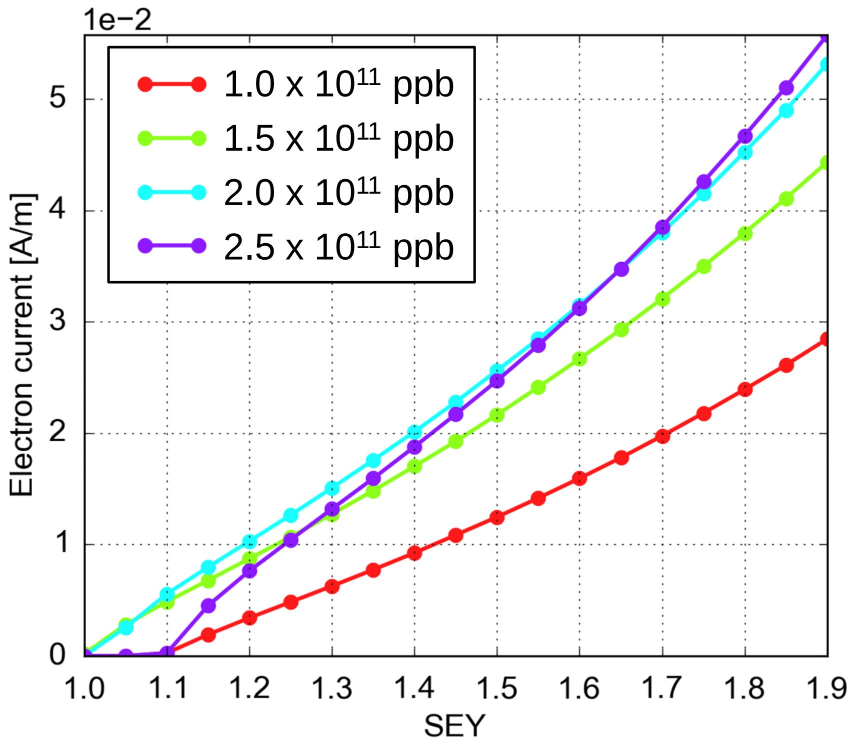




- Transverse distribution with two vertical stripes (typical of e-cloud in dipoles)
- Multipacting threshold at **SEY_{thr}=1.35** (due to larger vertical size w.r.t MBA)
- Dependence on bunch intensity is quite weak

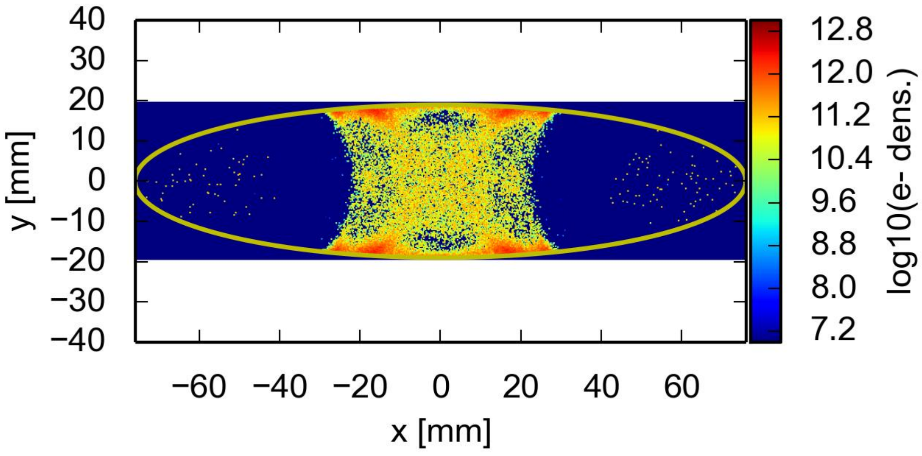
Simulation results: QD-type quadrupoles

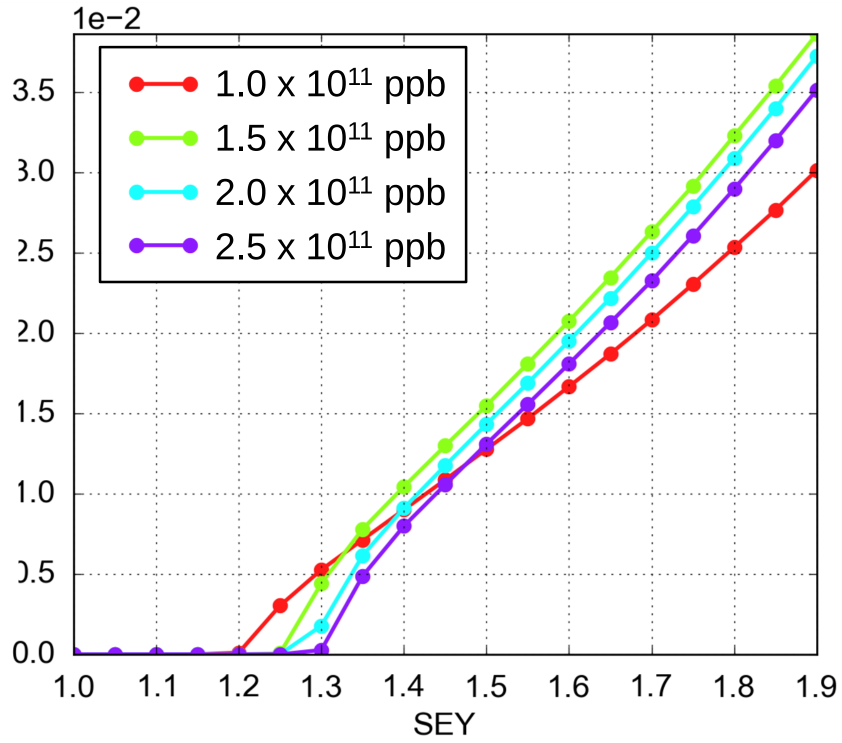




- Electrons **“trapped” on the quadrupole field lines**
- Multipacting threshold at **SEY_{thr}=1.10**
- Dependence on bunch intensity is quite weak

Simulation results: QF-type quadrupoles

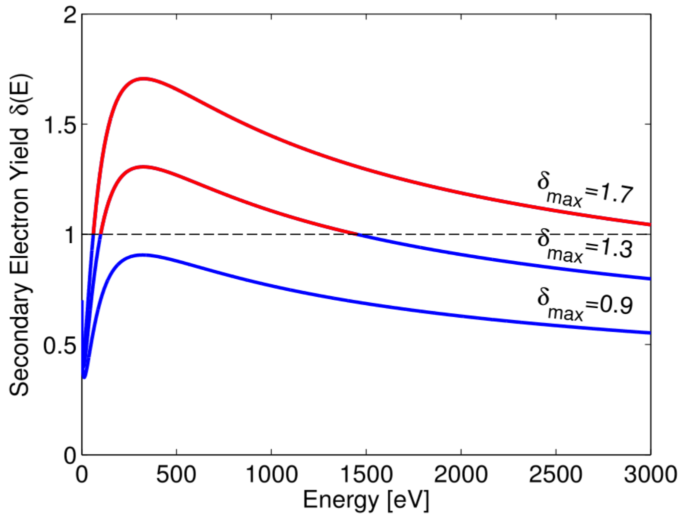




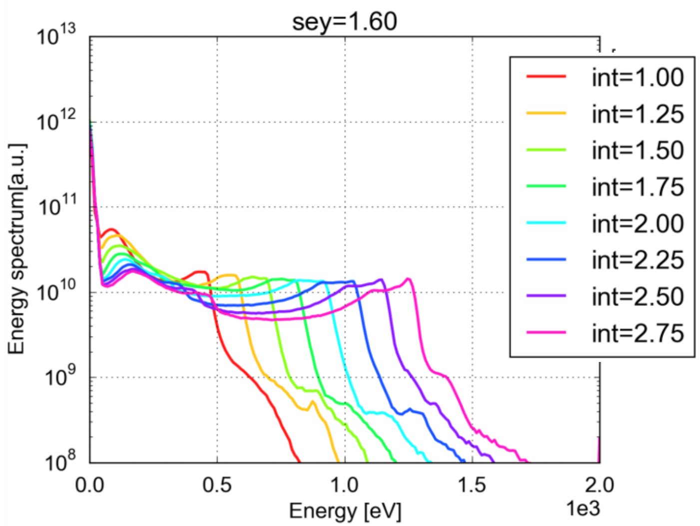
- Electrons **“trapped” on the quadrupole field lines**
- Multipacting threshold at around **SEY_{thr}=1.25**
- Dependence on bunch intensity quite weak

Underlying mechanism:

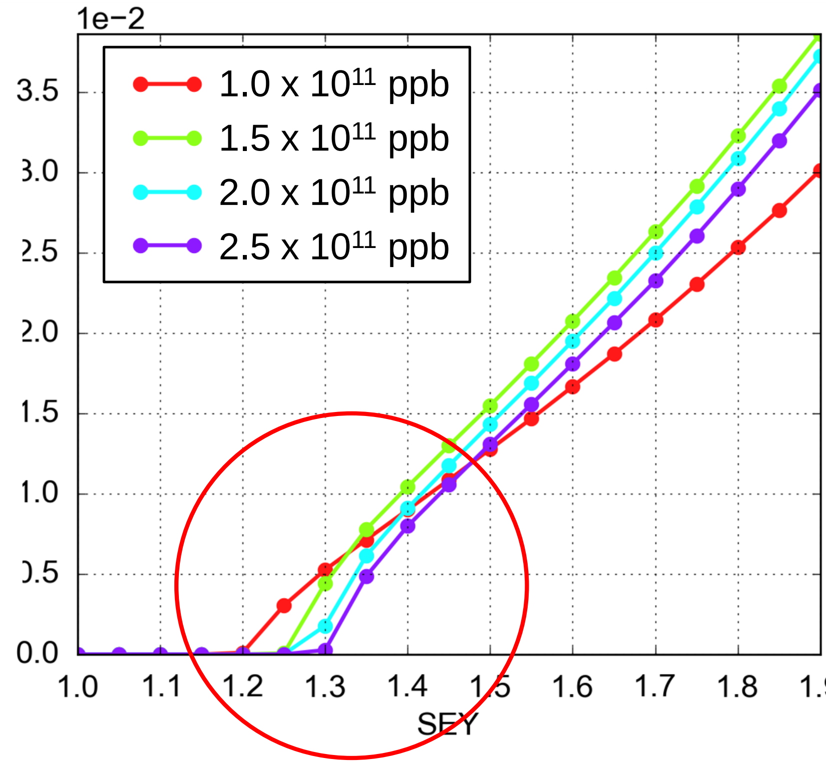
When the SEY decreases the **energy window for multipacting** becomes narrower



For high bunch intensity the e- spectrum drifts to higher energies and can move outside the most efficient region



F-type quadrupoles

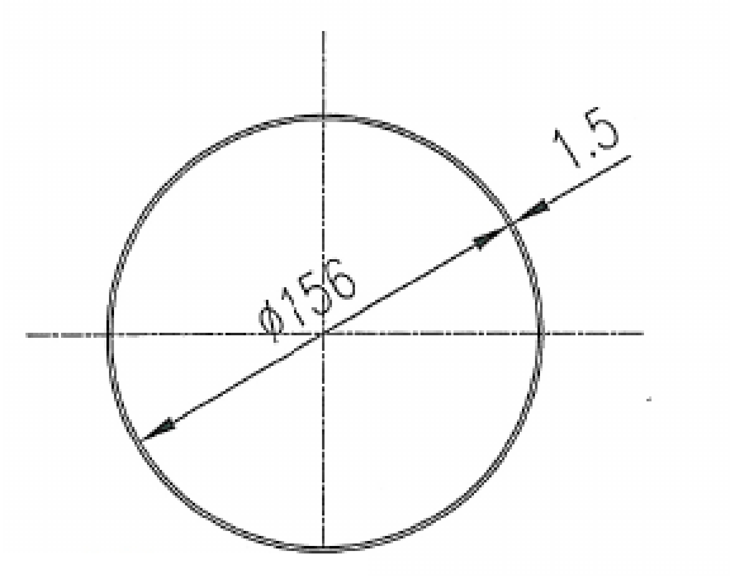


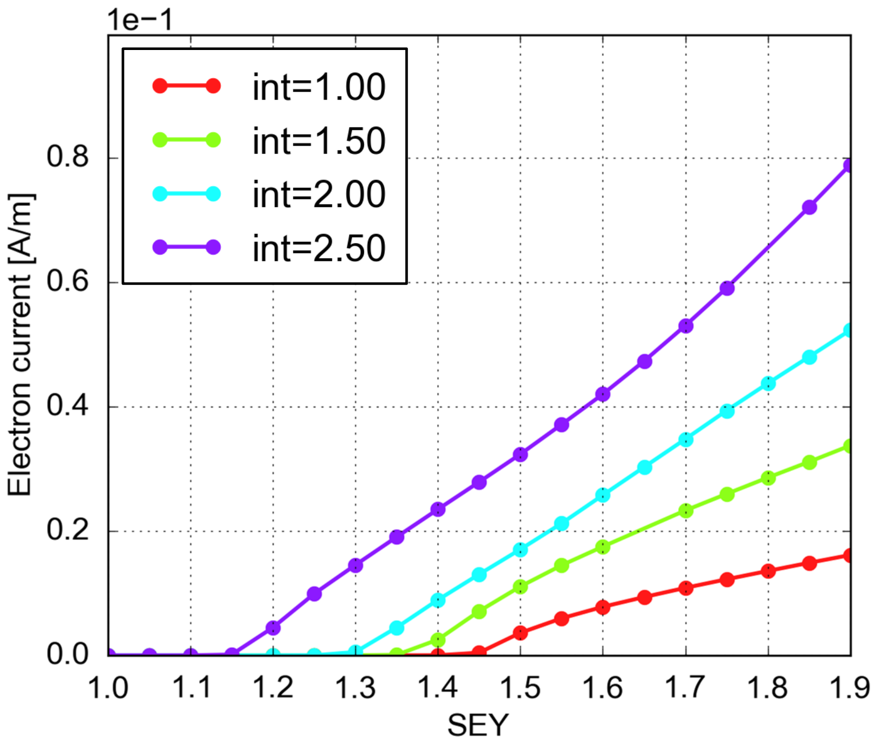
d lines

.25

k

Simulation results: 156-mm drift chamber





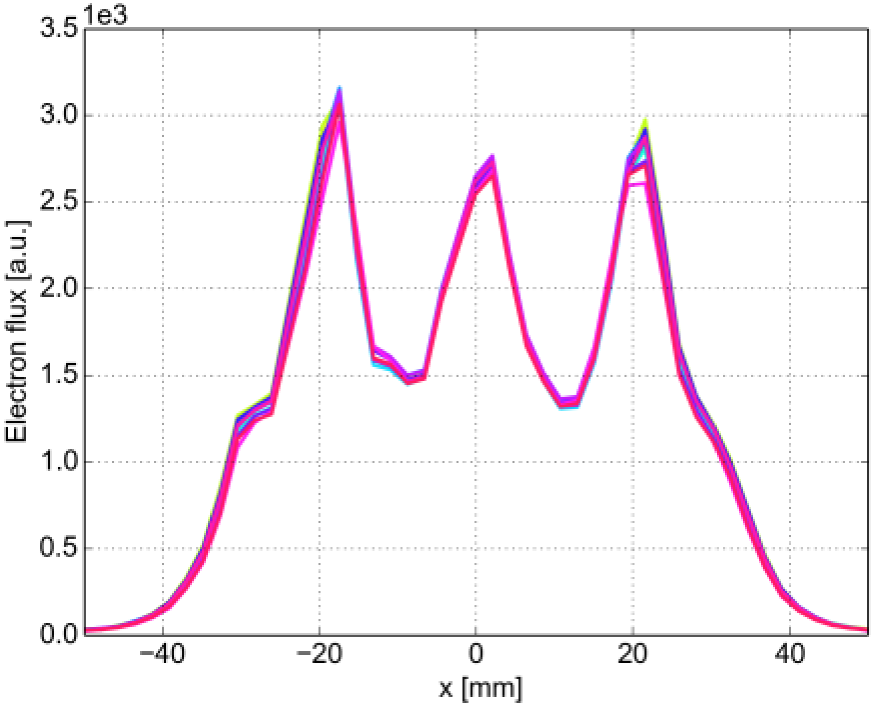
- Standard SPS drift chamber
- ~800 m along the machine **- ~4.1 % of the SPS length**
- Multipacting threshold **decreasing with bunch intensity**

Comparison against experimental data

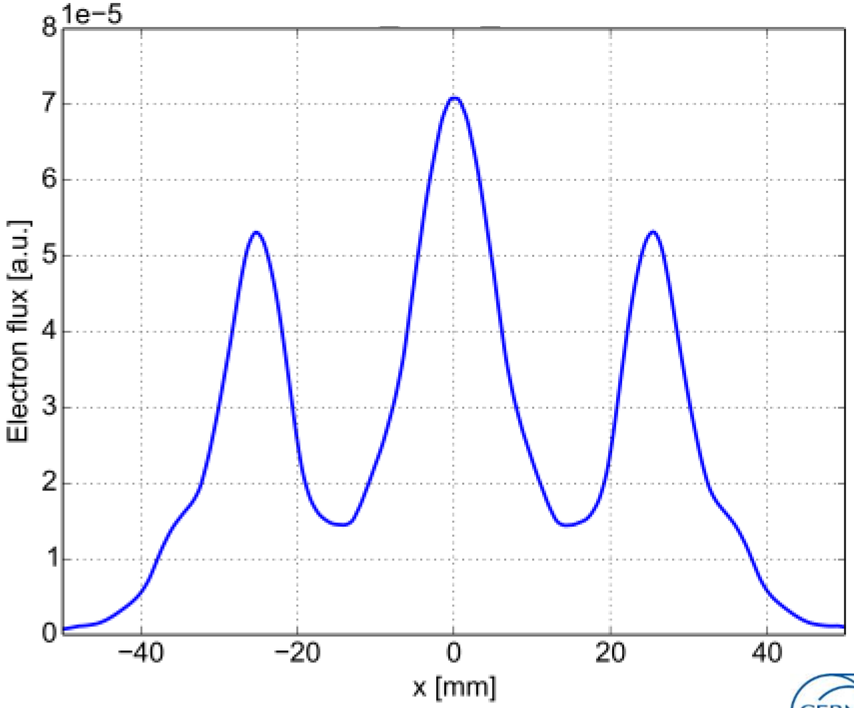
- When changing the **B field on the e-cloud monitor**, different patterns are observed on the horizontal distribution of the electron flux
- The different distributions are **successfully reproduced by PyECLOUD simulations**

B = 42 G

Measurement



Simulation

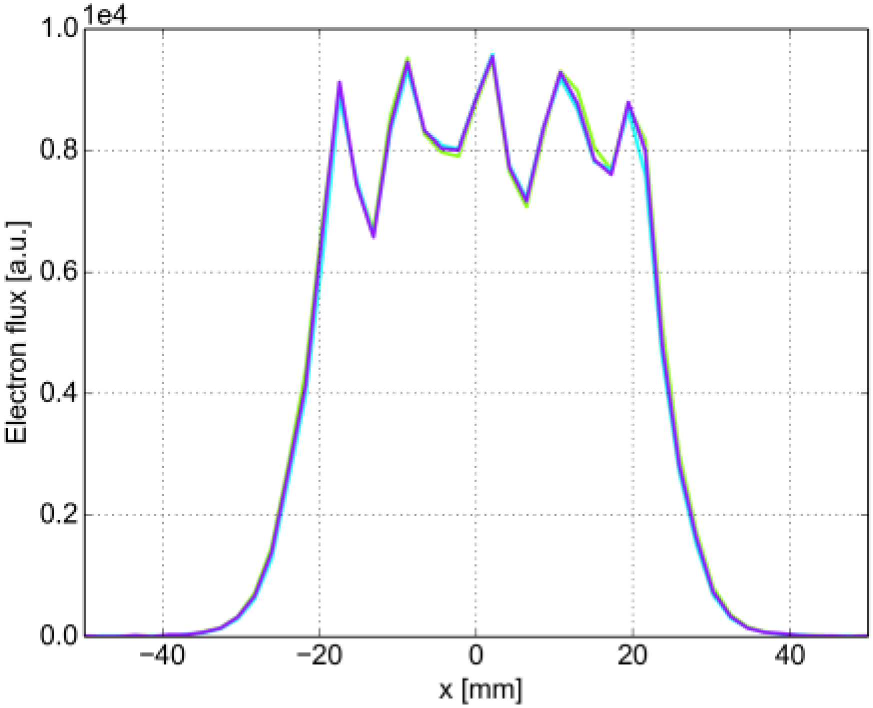


Comparison against experimental data

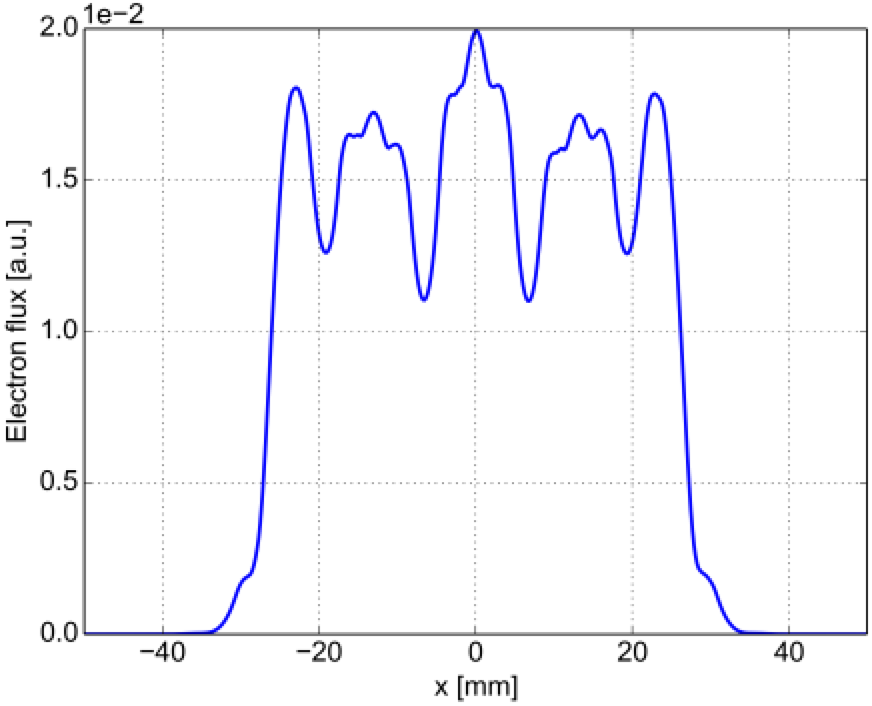
- When changing the **B field on the e-cloud monitor**, different patterns are observed on the horizontal distribution of the electron flux
- The different distributions are **successfully reproduced by PyECLOUD simulations**

B = 83 G

Measurement



Simulation

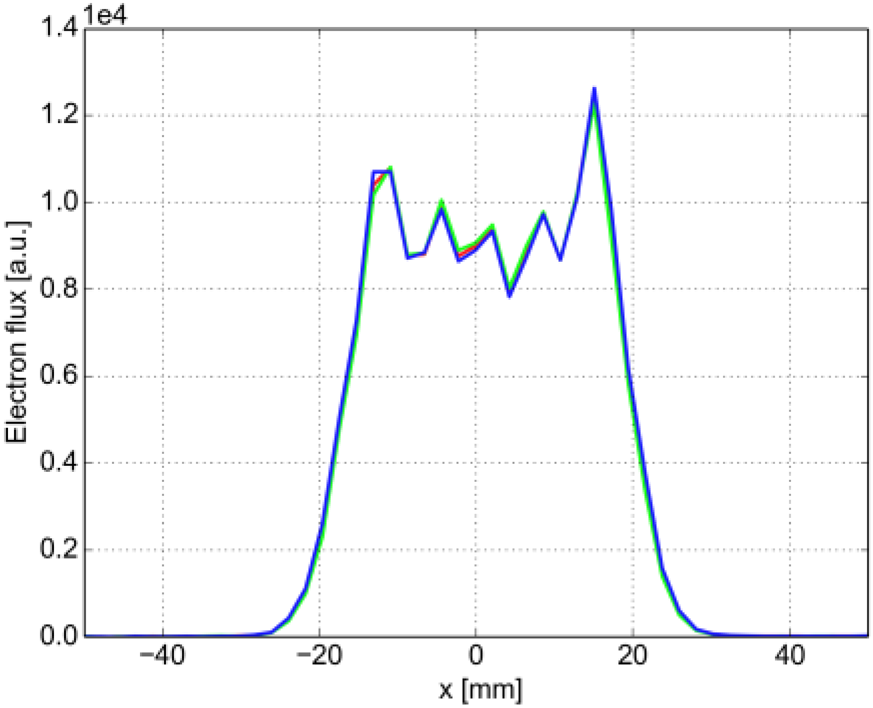


Comparison against experimental data

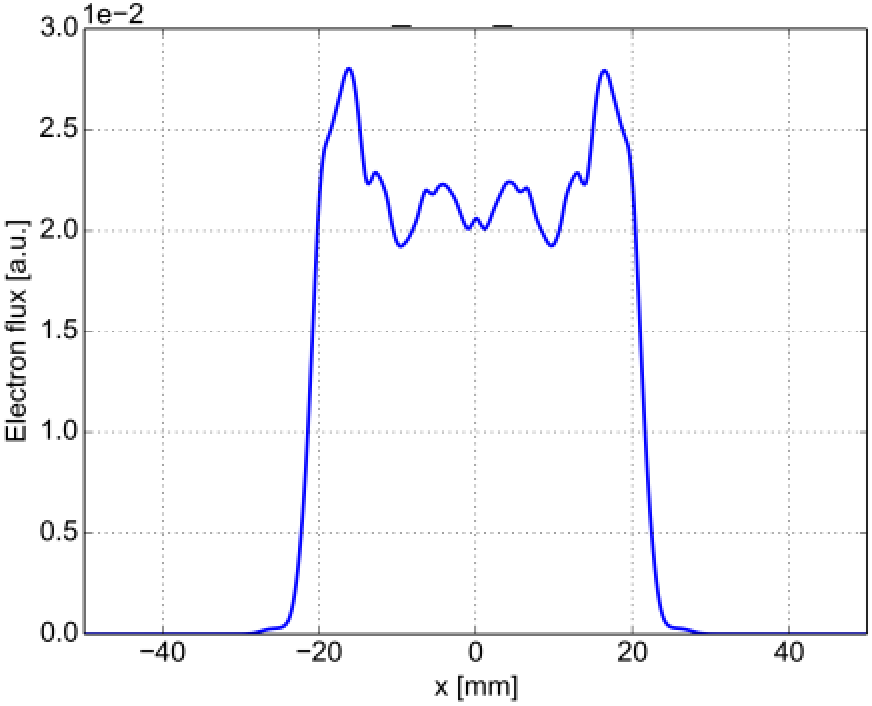
- When changing the **B field on the e-cloud monitor**, different patterns are observed on the horizontal distribution of the electron flux
- The different distributions are **successfully reproduced by PyECLOUD simulations**

B = 125 G

Measurement



Simulation

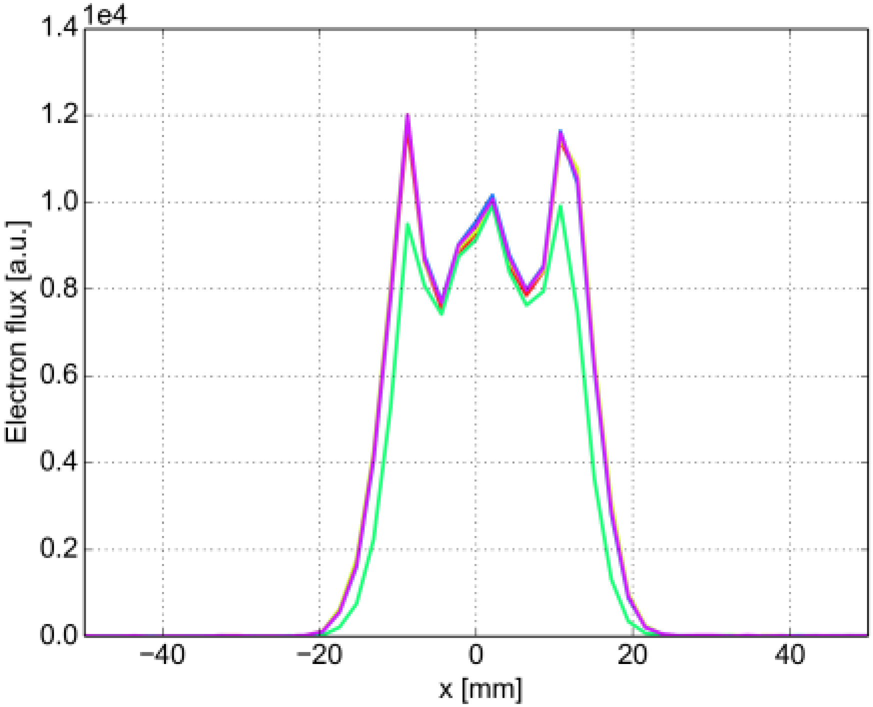


Comparison against experimental data

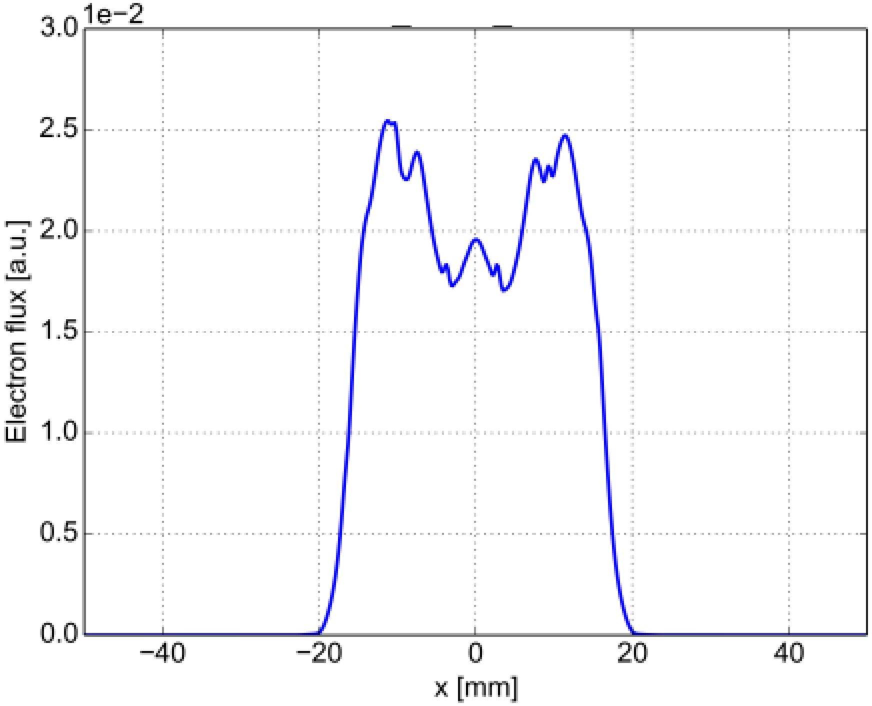
- When changing the **B field on the e-cloud monitor**, different patterns are observed on the horizontal distribution of the electron flux
- The different distributions are **successfully reproduced by PyECLOUD simulations**

B = 175G

Measurement



Simulation

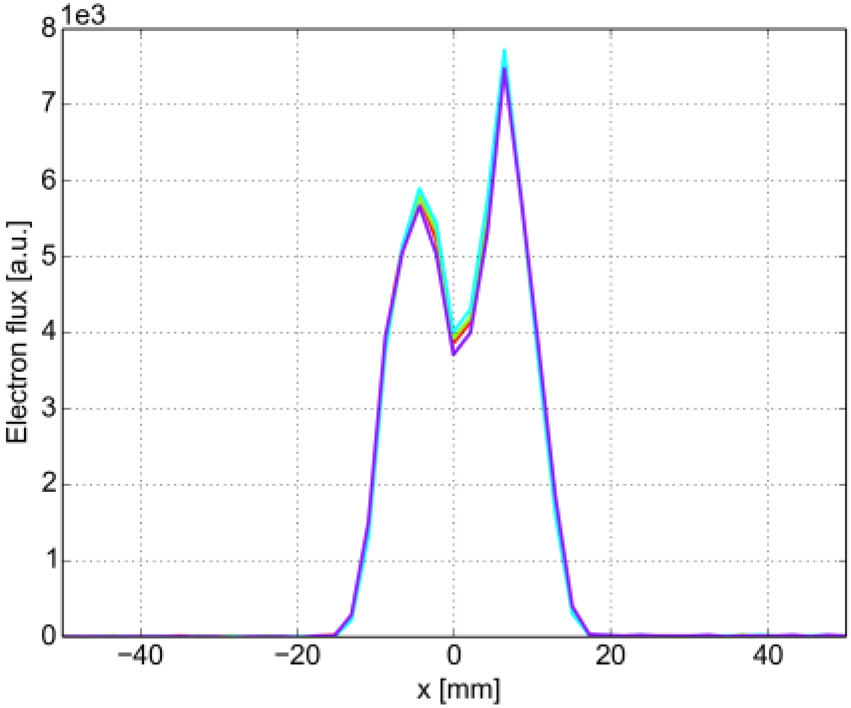


Comparison against experimental data

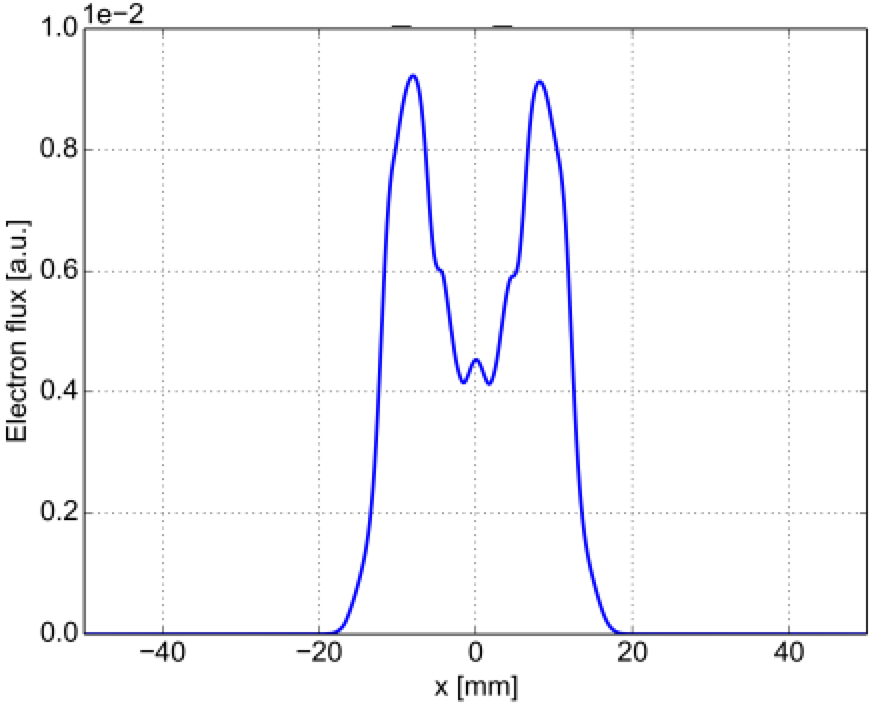
- When changing the **B field on the e-cloud monitor**, different patterns are observed on the horizontal distribution of the electron flux
- The different distributions are **successfully reproduced by PyECLOUD simulations**

B = 250 G

Measurement



Simulation

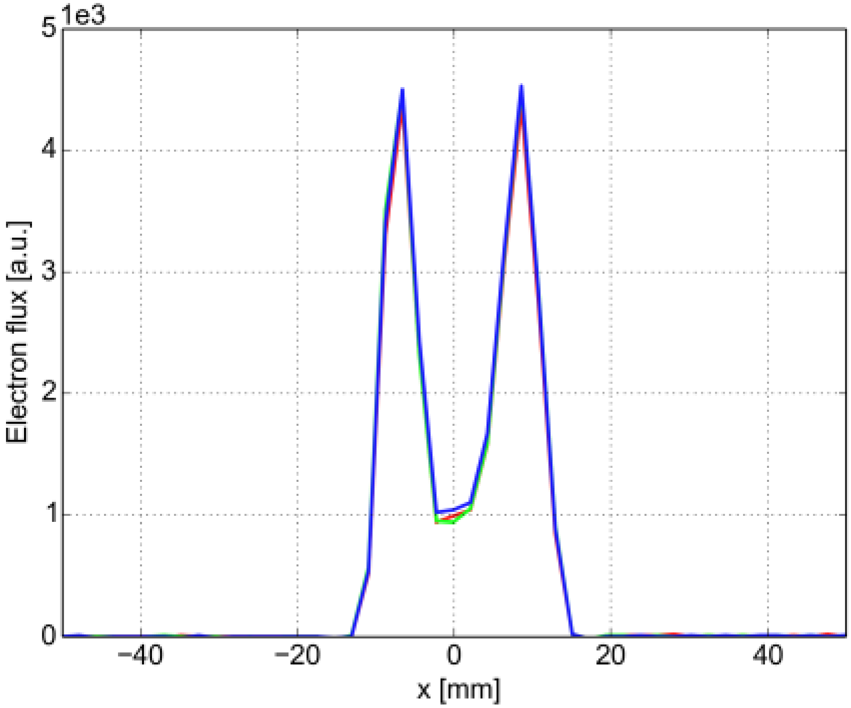


Comparison against experimental data

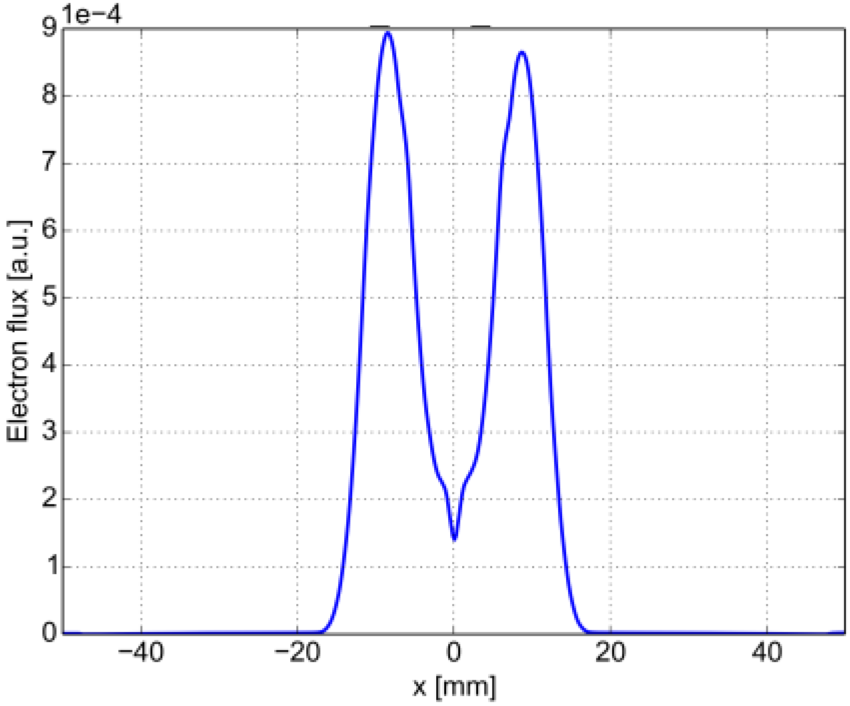
- When changing the **B field on the e-cloud monitor**, different patterns are observed on the horizontal distribution of the electron flux
- The different distributions are **successfully reproduced by PyECLOUD simulations**

B = 833 G

Measurement



Simulation

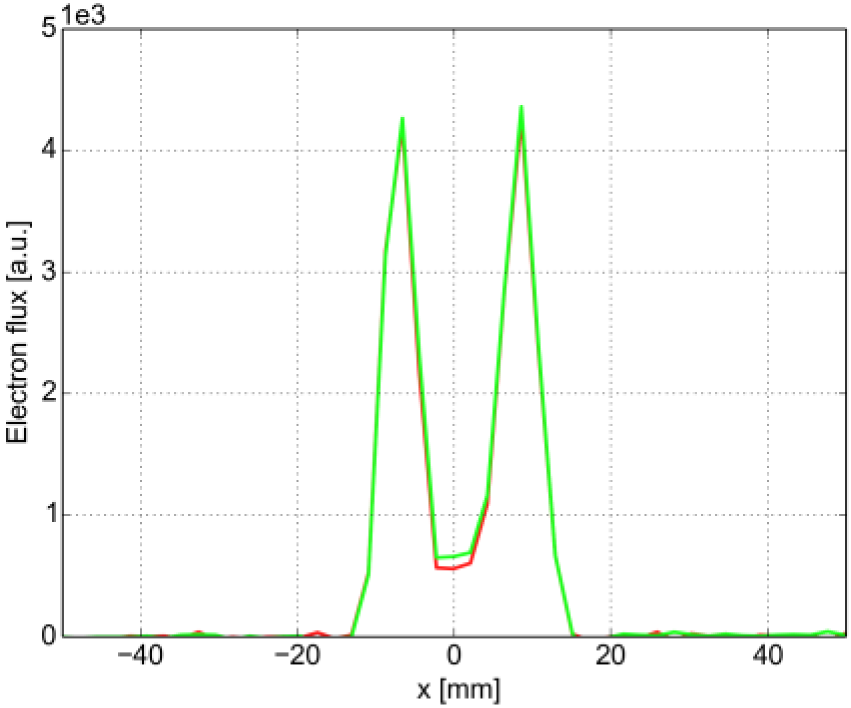


Comparison against experimental data

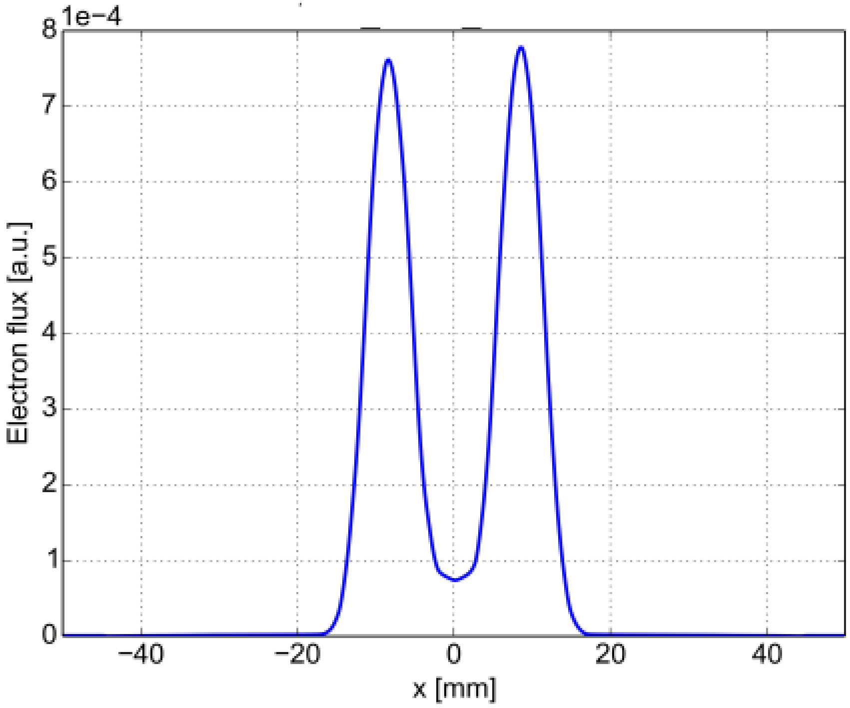
- When changing the **B field on the e-cloud monitor**, different patterns are observed on the horizontal distribution of the electron flux
- The different distributions are **successfully reproduced by PyECLOUD simulations**

B = 1000 G

Measurement

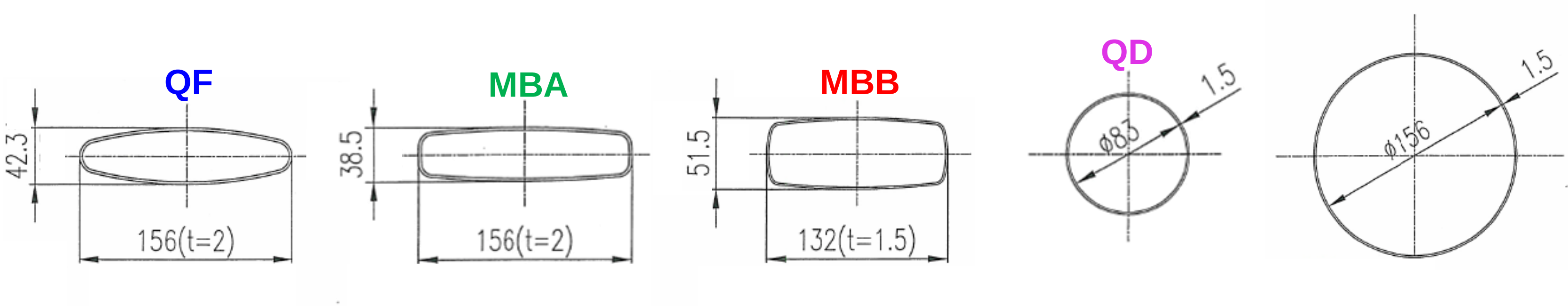


Simulation



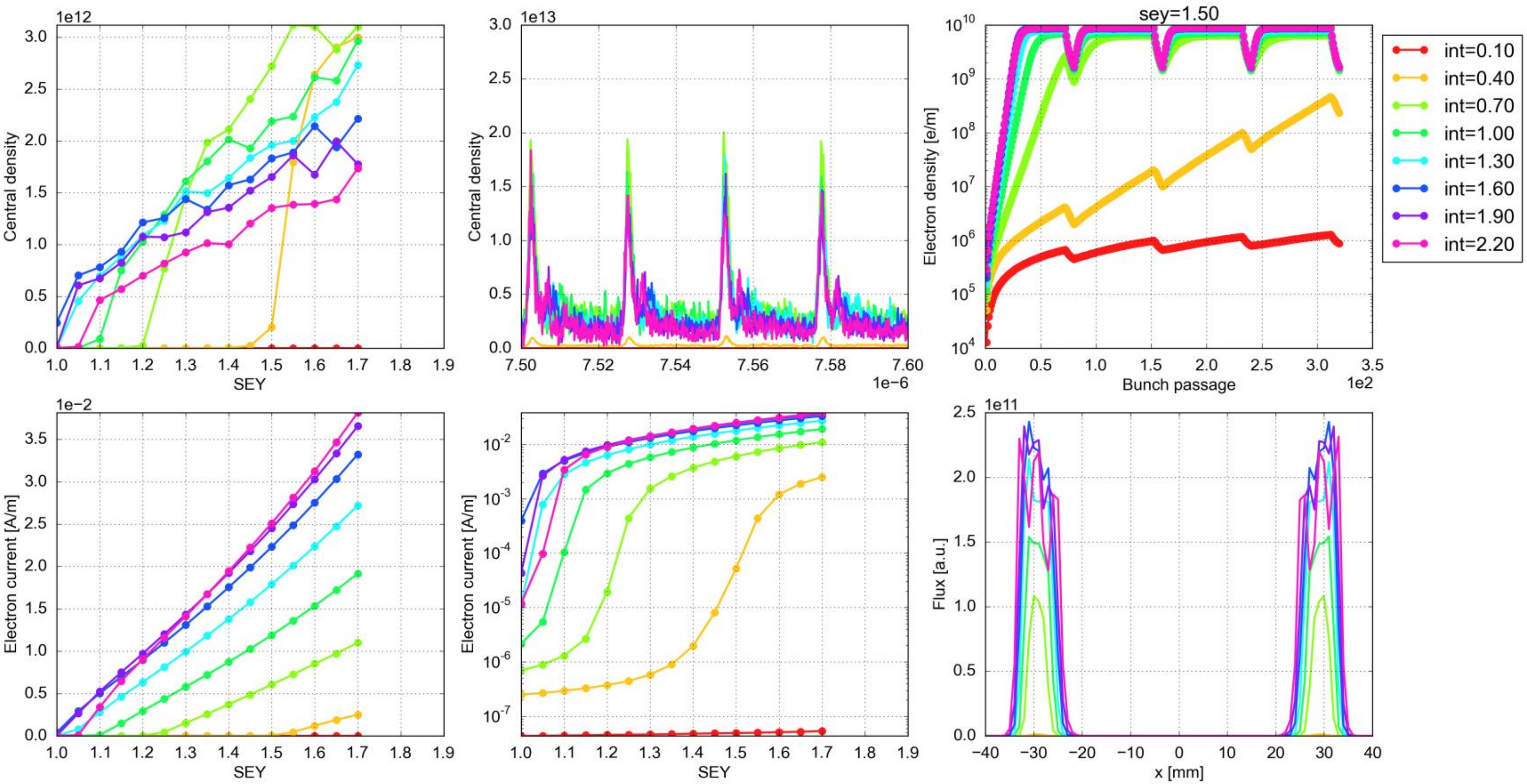
Multipacting thresholds: summary table

Machine element	Fraction of the machine	Multipacting threshold (SEY)			
		1.0×10^{11} ppb	1.5×10^{11} ppb	2.0×10^{11} ppb	2.5×10^{11} ppb
MBA dipole magnet	32.8 %	1.60	1.60	1.60	**1.6**
MBB dipole magnet	**35.0 %**	1.35	1.35	1.40	**1.40**
QF quadrupole magnet	4.8 %	1.25	1.30	1.30	1.35
QD quadrupole magnet	4.8 %	1.15	1.05	1.05	**1.15**
156-mm drift chamber	4.1 %	1.50	1.40	1.35	**1.20**



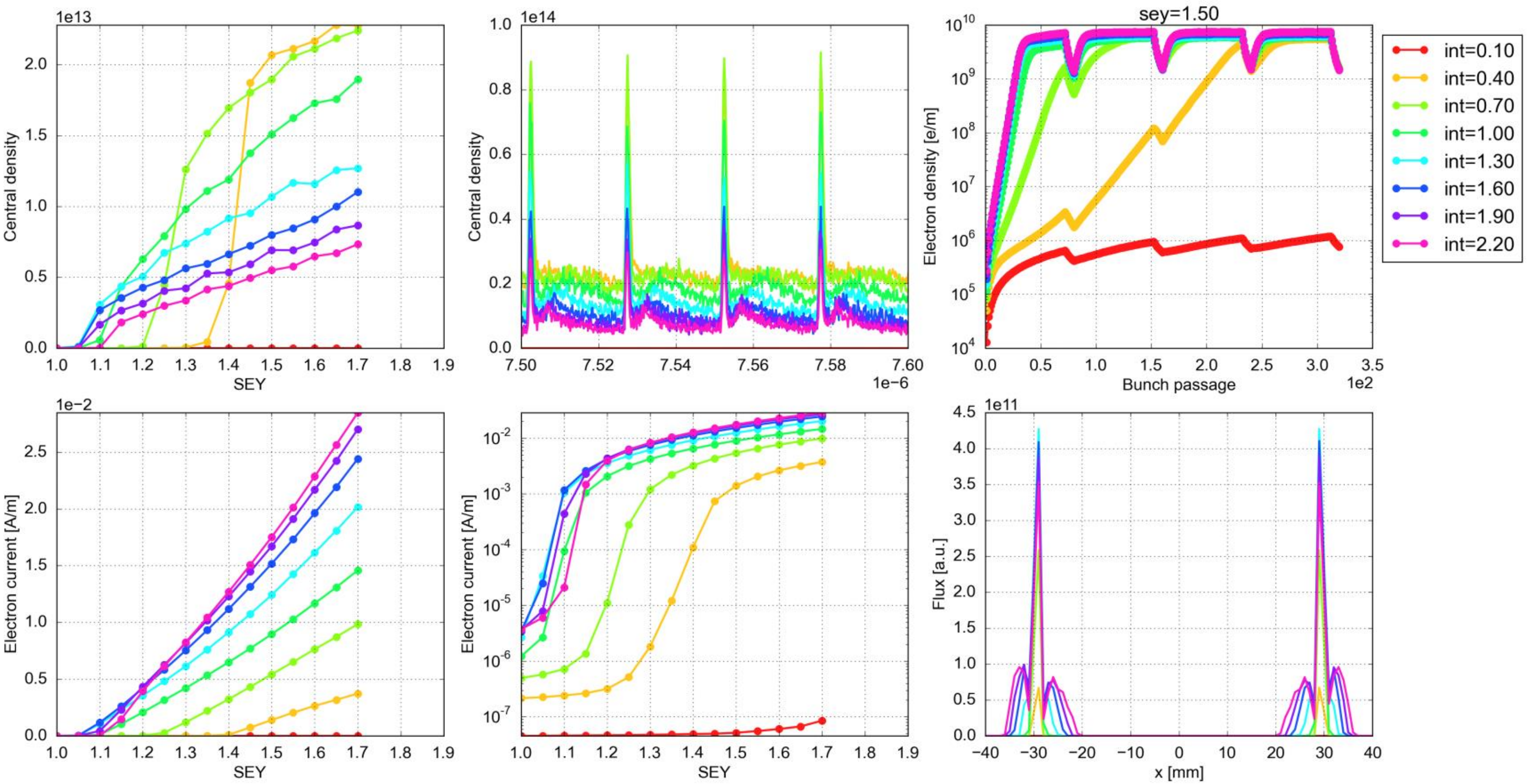
Thank you for your attention!

SPS_QD_26GeV

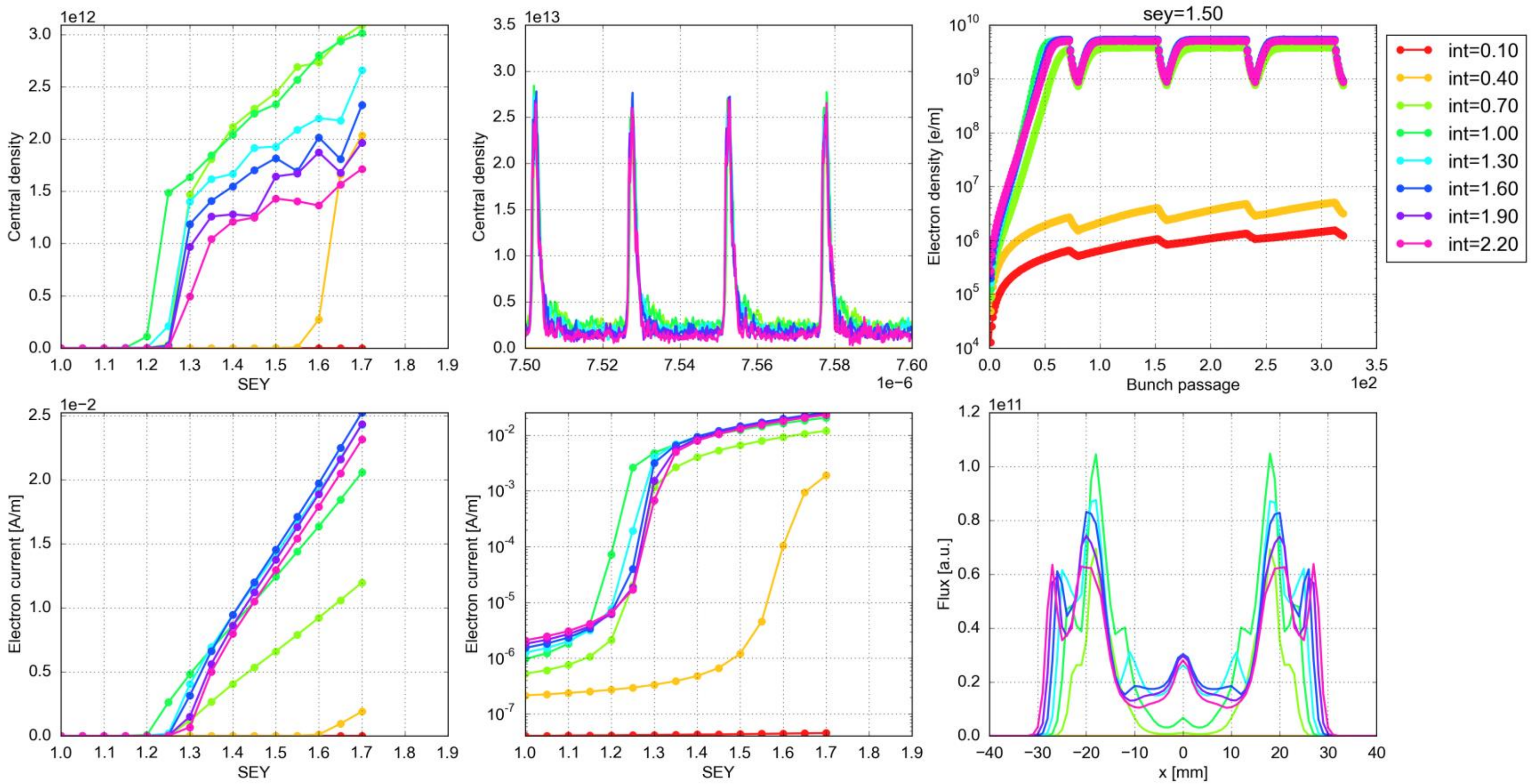


sey=1.50
int=0.10
int=0.40
int=0.70
int=1.00
int=1.30
int=1.60
int=1.90
int=2.20
Central density
SEY
Bunch passage
Electron density [e/m]
Electron current [A/m]
Flux [a.u.]
x [mm]

SPS_QD_450GeV

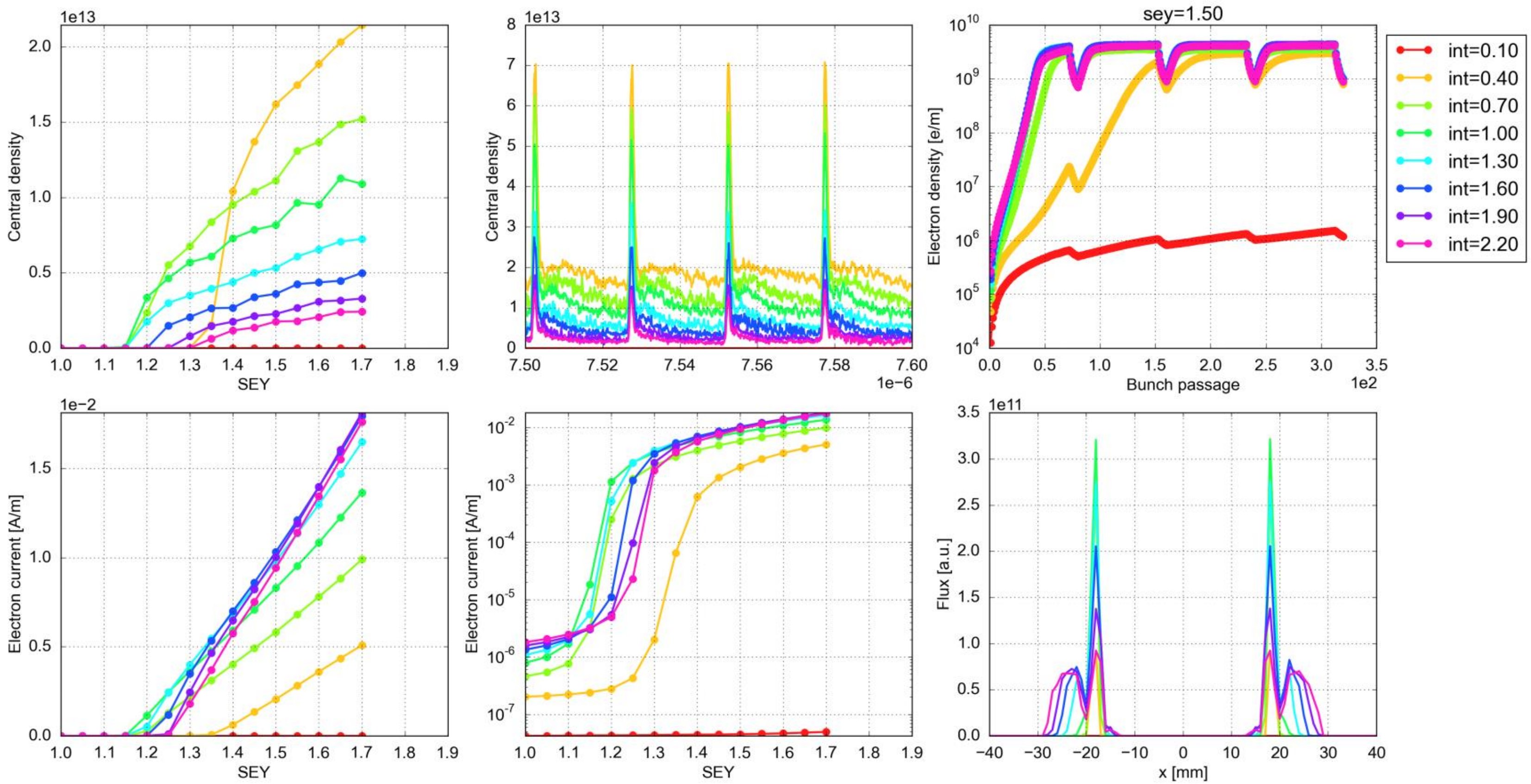


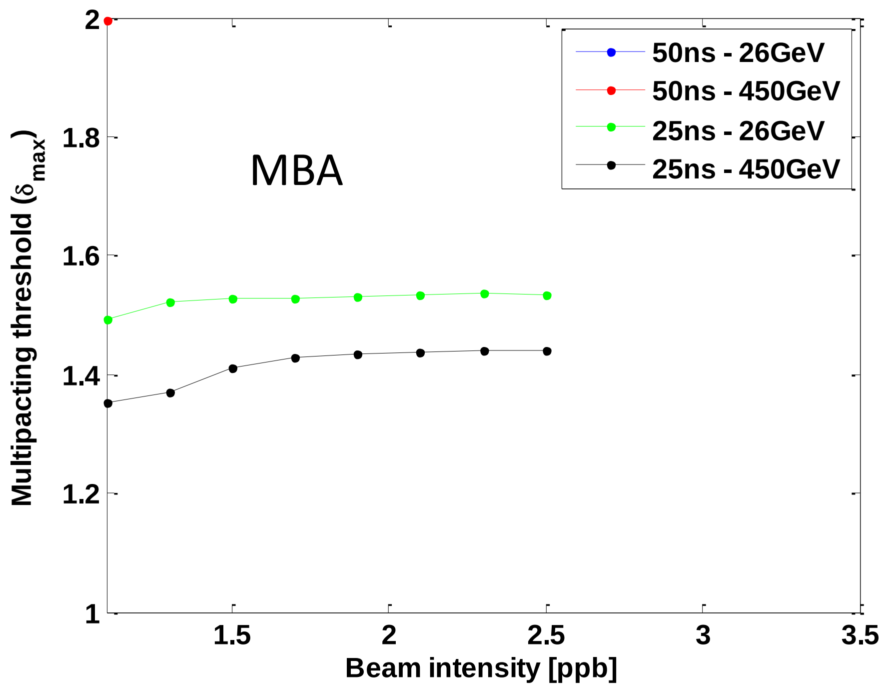
SPS_QF_26GeV



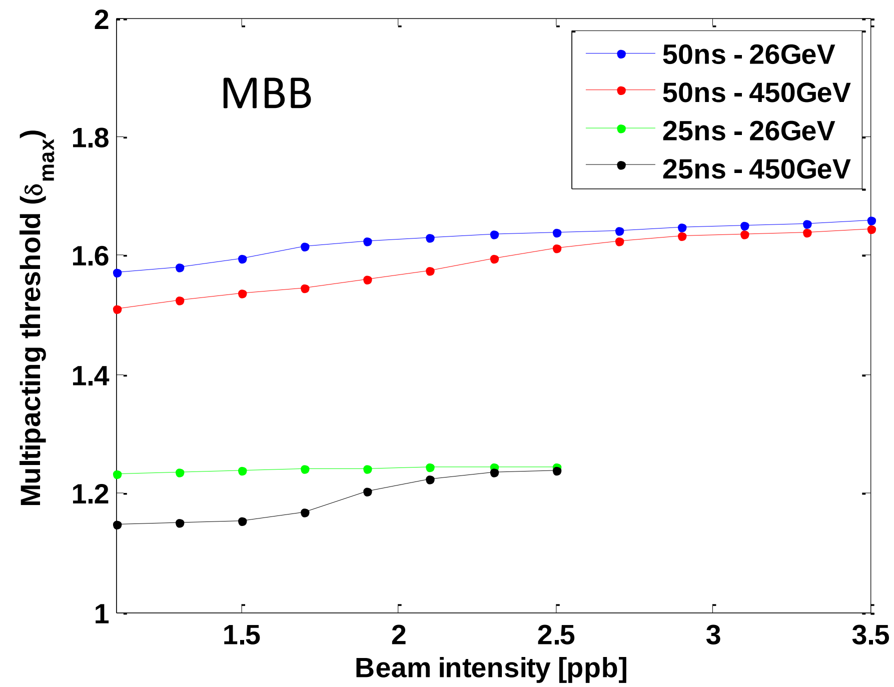
1e12
Central density
SEY
1e13
Central density
1e−6
sey=1.50
Electron density [e/m]
Bunch passage
1e2
int=0.10
int=0.40
int=0.70
int=1.00
int=1.30
int=1.60
int=1.90
int=2.20
1e−2
Electron current [A/m]
SEY
Electron current [A/m]
SEY
1e11
Flux [a.u.]
x [mm]

SPS_QF_450GeV





MBA
50ns - 26GeV
50ns - 450GeV
25ns - 26GeV
25ns - 450GeV
Multipacting threshold (δ_{max})
Beam intensity [ppb]
2
1.8
1.6
1.4
1.2
1
1.5
2
2.5
3
3.5



MBB
50ns - 26GeV
50ns - 450GeV
25ns - 26GeV
25ns - 450GeV
Multipacting threshold (δ_{max})
Beam intensity [ppb]
2
1.8
1.6
1.4
1.2
1
1.5
2
2.5
3
3.5