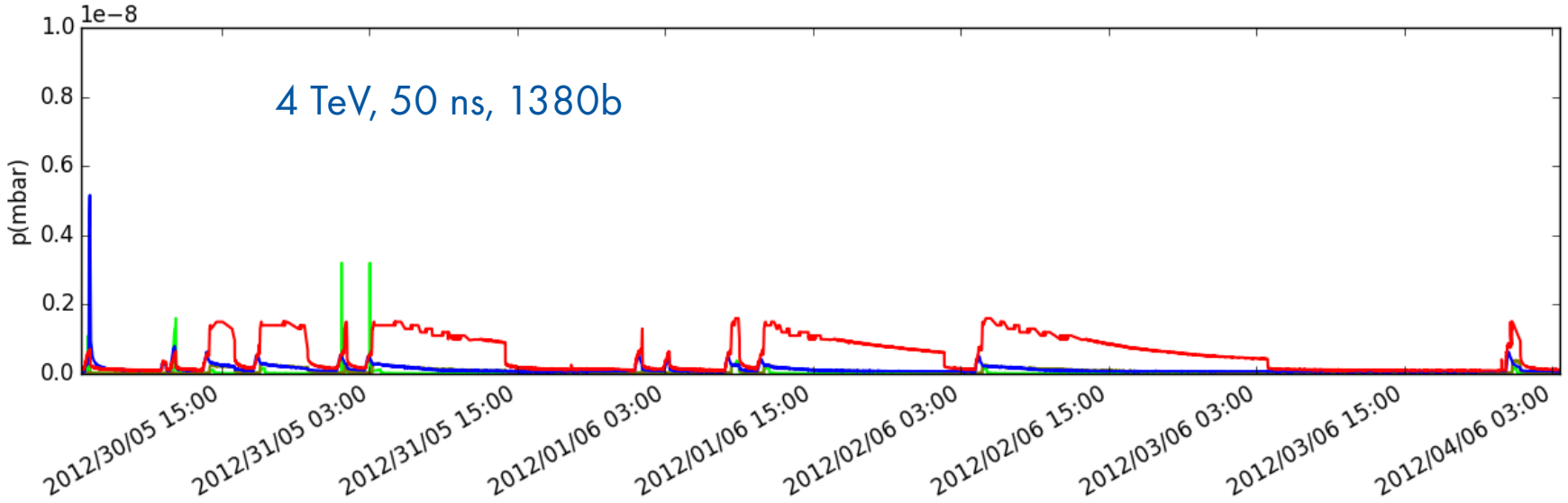
Simulation studies of e-cloud in LHC LSS
and its effect on dynamic vacuum

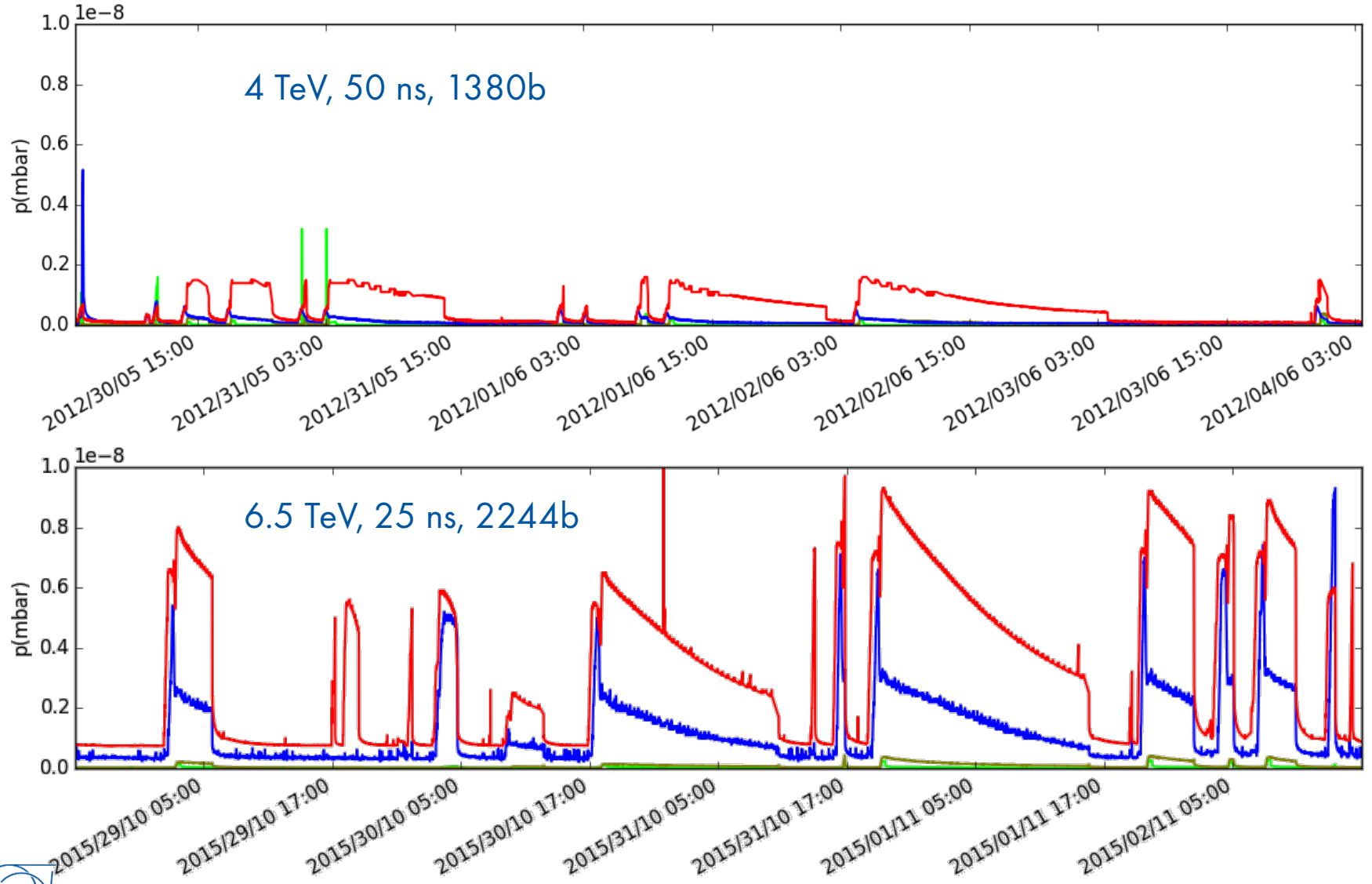
Jan Sopousek, TE-VSC-BVO

Electron Cloud Meeting 13/7/2016

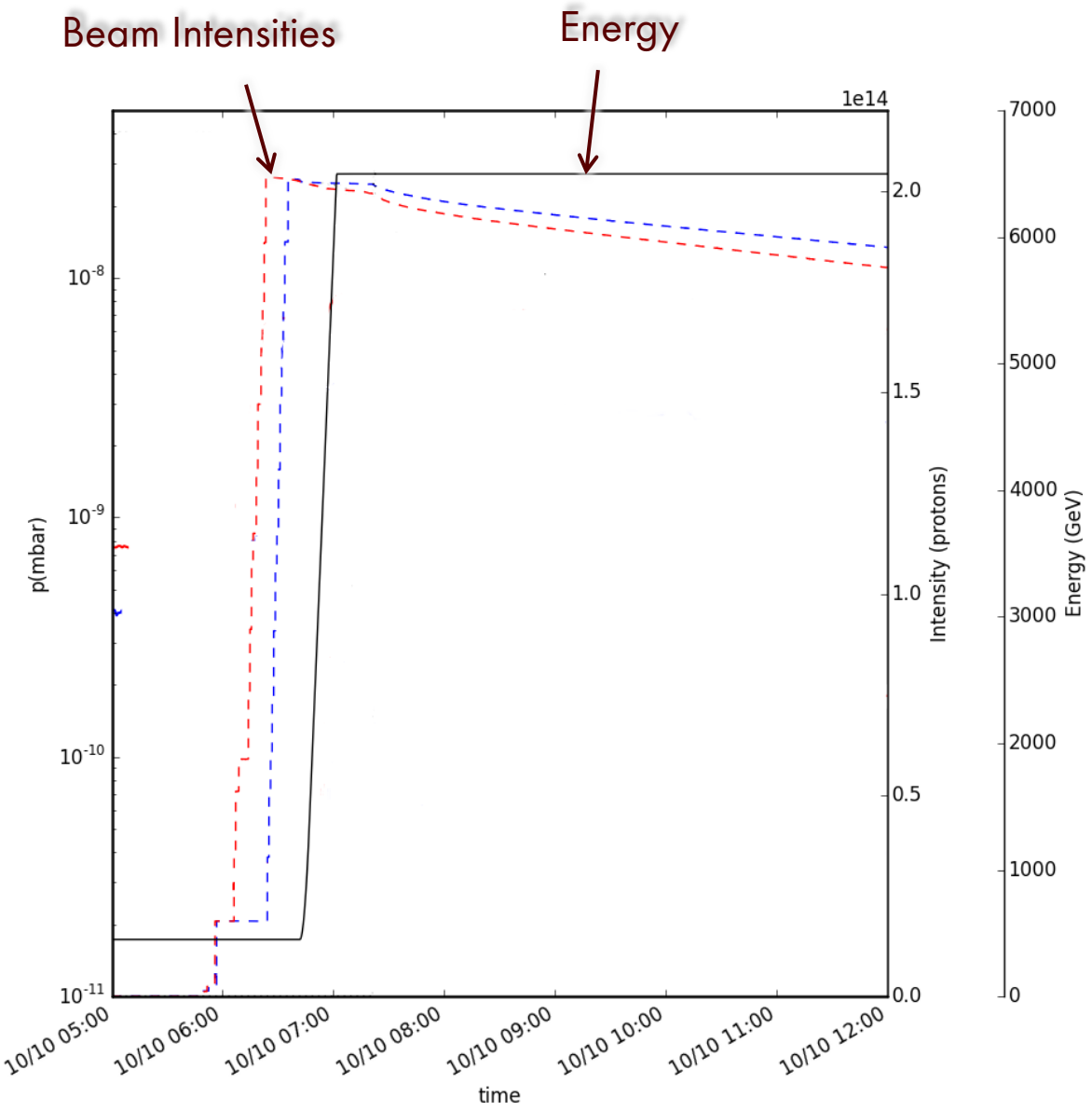
Motivation

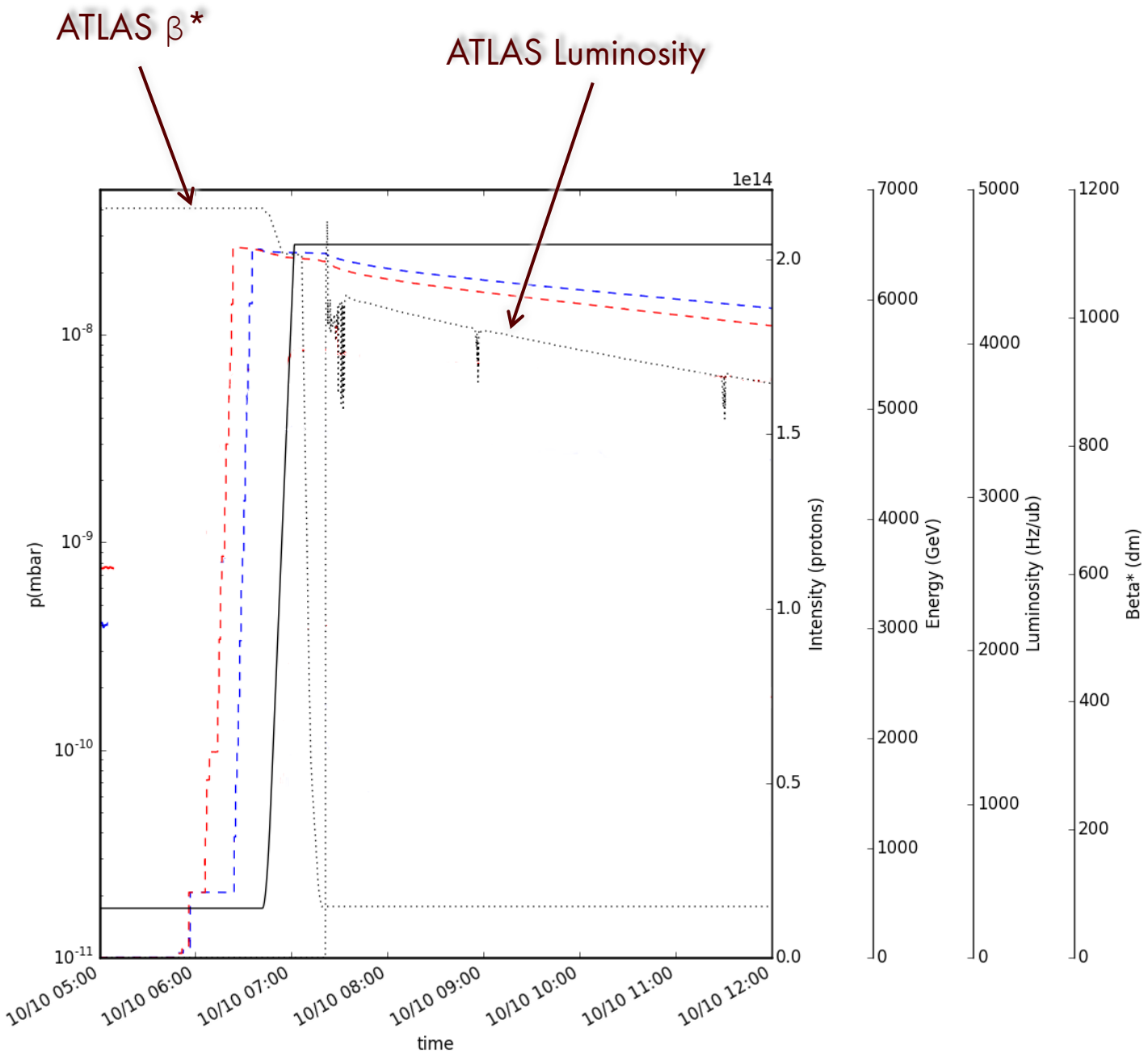

1e−8
1.0
0.8
0.6
0.4
0.2
0.0
p(mbar)
4 TeV, 50 ns, 1380b
2012/30/05 15:00
2012/31/05 03:00
2012/31/05 15:00
2012/01/06 03:00
2012/01/06 15:00
2012/02/06 03:00
2012/02/06 15:00
2012/03/06 03:00
2012/03/06 15:00
2012/04/06 03:00

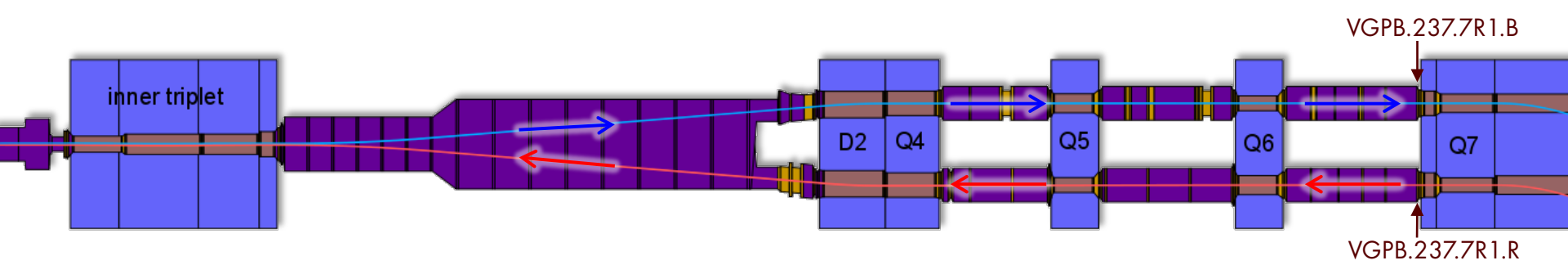
Motivation

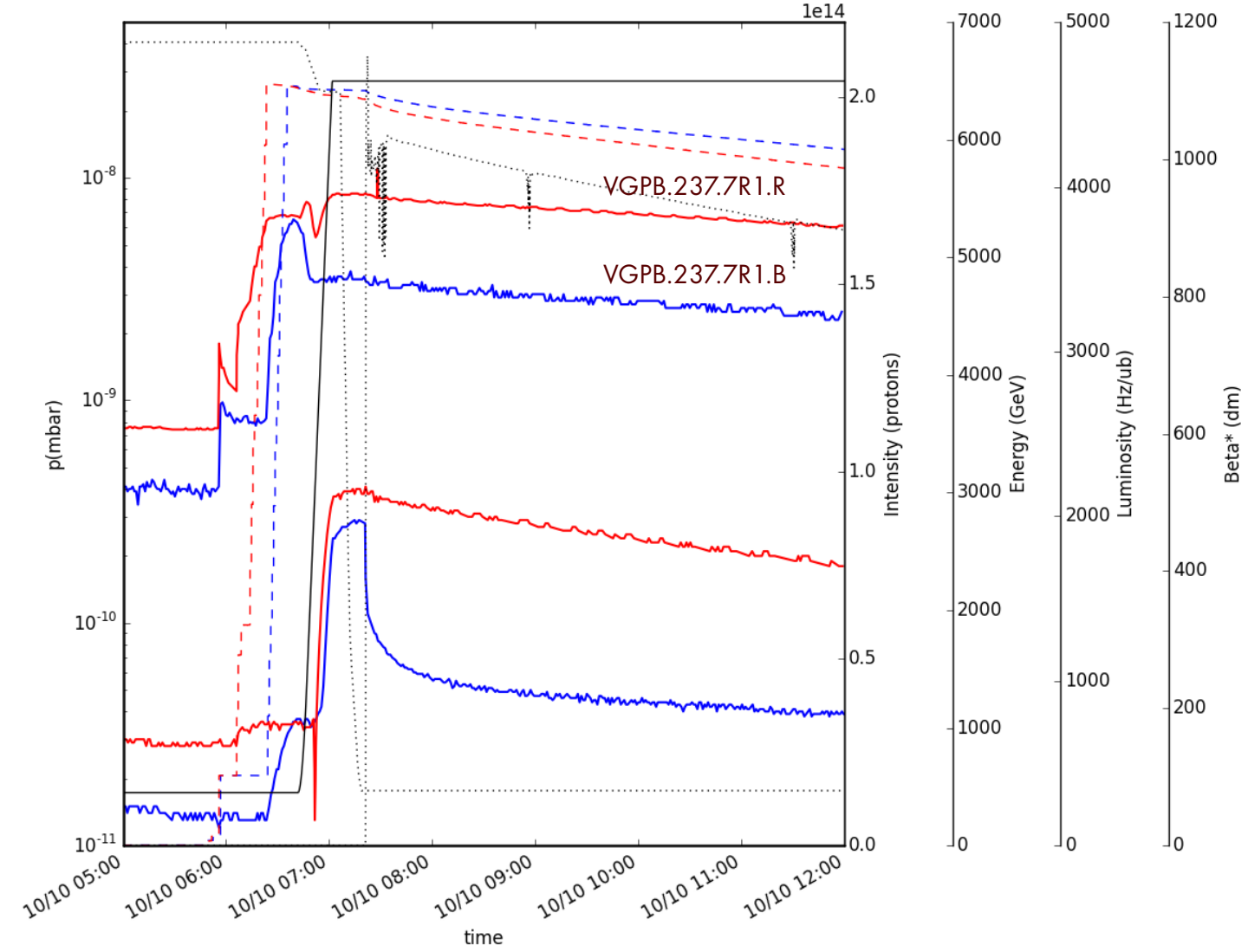

1e−8
1.0
0.8
0.6
0.4
0.2
0.0
p(mbar)
4 TeV, 50 ns, 1380b
2012/30/05 15:00
2012/31/05 03:00
2012/31/05 15:00
2012/01/06 03:00
2012/01/06 15:00
2012/02/06 03:00
2012/02/06 15:00
2012/03/06 03:00
2012/03/06 15:00
2012/04/06 03:00
1e−8
1.0
0.8
0.6
0.4
0.2
0.0
p(mbar)
6.5 TeV, 25 ns, 2244b
2015/29/10 05:00
2015/29/10 17:00
2015/30/10 05:00
2015/30/10 17:00
2015/31/10 05:00
2015/31/10 17:00
2015/01/11 05:00
2015/01/11 17:00
2015/02/11 05:00

Pressure evolution during one fill




ATLAS β*
ATLAS Luminosity
1e14
p(mbar)
Intensity (protons)
Energy (GeV)
Luminosity (Hz/ub)
Beta* (dm)
time
10/10 05:00
10/10 06:00
10/10 07:00
10/10 08:00
10/10 09:00
10/10 10:00
10/10 11:00
10/10 12:00


VGPB.237.7R1.B
inner triplet
D2
Q4
Q5
Q6
Q7
VGPB.237.7R1.R


1e14
VGPB.237.7R1.R
VGPB.237.7R1.B
p(mbar)
Intensity (protons)
Energy (GeV)
Luminosity (Hz/ub)
Beta* (dm)
time
10/10 05:00
10/10 06:00
10/10 07:00
10/10 08:00
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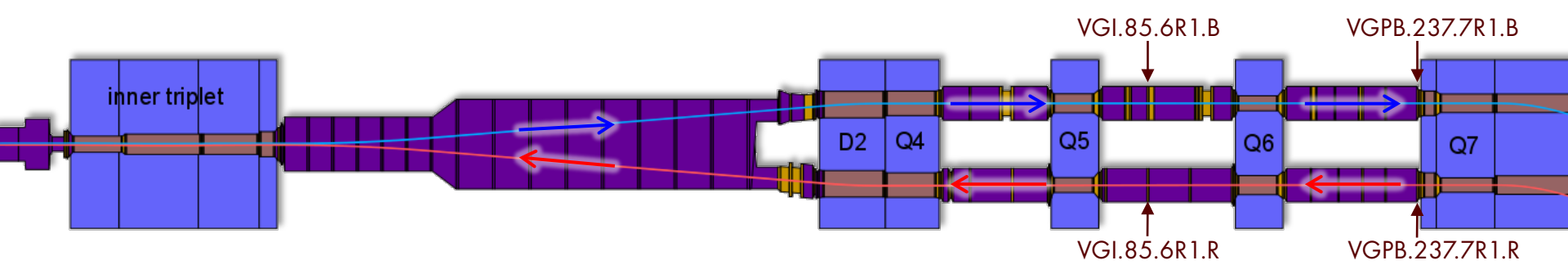
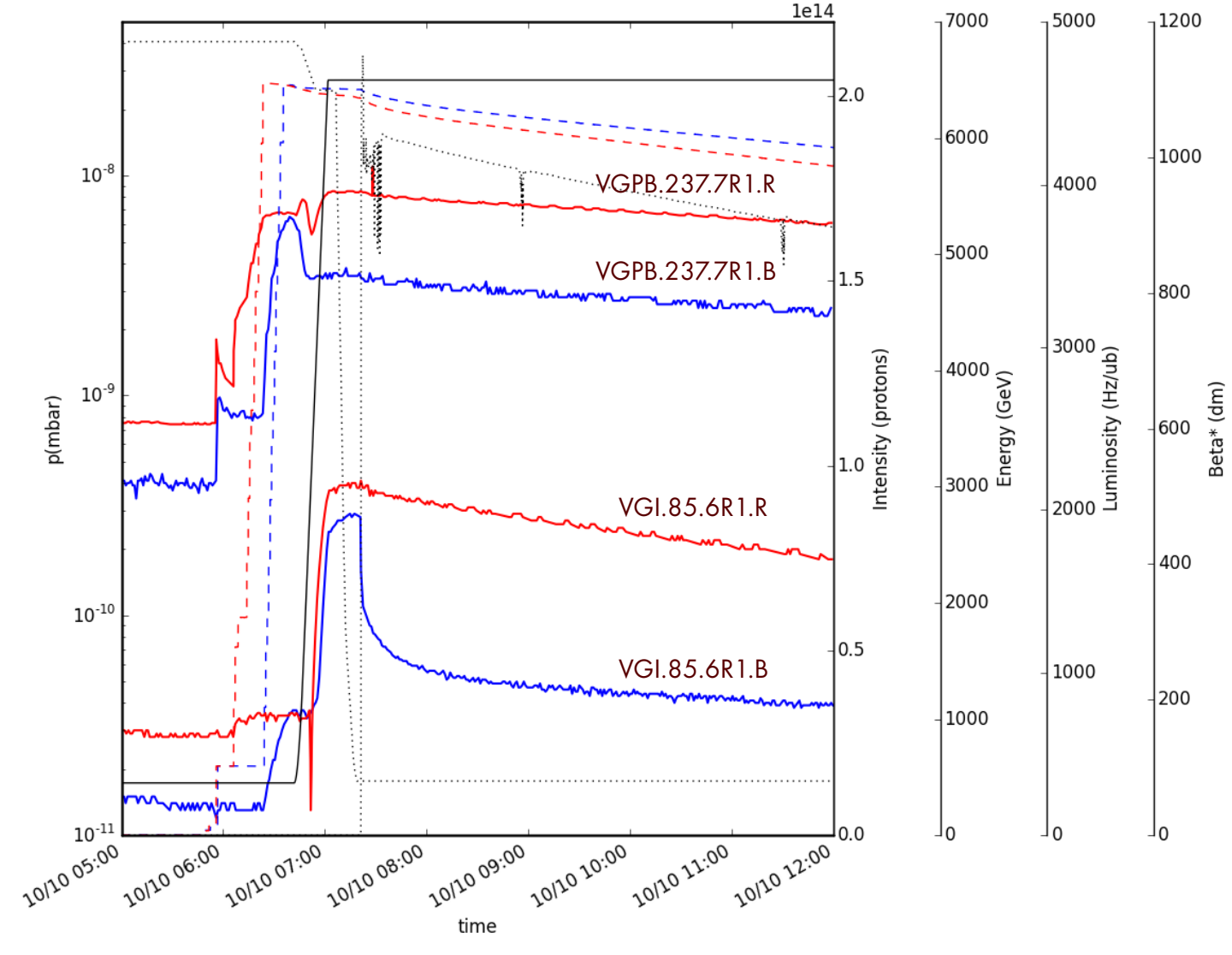
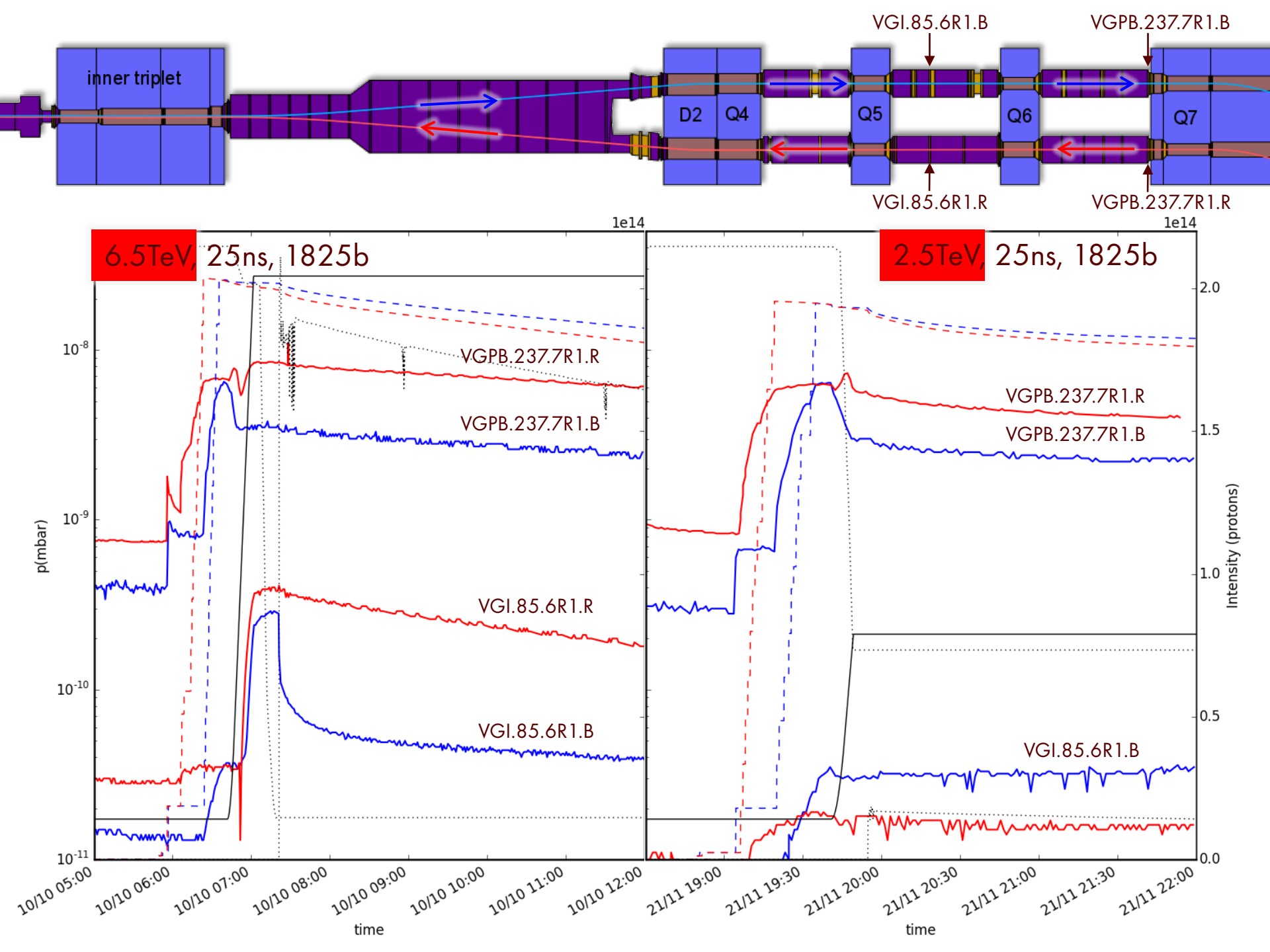
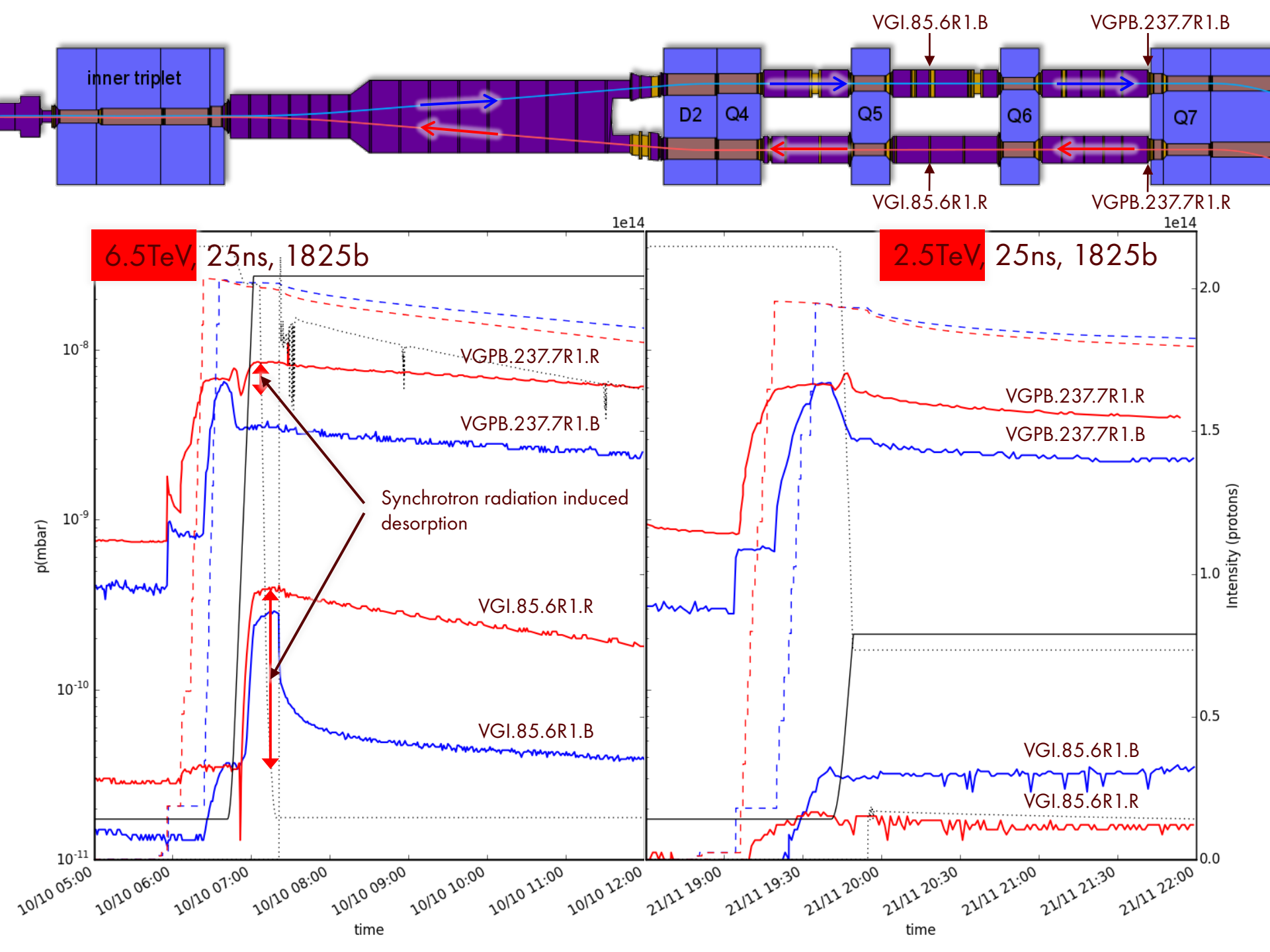
10/10 11:00
10/10 12:00


VGI.85.6R1.B
VGPB.237.7R1.B
inner triplet
D2
Q4
Q5
Q6
Q7
VGI.85.6R1.R
VGPB.237.7R1.R


1e14
p(mbar)
10^{-8}
10^{-9}
10^{-10}
10^{-11}
VGPB.237.7R1.R
VGPB.237.7R1.B
VGI.85.6R1.R
VGI.85.6R1.B
Intensity (protons)
2.0
1.5
1.0
0.5
0.0
Energy (GeV)
7000
6000
5000
4000
3000
2000
1000
0
Luminosity (Hz/ub)
5000
4000
3000
2000
1000
0
Beta* (dm)
1200
1000
800
600
400
200
0
10/10 05:00
10/10 06:00
10/10 07:00
10/10 08:00
10/10 09:00
10/10 10:00
10/10 11:00
10/10 12:00
time


VGI.85.6R1.B
VGPB.237.7R1.B
inner triplet
D2
Q4
Q5
Q6
Q7
VGI.85.6R1.R
VGPB.237.7R1.R
6.5TeV, 25ns, 1825b
2.5TeV, 25ns, 1825b
1e14
1e14
p(mbar)
Intensity (protons)
VGPB.237.7R1.R
VGPB.237.7R1.B
VGI.85.6R1.R
VGI.85.6R1.B
time
time


inner triplet
D2
Q4
Q5
Q6
Q7
VGI.85.6R1.B
VGPB.237.7R1.B
VGI.85.6R1.R
VGPB.237.7R1.R
6.5TeV, 25ns, 1825b
2.5TeV, 25ns, 1825b
1e14
p(mbar)
Intensity (protons)
time
Synchrotron radiation induced desorption
10/10 05:00
10/10 06:00
10/10 07:00
10/10 08:00
10/10 09:00
10/10 10:00
10/10 11:00
10/10 12:00
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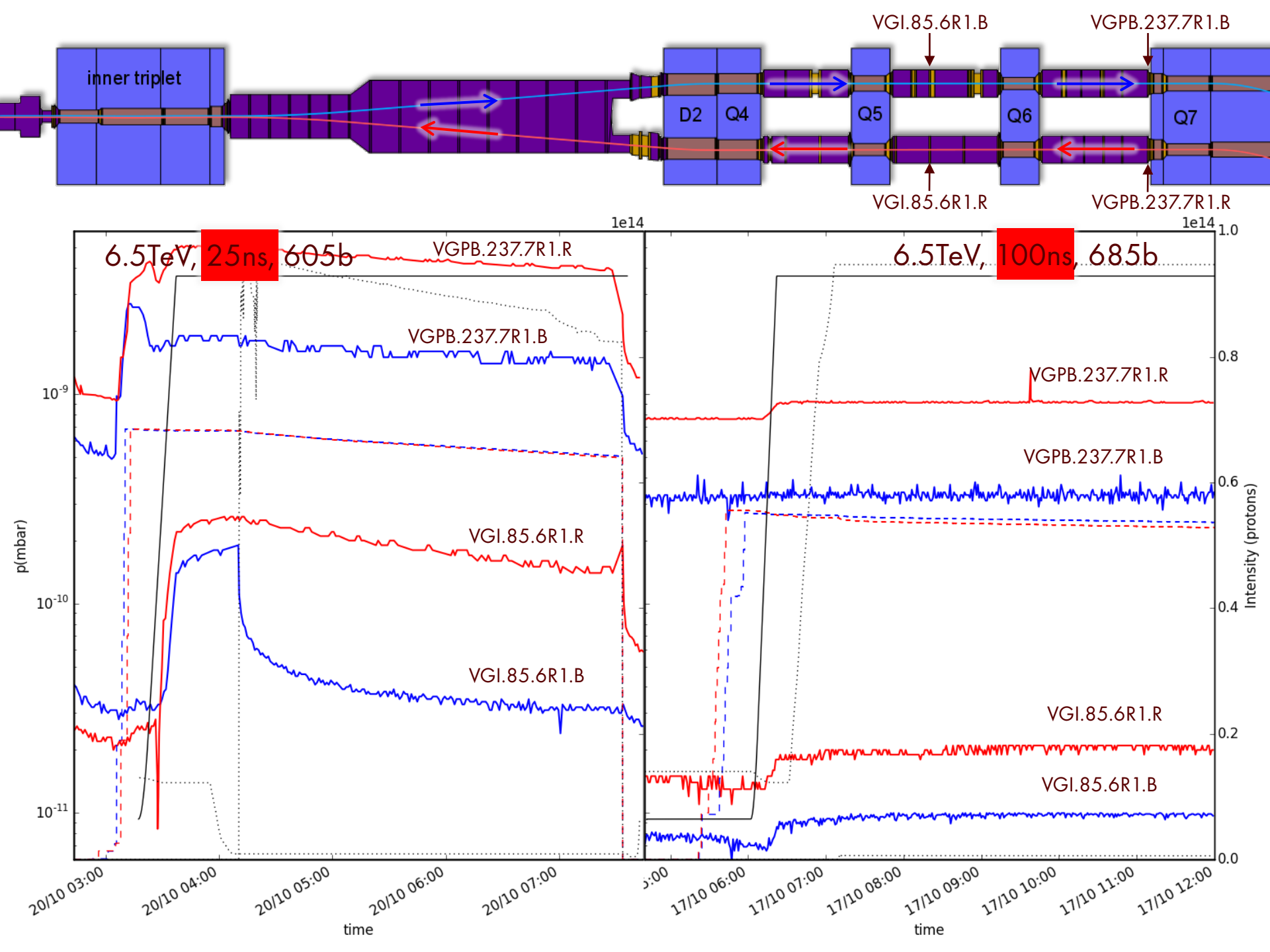
21/11 21:00
21/11 21:30
21/11 22:00

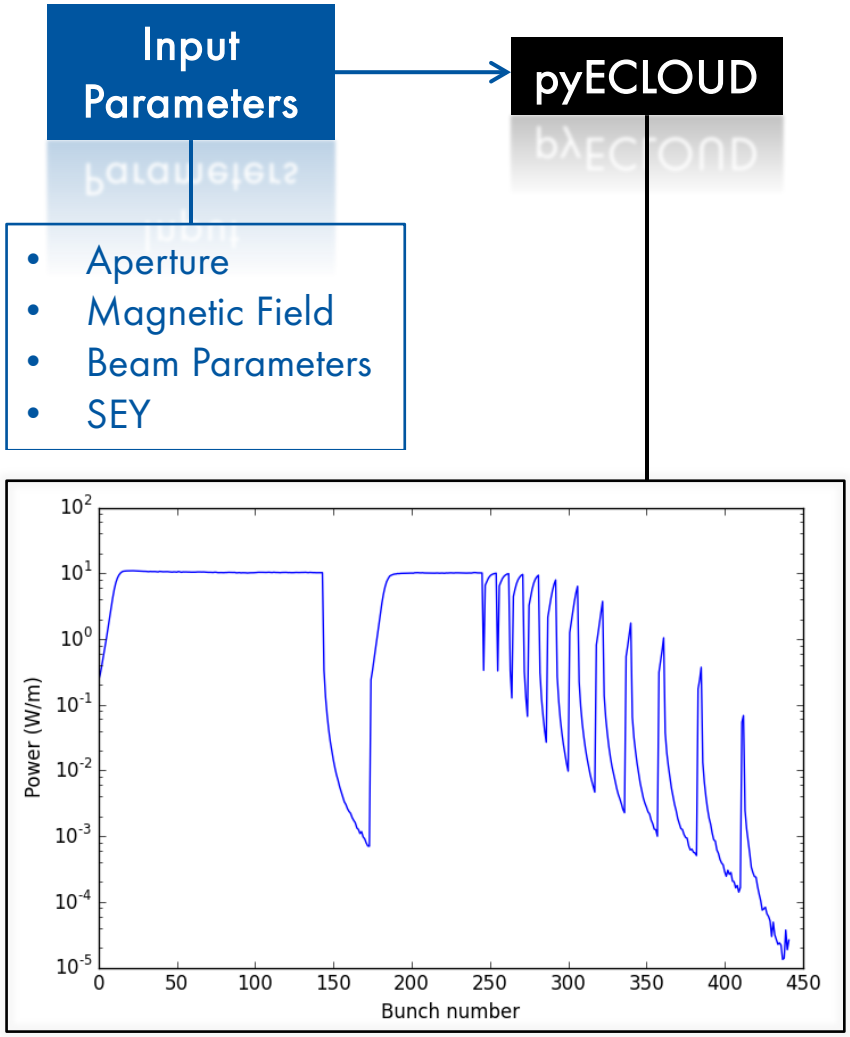

inner triplet
D2
Q4
Q5
Q6
Q7
VGI.85.6R1.B
VGPB.237.7R1.B
VGI.85.6R1.R
VGPB.237.7R1.R
6.5TeV, 25ns, 605b
6.5TeV, 100ns, 685b
1e14
1e14
VGPB.237.7R1.R
VGPB.237.7R1.B
VGI.85.6R1.R
VGI.85.6R1.B
p(mbar)
Intensity (protons)
time
time
20/10 03:00
20/10 04:00
20/10 05:00
20/10 06:00
20/10 07:00
17/10 06:00
17/10 07:00
17/10 08:00
17/10 09:00
17/10 10:00
17/10 11:00
17/10 12:00

ECLOUD Calculation

Input Parameters

- Aperture
- Magnetic Field
- Beam Parameters
- SEY

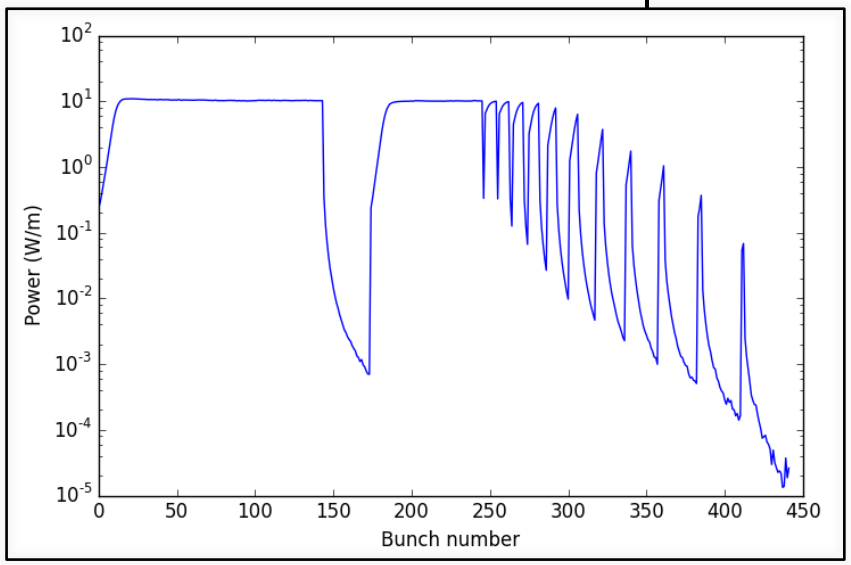
ECLOUD Calculation

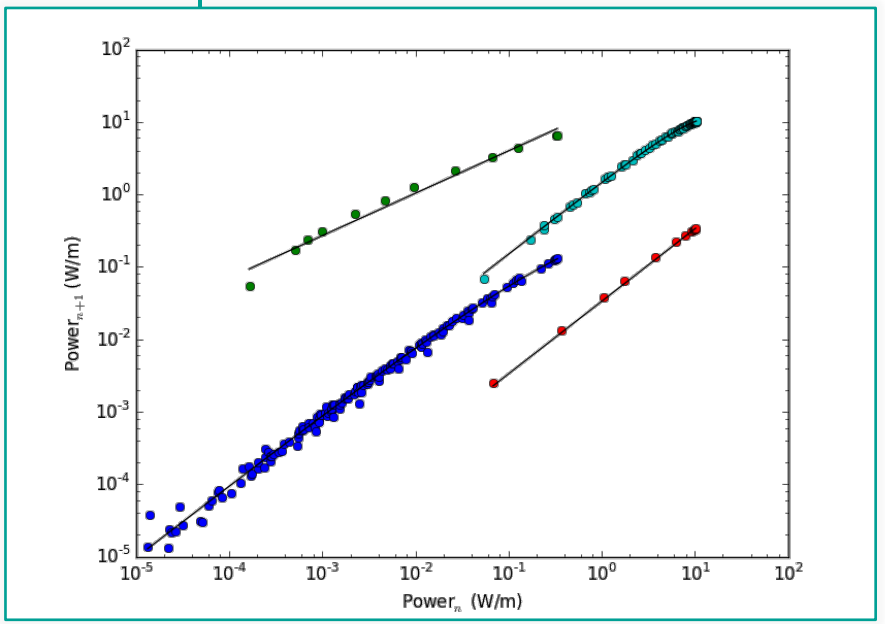


ECLOUD Calculation

Input Parameters → **pyECLOUD** → **Fitting** $y_{n+1}=f(y_n)$

- Aperture
- Magnetic Field
- Beam Parameters
- SEY



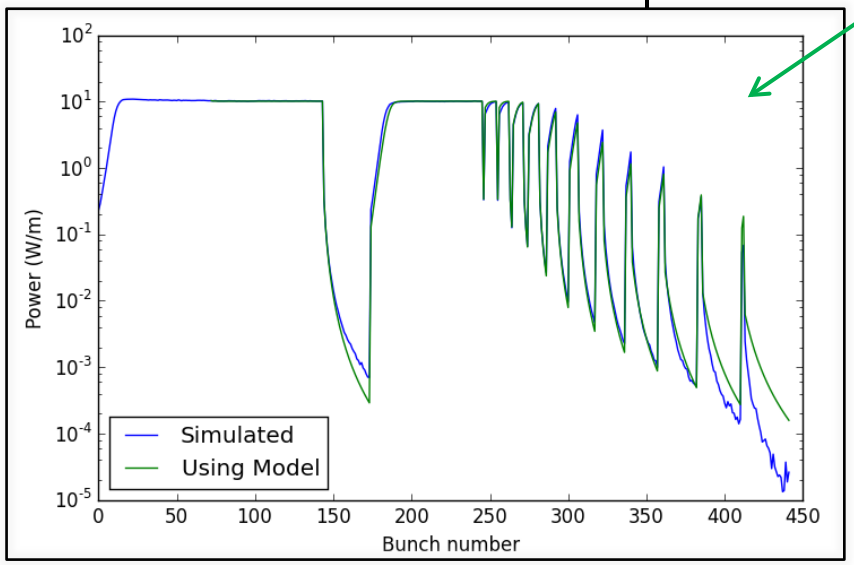


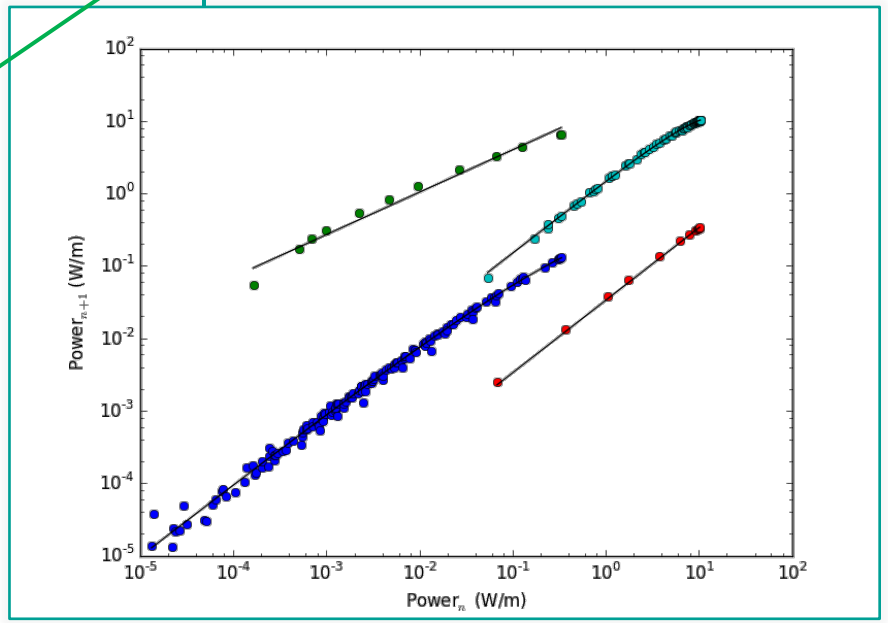
ECLOUD Calculation

Input Parameters → **pyECLOUD** → **Fitting** $y_{n+1}=f(y_n)$ → **HeatLoad**

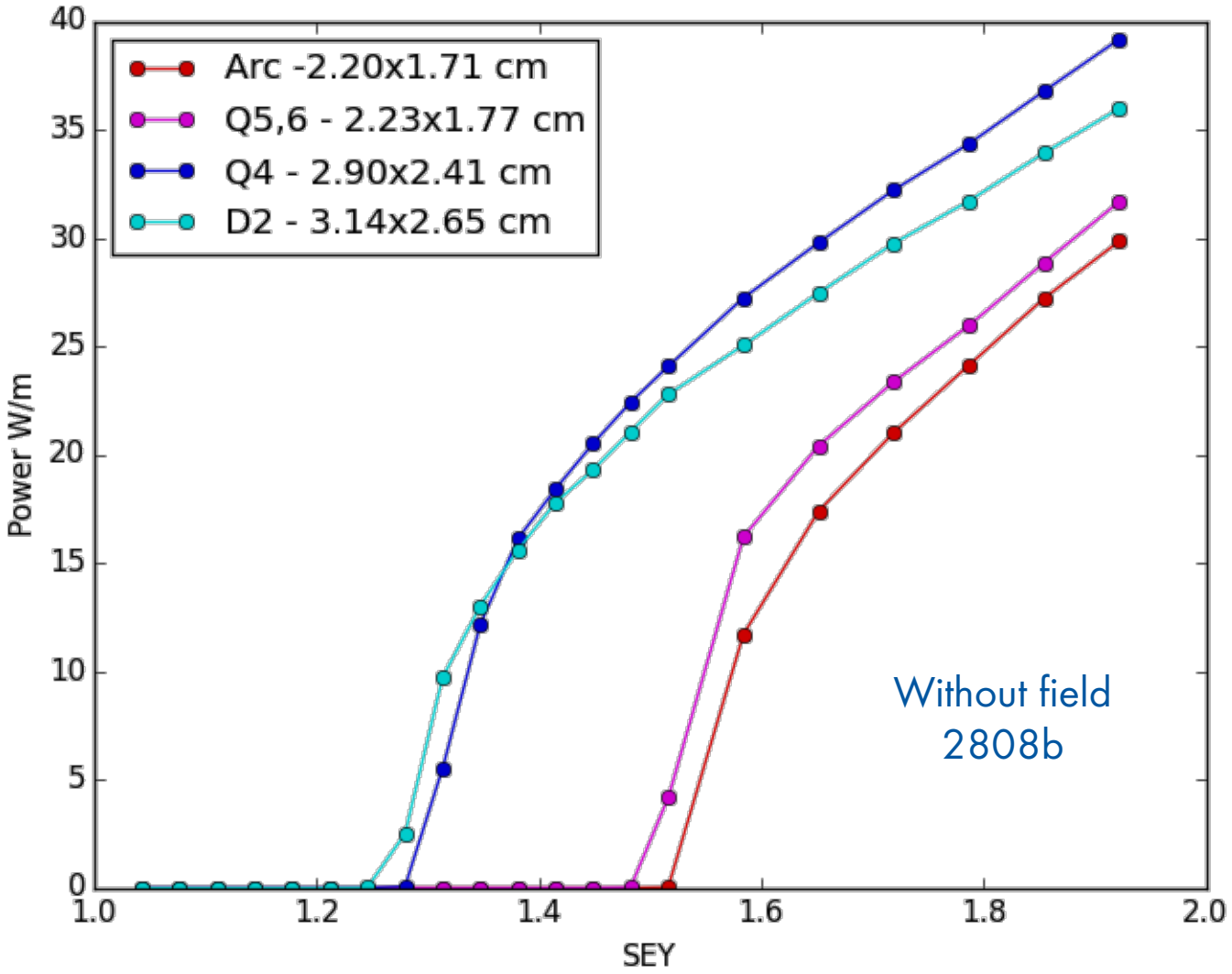
- Aperture
- Magnetic Field
- Beam Parameters
- SEY

- For different filling patterns

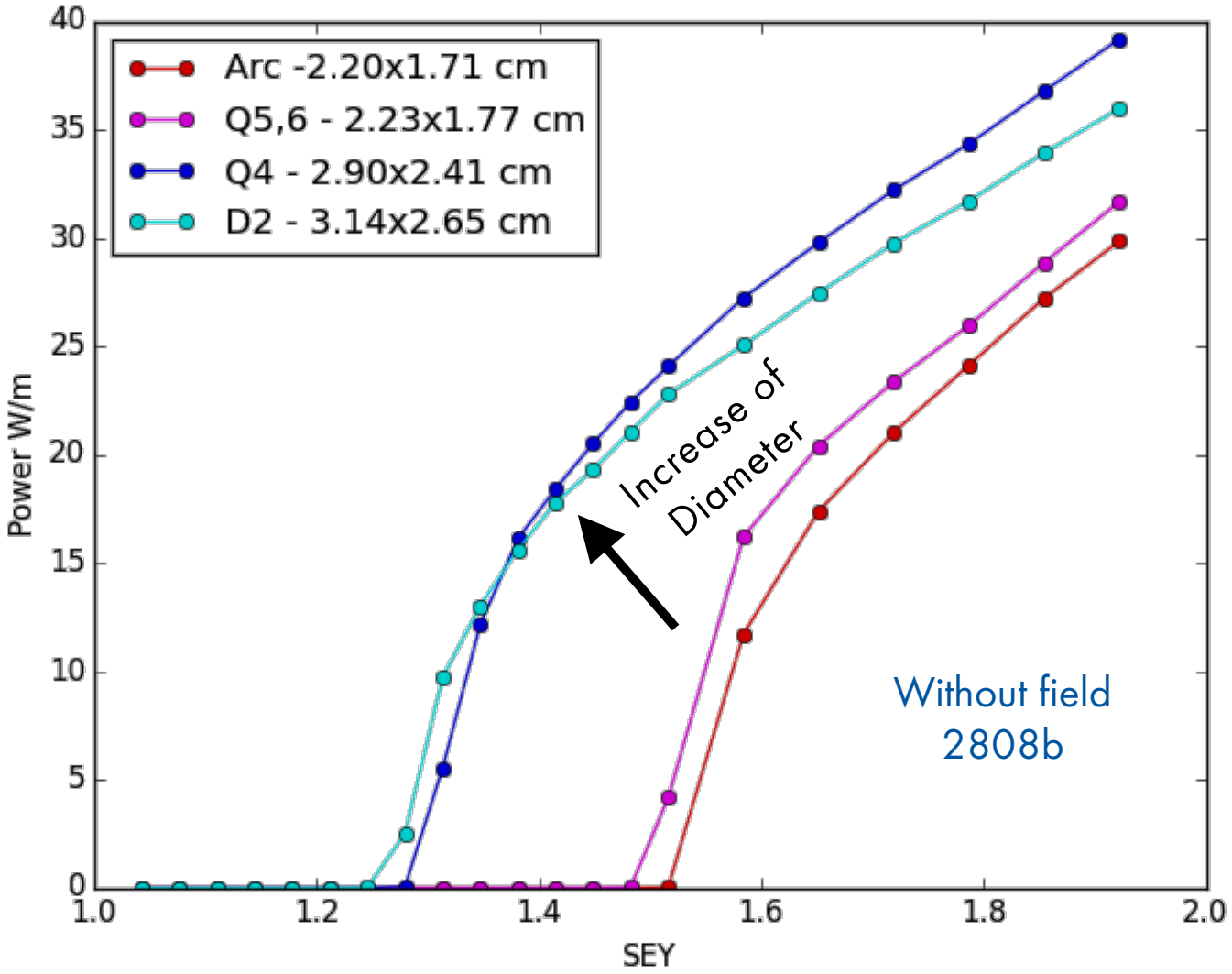




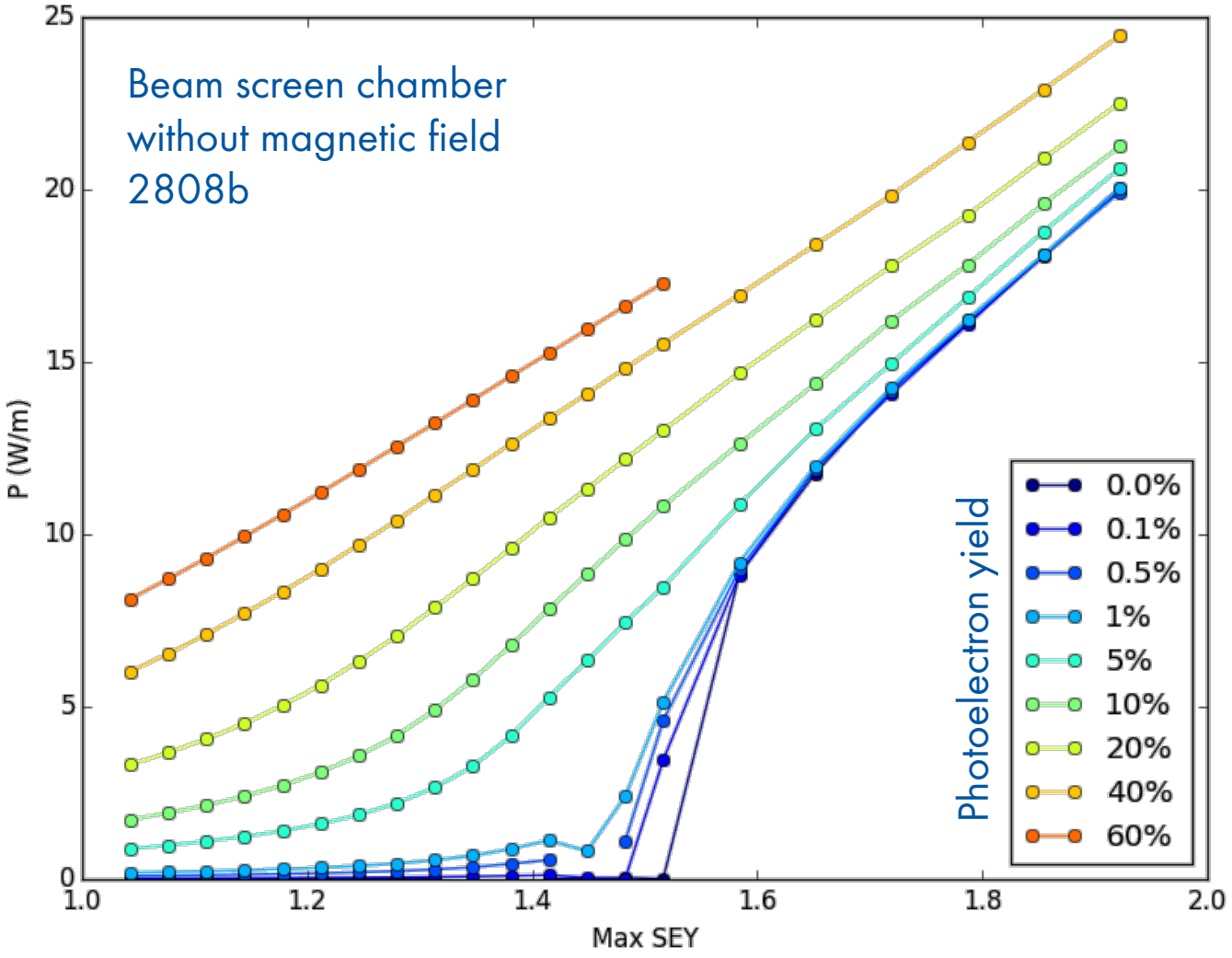
ECLOUD: Effect of Chamber Diameter



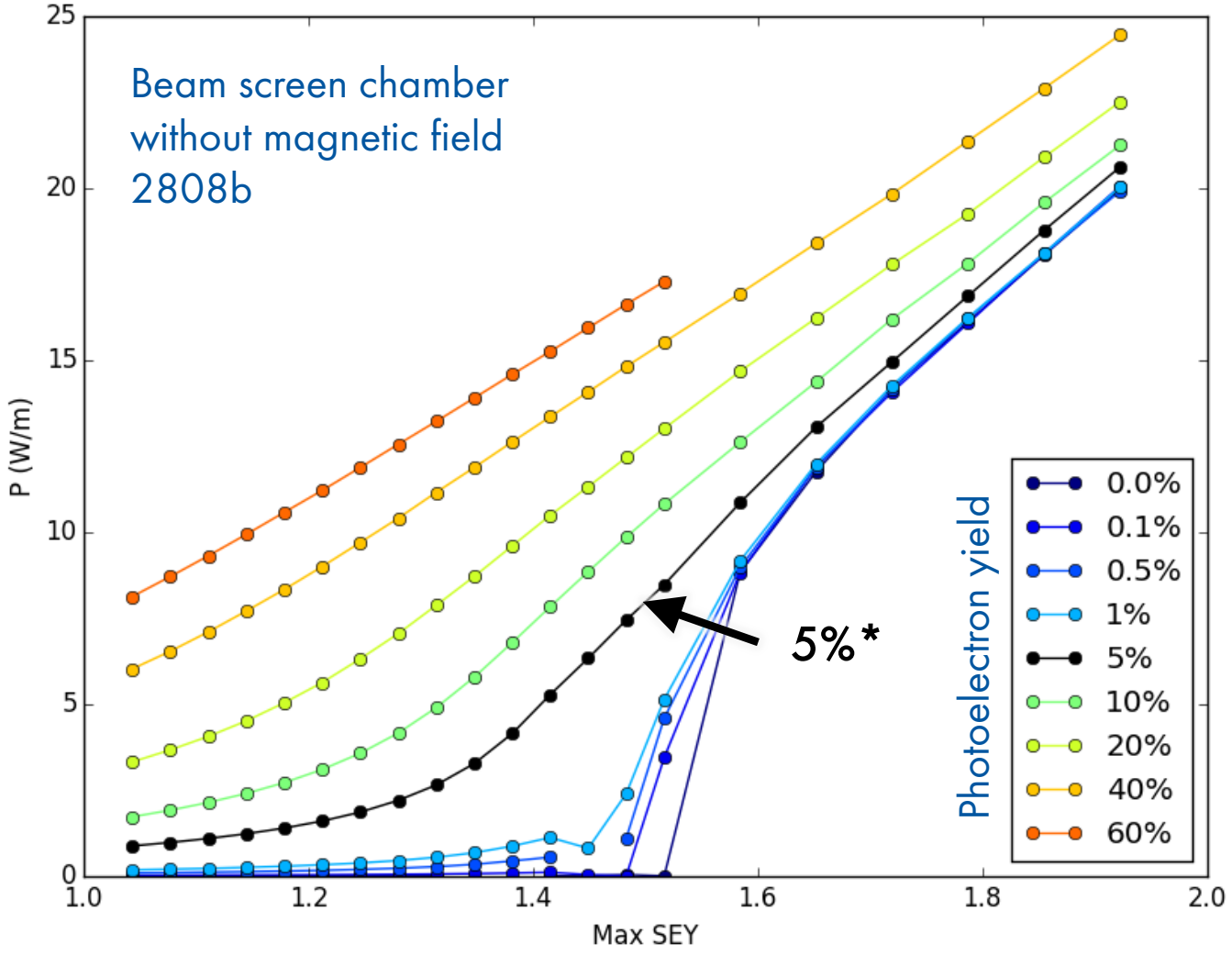
ECLOUD: Effect of Chamber Diameter



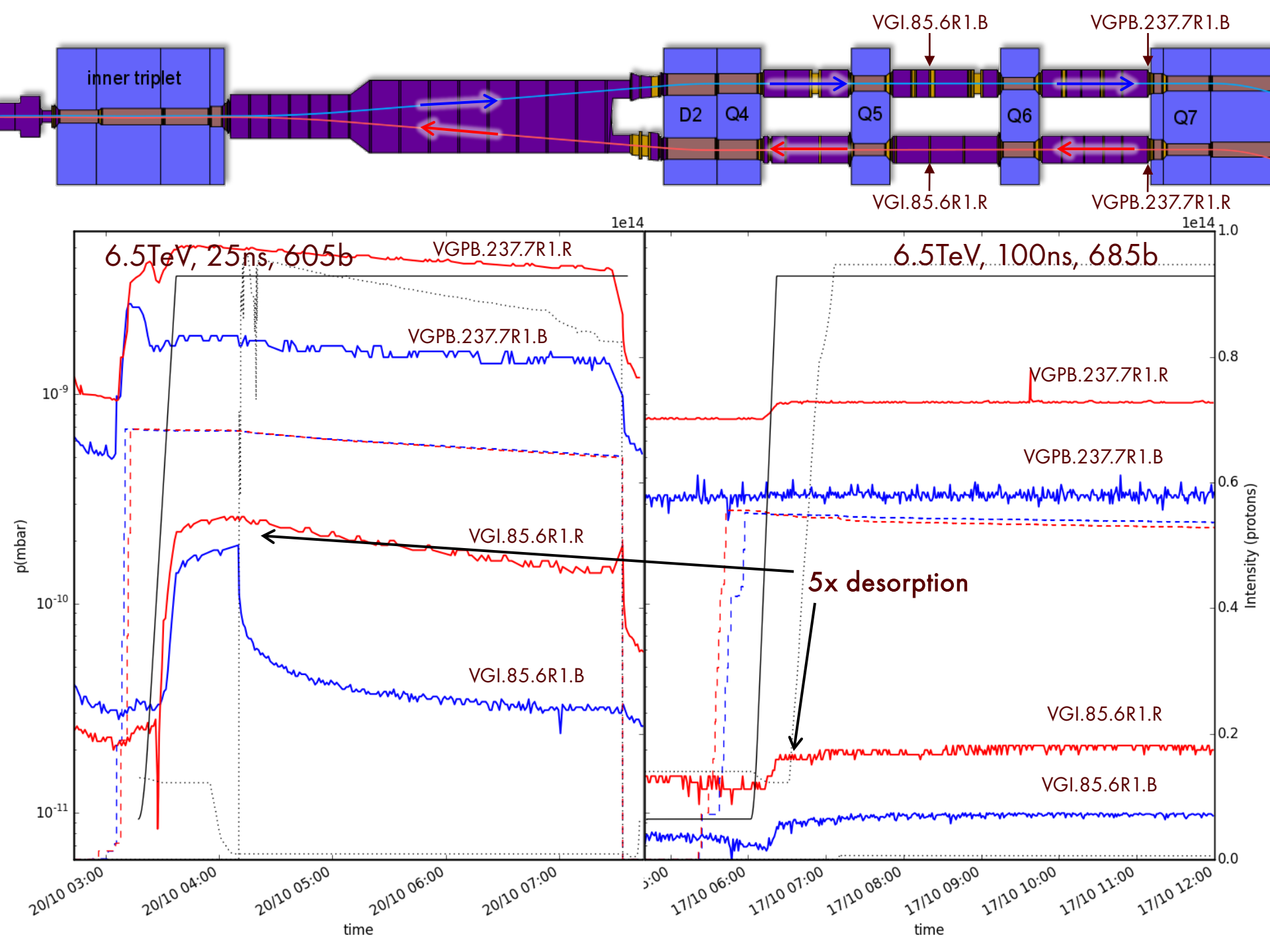
ECLOUD: Boost by Syn. Radiation



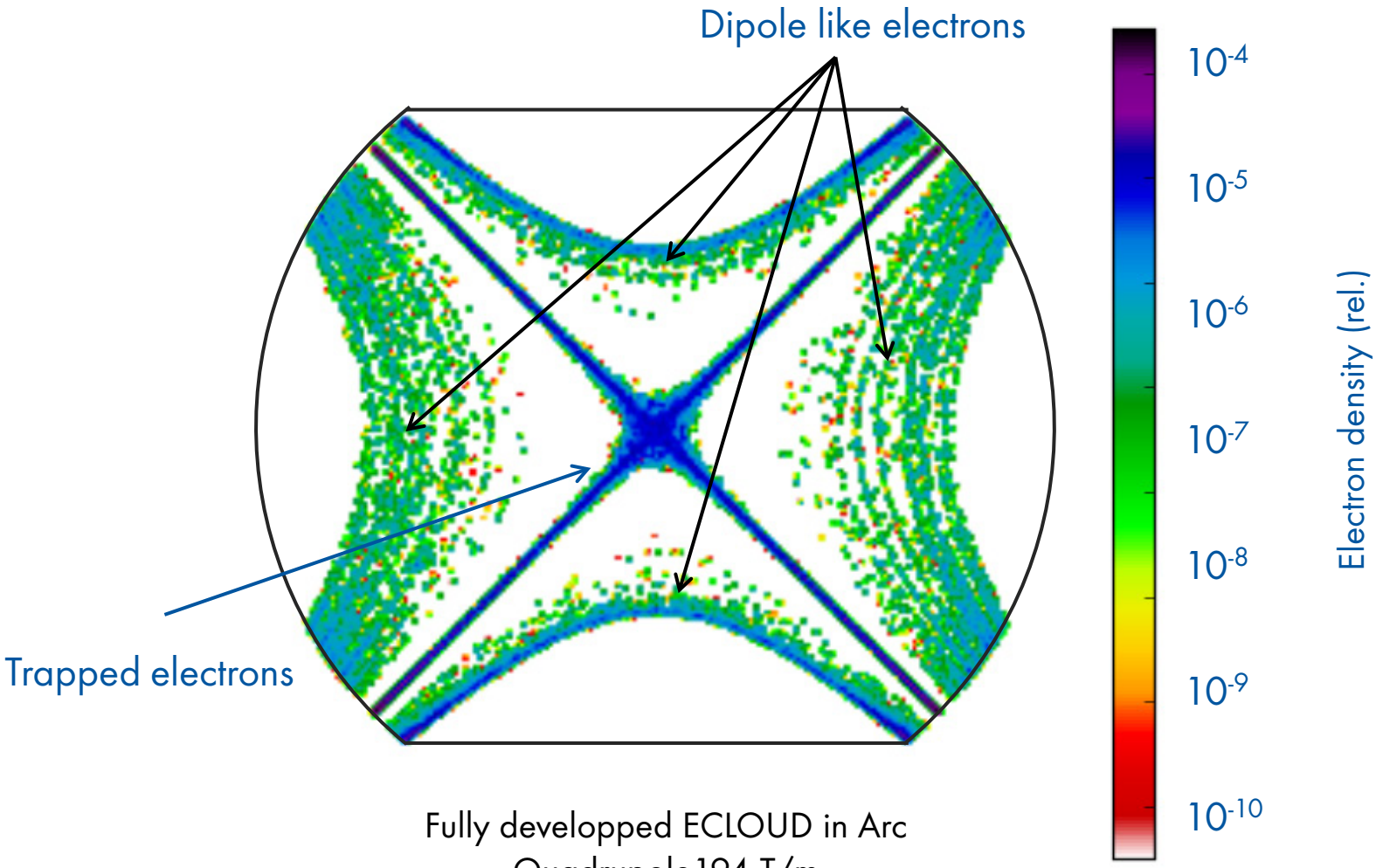
ECLOUD: Boost by Syn. Radiation



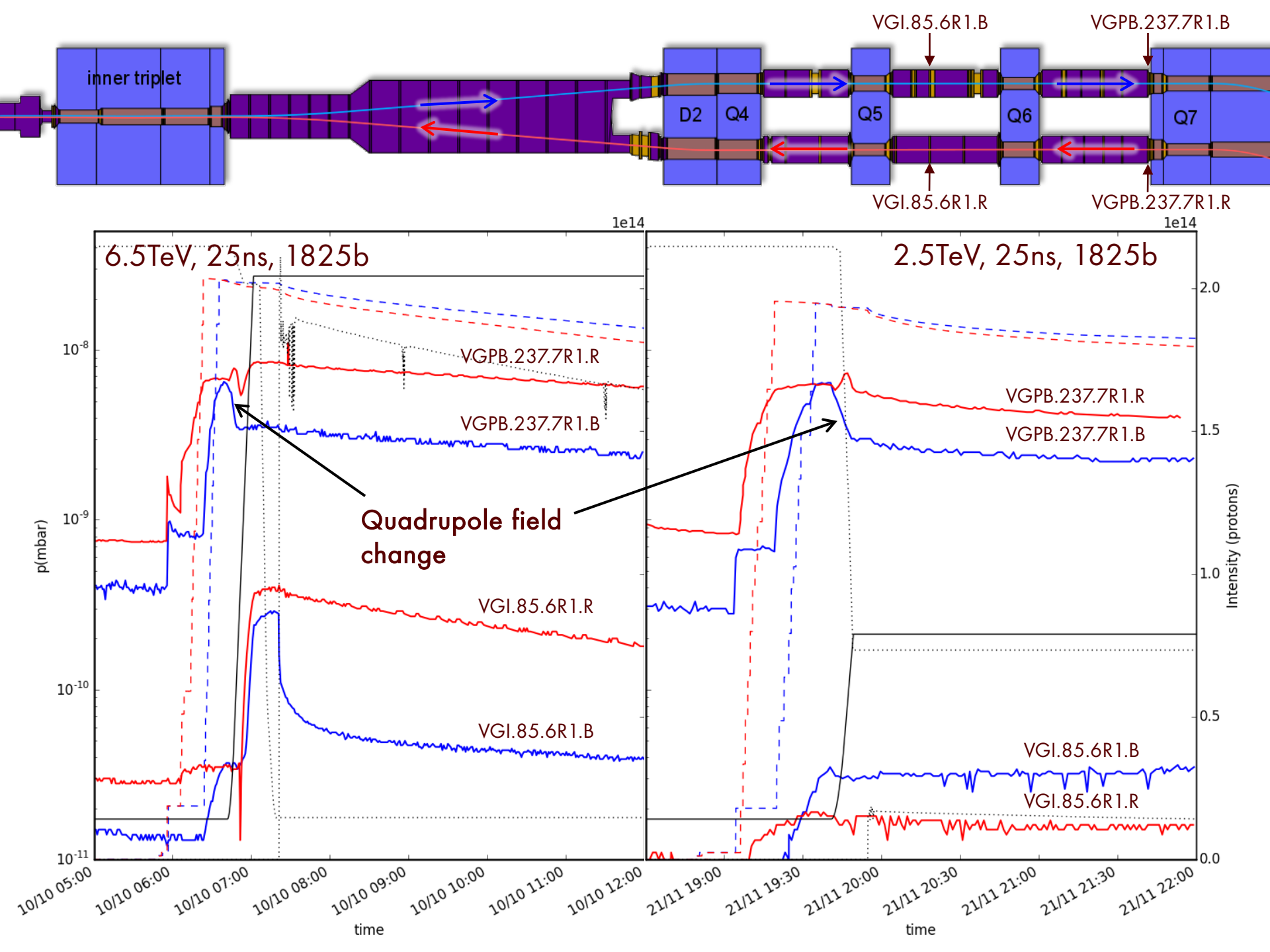
*V. Baglin


inner triplet
D2
Q4
Q5
Q6
Q7
VGI.85.6R1.B
VGPB.237.7R1.B
VGI.85.6R1.R
VGPB.237.7R1.R
6.5TeV, 25ns, 605b
6.5TeV, 100ns, 685b
1e14
1e14
VGPB.237.7R1.R
VGPB.237.7R1.B
VGI.85.6R1.R
VGI.85.6R1.B
5x desorption
p(mbar)
Intensity (protons)
time
time
20/10 03:00
20/10 04:00
20/10 05:00
20/10 06:00
20/10 07:00
17/10 06:00
17/10 07:00
17/10 08:00
17/10 09:00
17/10 10:00
17/10 11:00
17/10 12:00

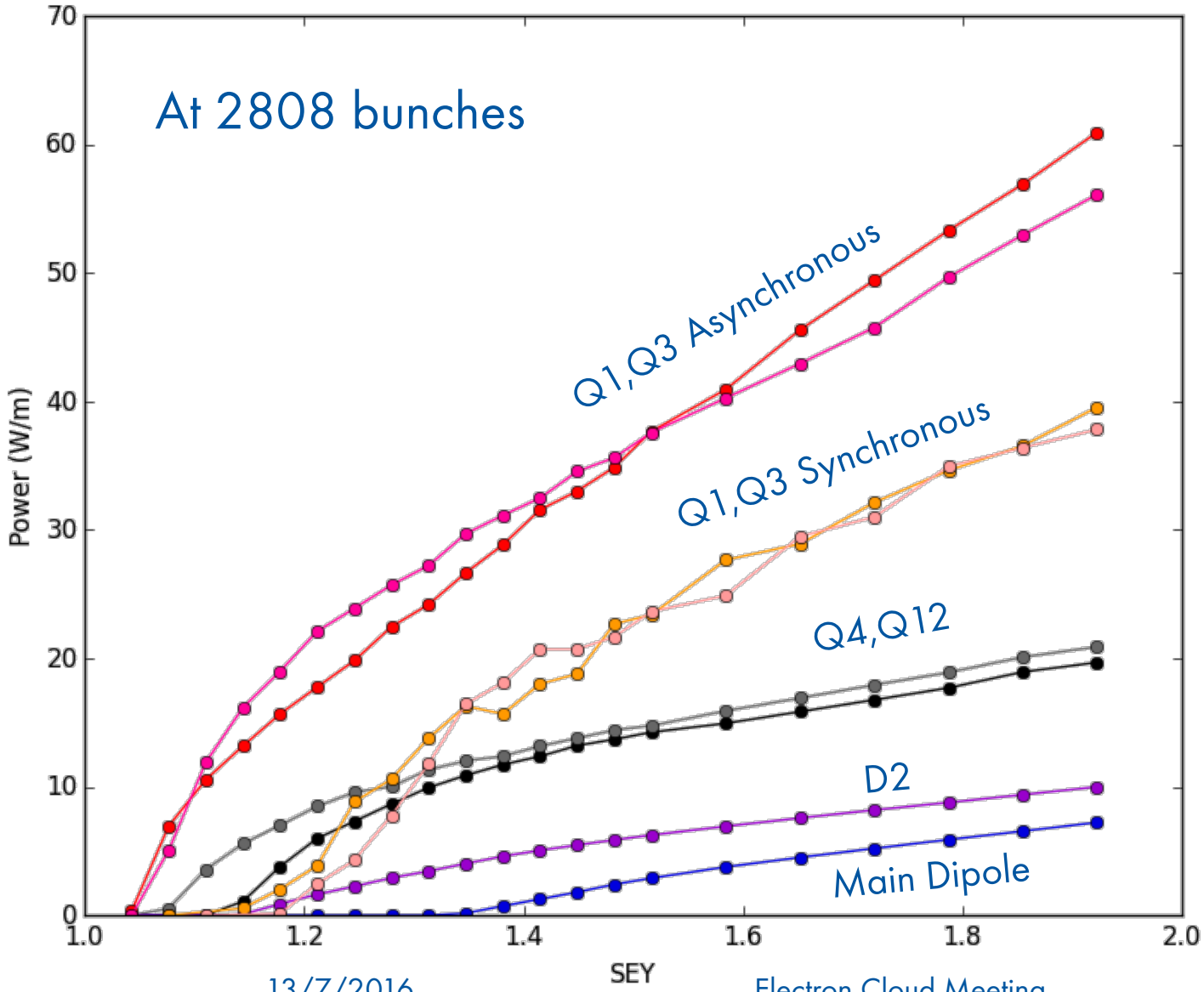
ECLOUD: Trapping effect



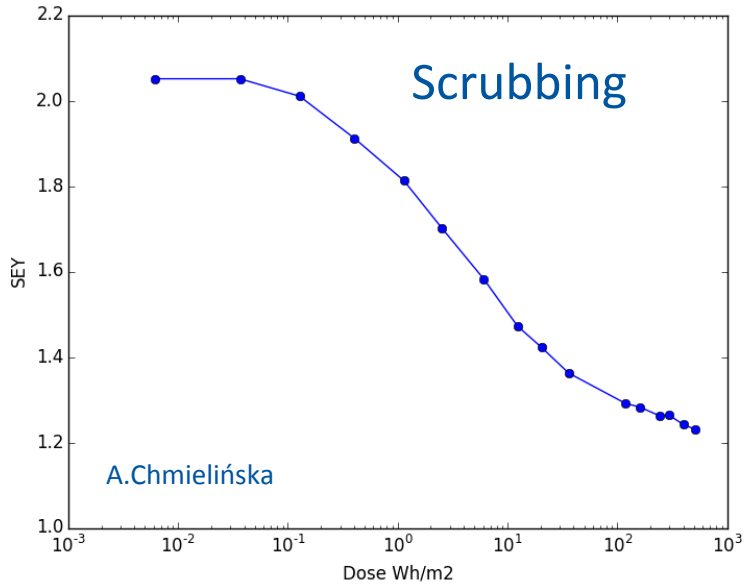
Fully developped ECLOUD in Arc Quadrupole194 T/m


VGI.85.6R1.B
VGPB.237.7R1.B
inner triplet
D2
Q4
Q5
Q6
Q7
VGI.85.6R1.R
VGPB.237.7R1.R
6.5TeV, 25ns, 1825b
2.5TeV, 25ns, 1825b
1e14
1e14
VGPB.237.7R1.R
VGPB.237.7R1.B
VGI.85.6R1.R
VGI.85.6R1.B
Quadrupole field change
p(mbar)
Intensity (protons)
time
time
10/10 05:00
10/10 06:00
10/10 07:00
10/10 08:00
10/10 09:00
10/10 10:00
10/10 11:00
10/10 12:00
21/11 19:00
21/11 19:30
21/11 20:00
21/11 20:30
21/11 21:00
21/11 21:30
21/11 22:00

ECLOUD: Magnets

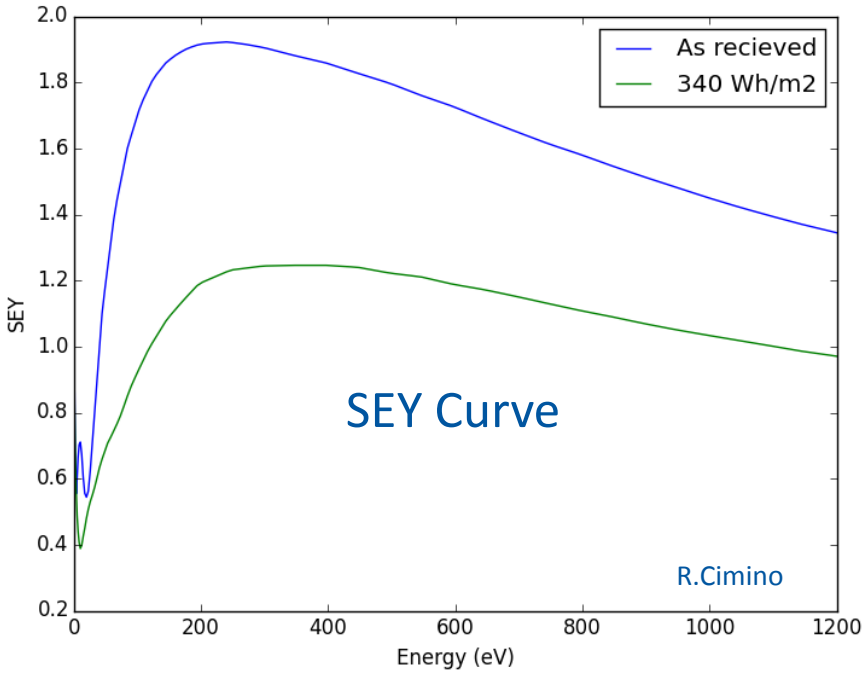


Materials: Copper - SEY



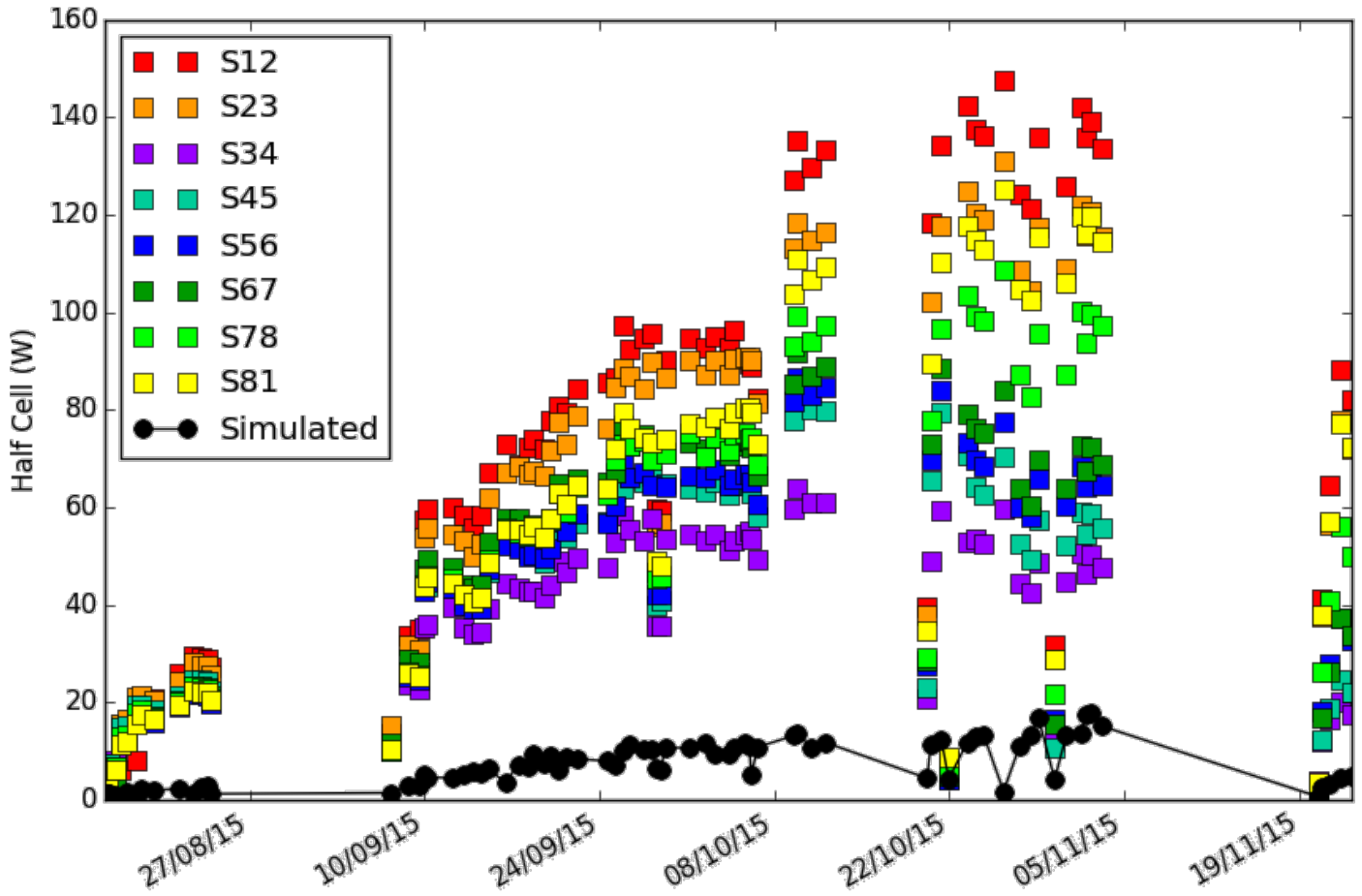
- Max SEY at the begining: 2.05
- Fully Scrubbed: 1.25
  (and possibly more)

- No difference between room temperature and cryo surfaces



HeatLoad in Arcs 2015

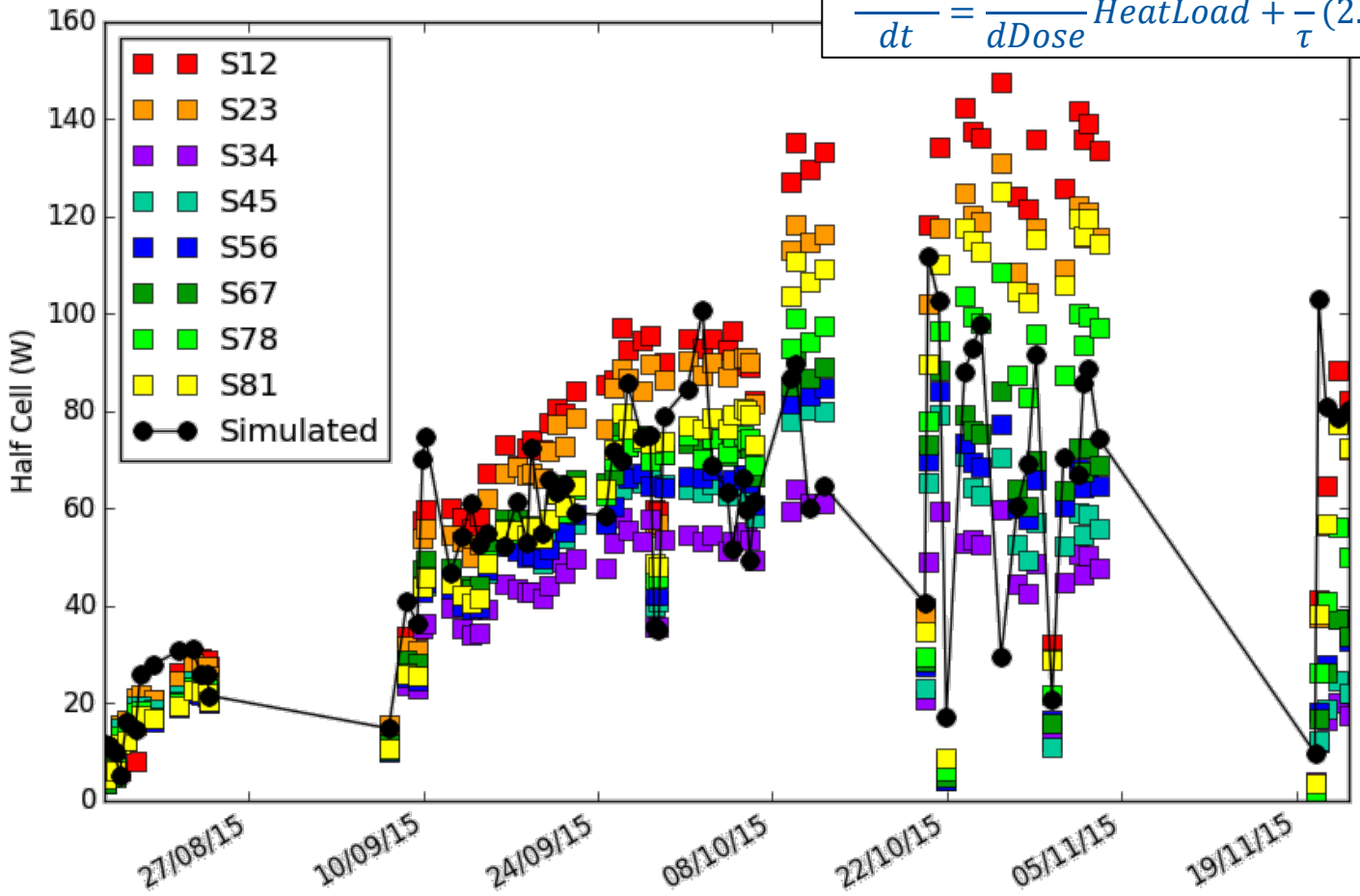
Synchrotron Radiation + Impedance + ECLOUD from Dipoles and Quadrupoles



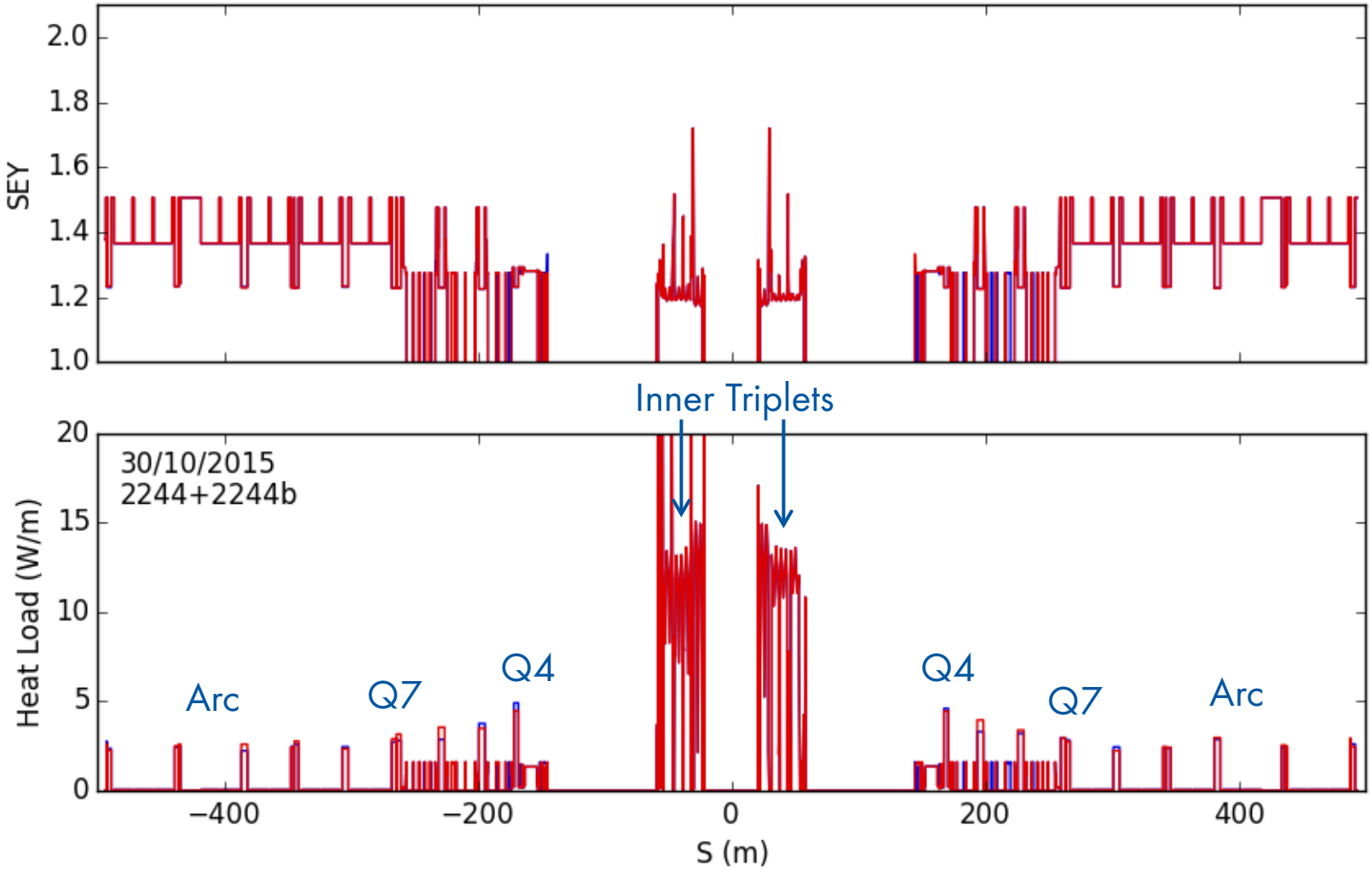
HeatLoad in Arcs 2015

67x slower conditioning + 40 days deconditioning effect

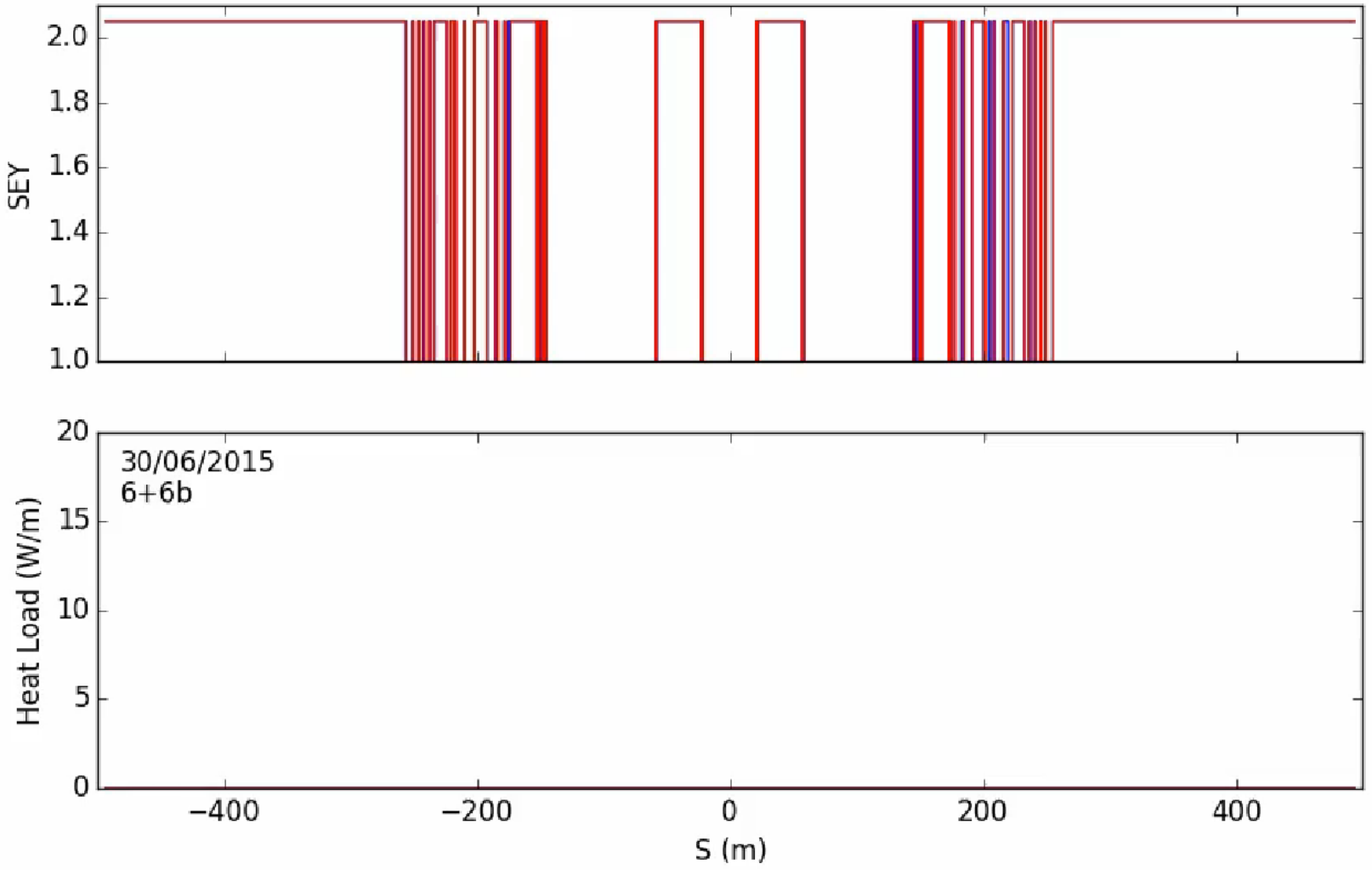
$$\frac{dSEY}{dt} = \frac{dSEY}{dDose} HeatLoad + \frac{1}{\tau}(2.05 - SEY)$$



ECLOUD: ATLAS LSS



ECLOUD: ATLAS LSS



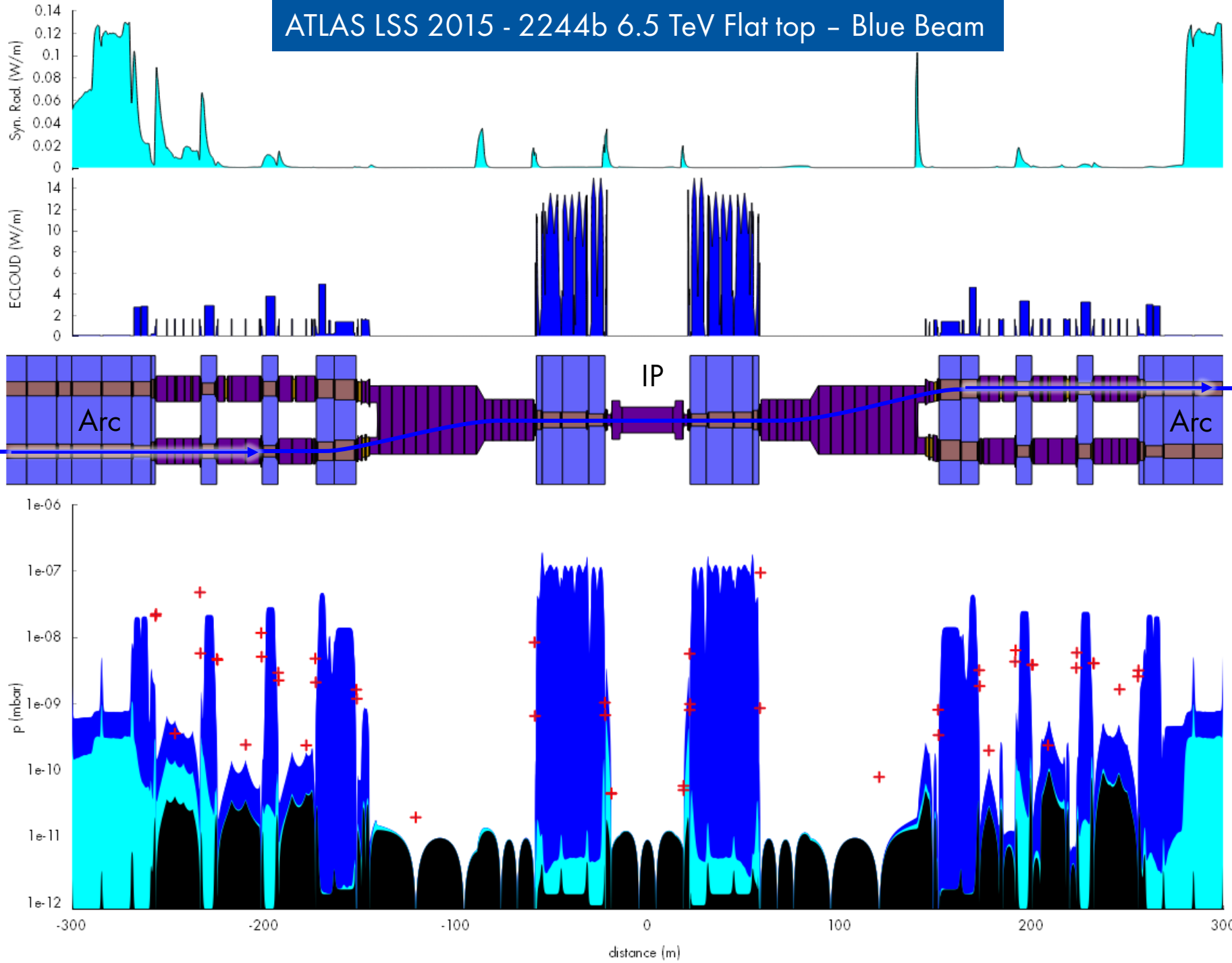
Vacuum simulation

VASCO

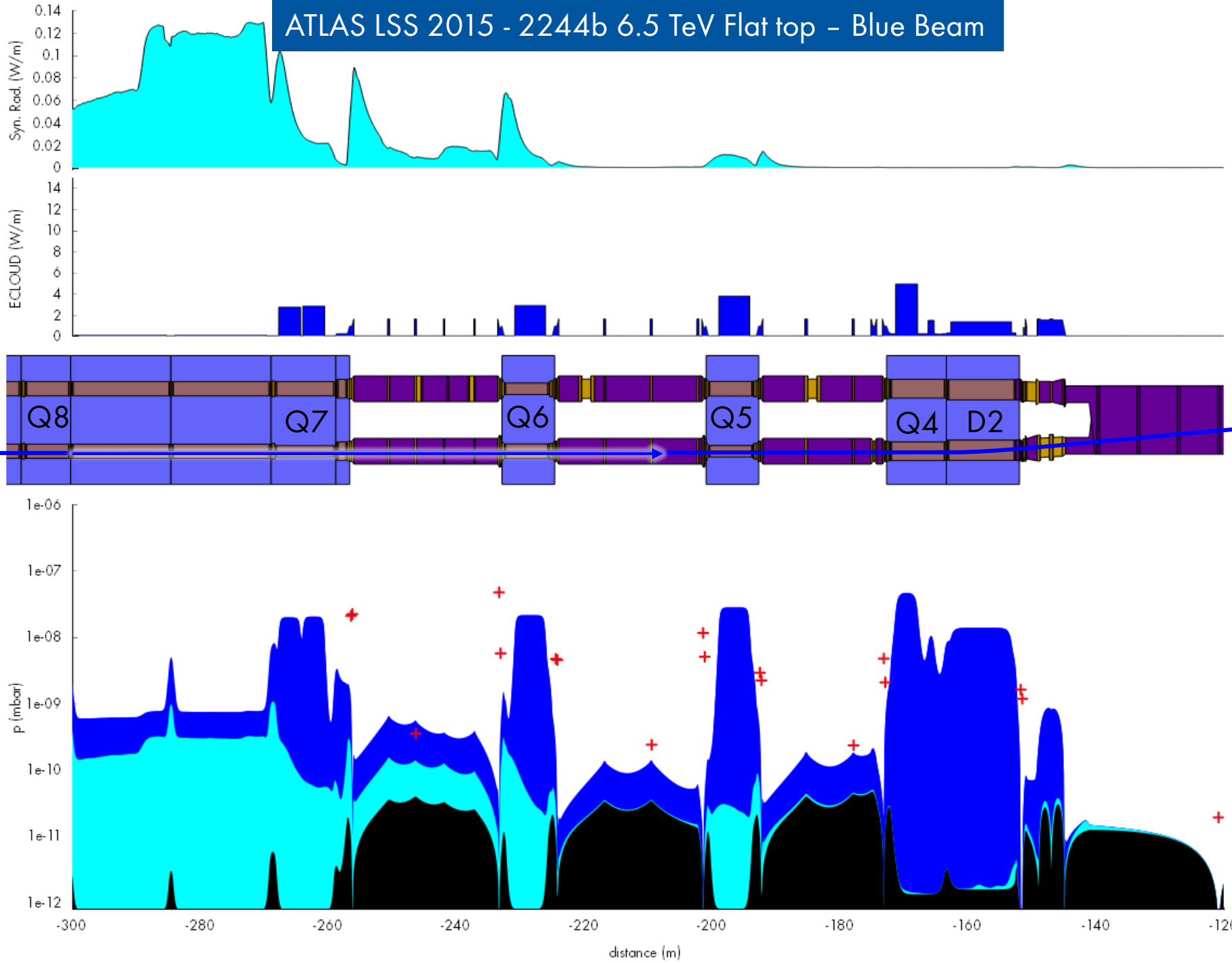
- Cu, NEG, Beam screen inside/outside coldmass
- Ionization pumps, NEG Cartidges
- No outgassing from instrumentation

- Static pressure
- Synchrotron radiation desorption
- ECLOUD desorption

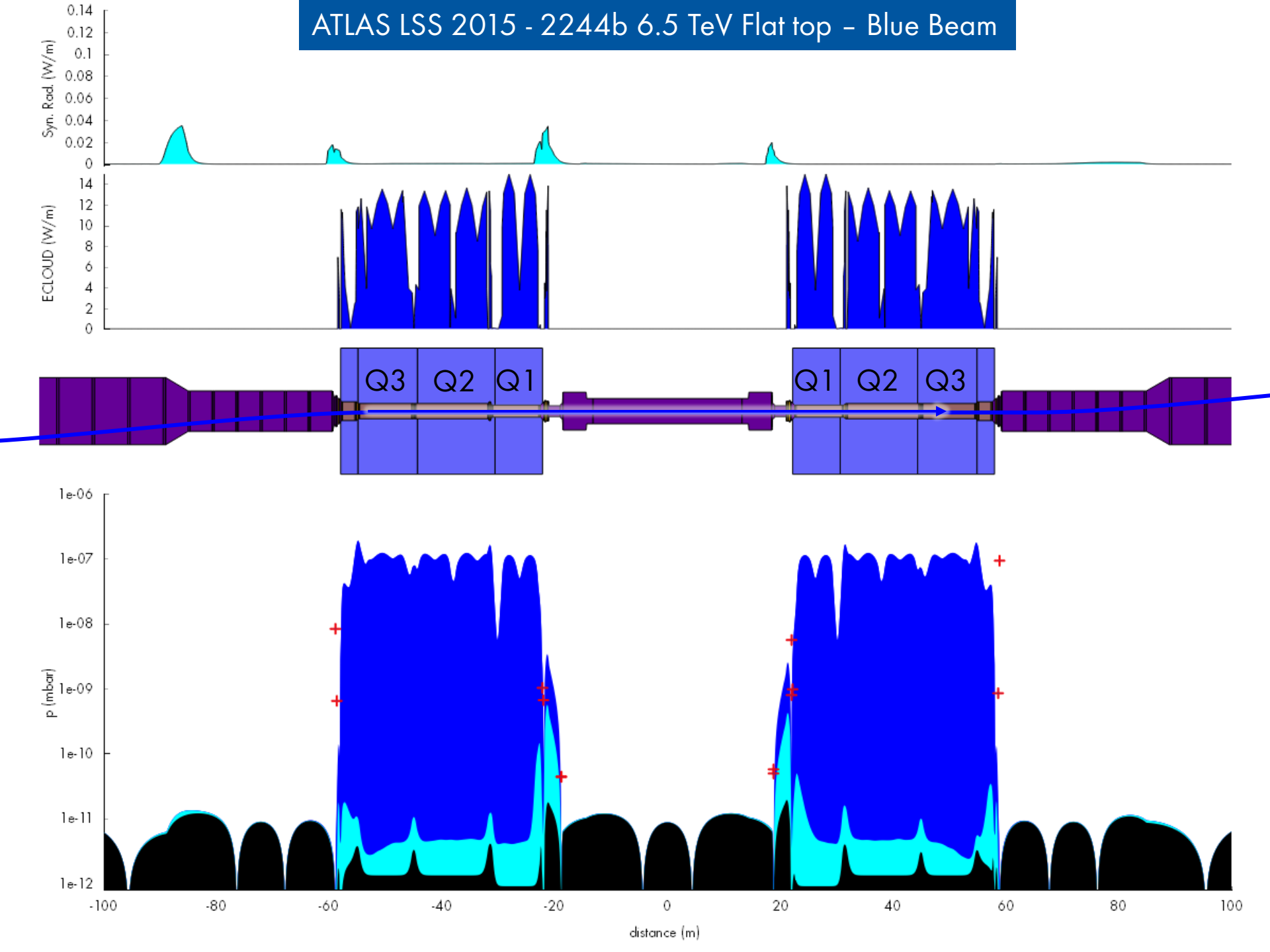
ATLAS LSS 2015 - 2244b 6.5 TeV Flat top – Blue Beam



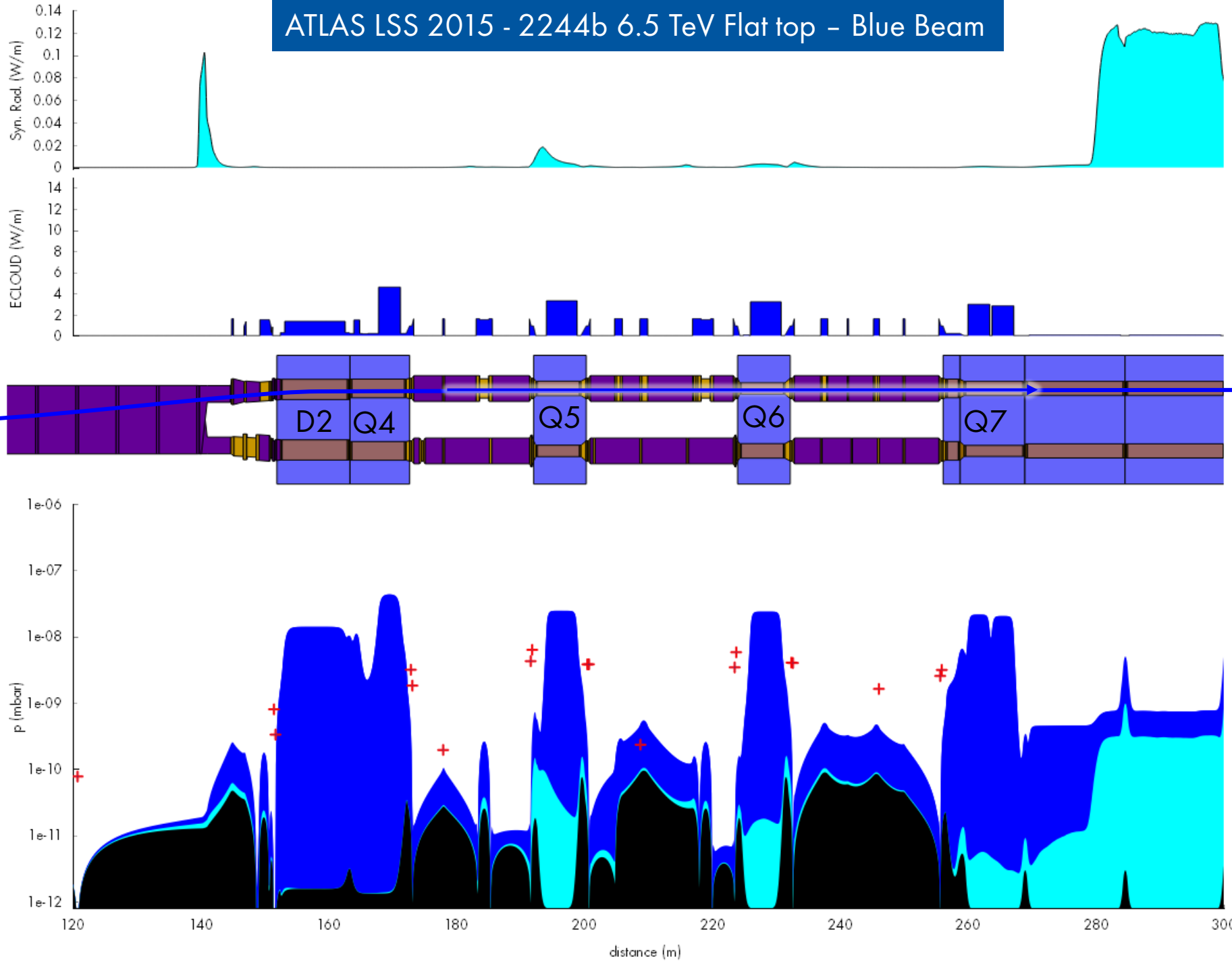
ATLAS LSS 2015 - 2244b 6.5 TeV Flat top – Blue Beam



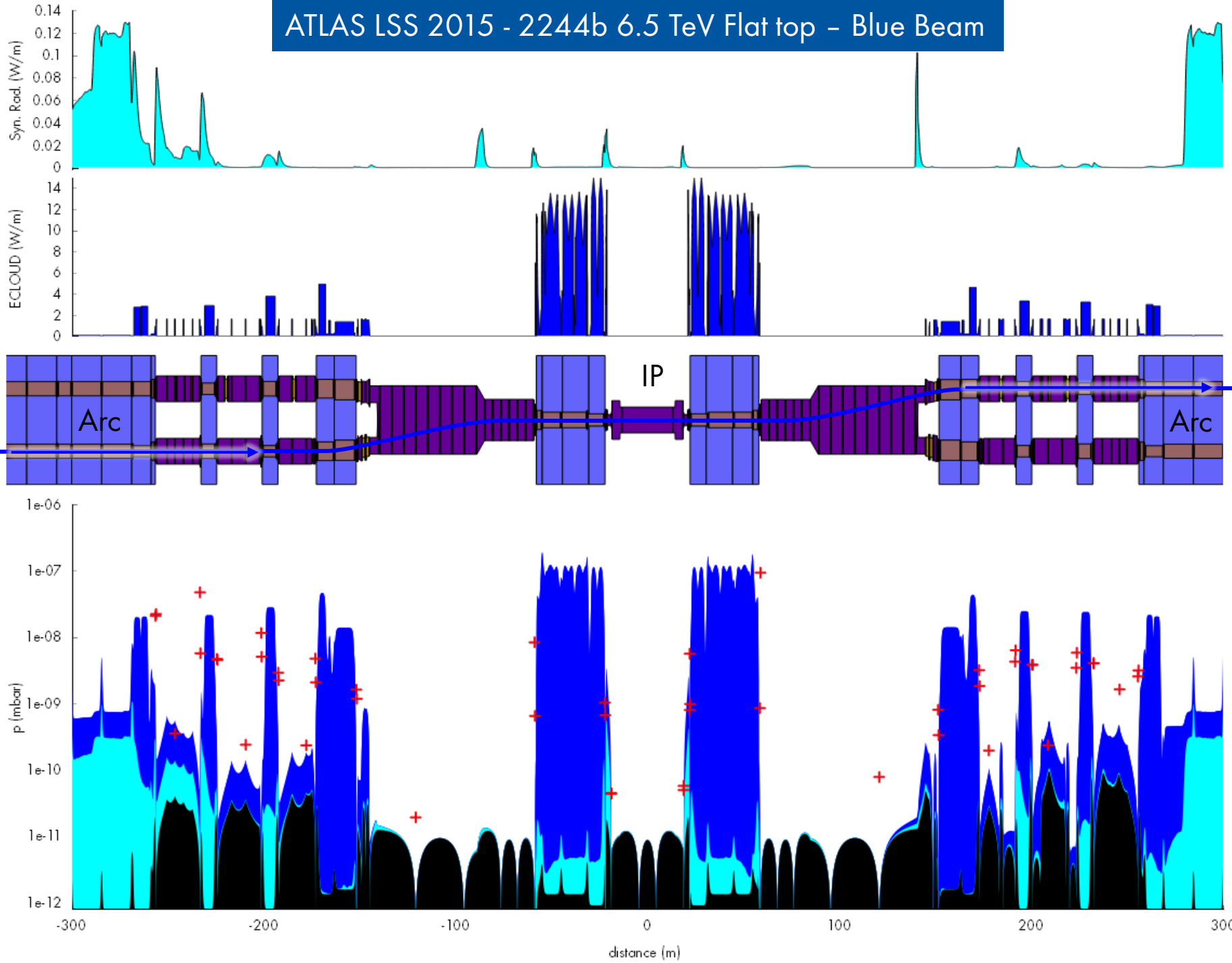
ATLAS LSS 2015 - 2244b 6.5 TeV Flat top – Blue Beam



ATLAS LSS 2015 - 2244b 6.5 TeV Flat top – Blue Beam

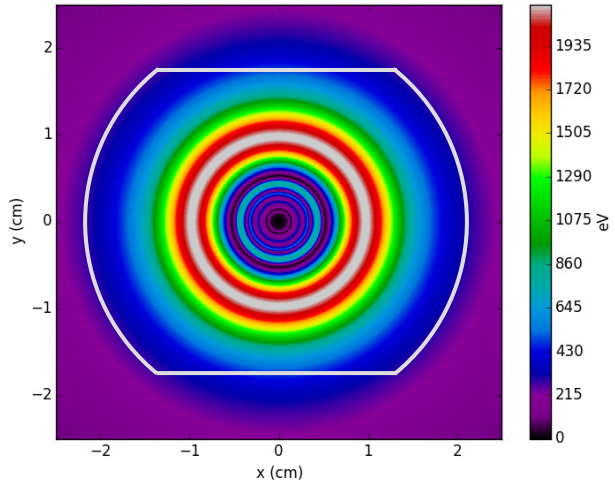


ATLAS LSS 2015 - 2244b 6.5 TeV Flat top – Blue Beam

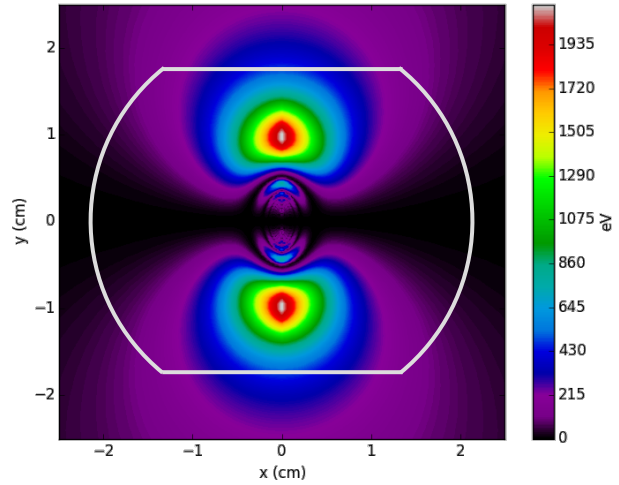


Thank you for your attention

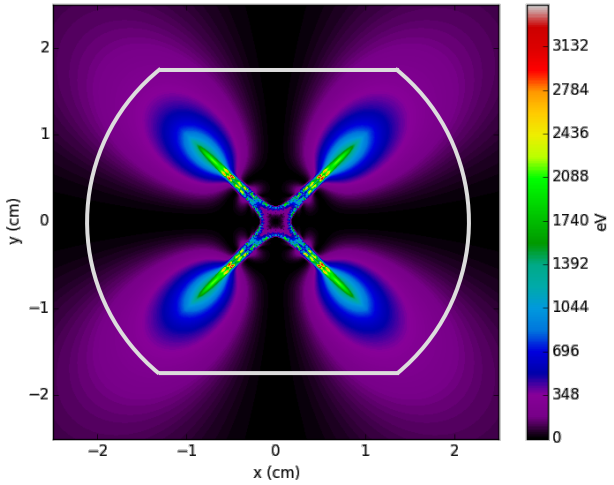
ECLOUD: Acceleration



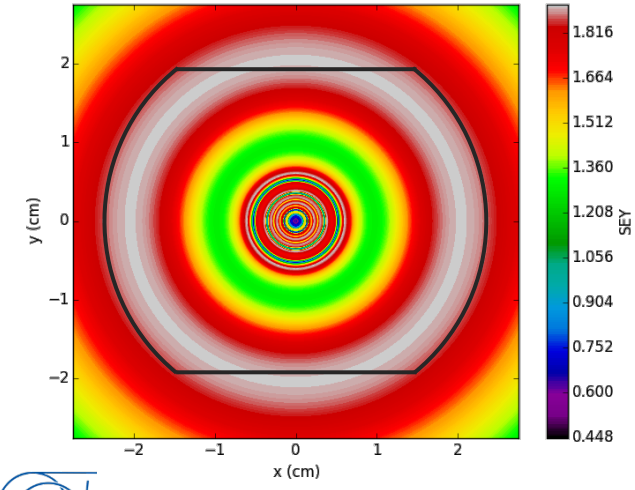
Without field

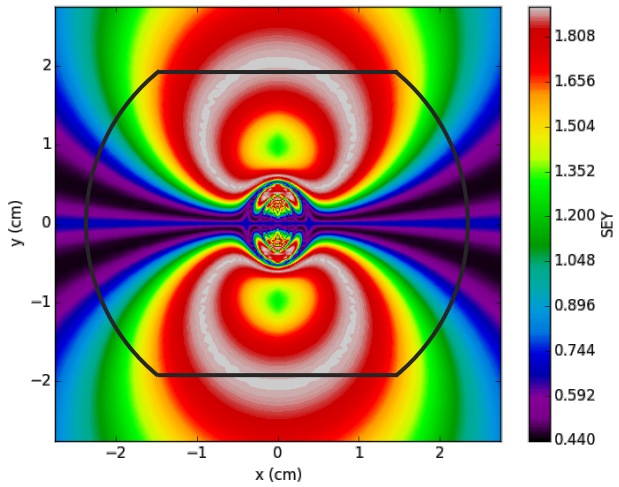


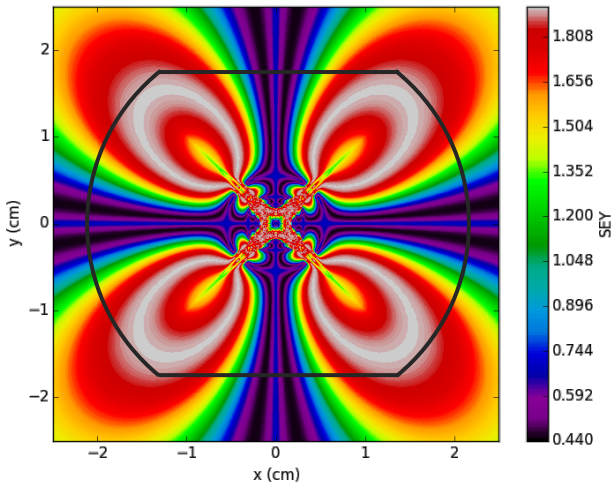
Dipole 7.7 T



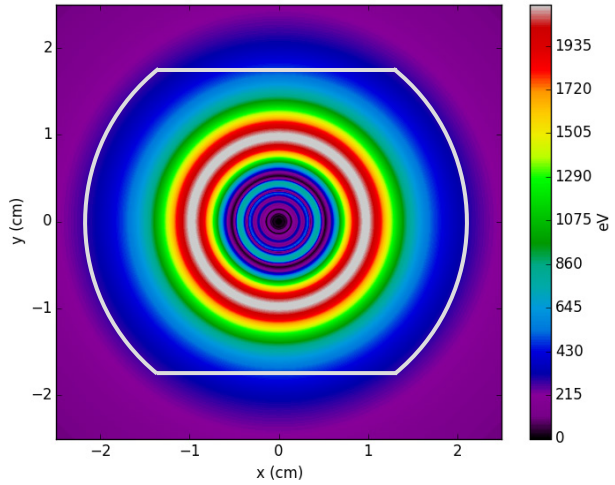
Quadrupole 100 T/m



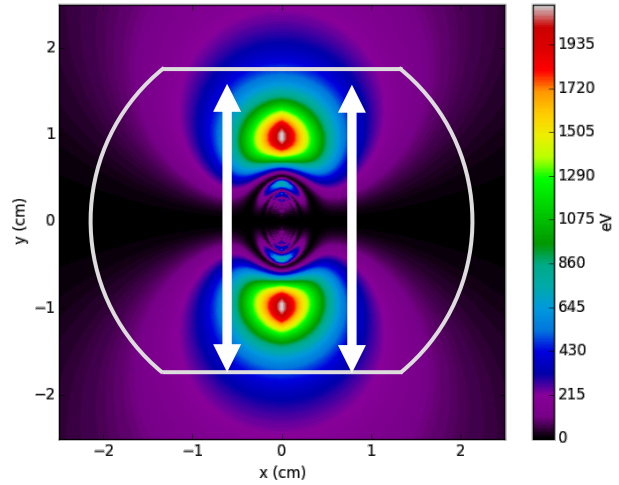




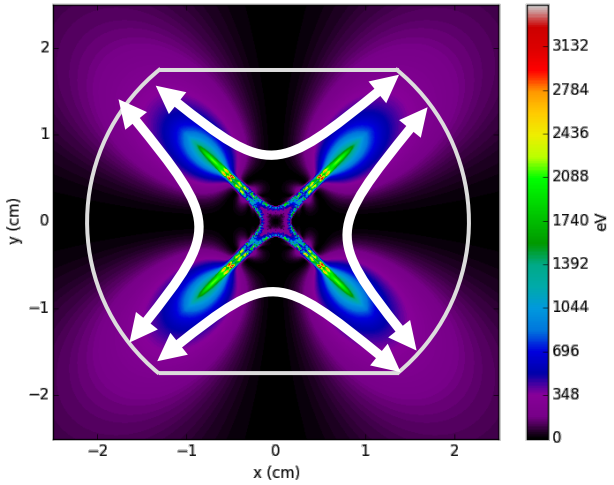
ECLOUD: Acceleration



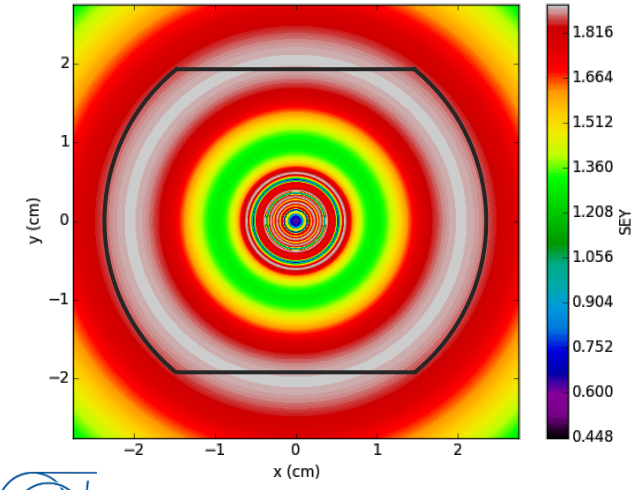
Without field

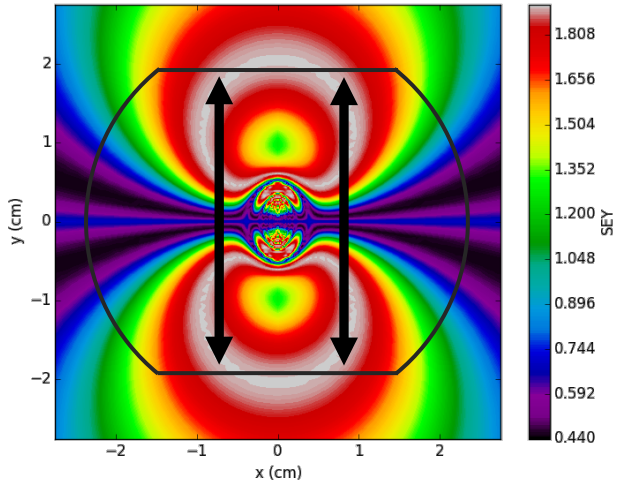


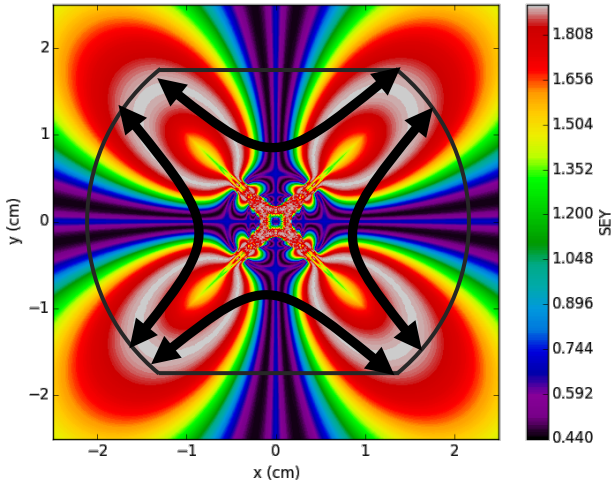
Dipole 7.7 T



Quadrupole 100 T/m







Electron Cloud Effect

$$L = \frac{1}{2}m(\dot{x}^2 + \dot{y}^2 + \dot{z}^2) - q\dot{z}A_z(x,y) + q\varphi(x,y)$$

Kinetic Energy — Magnetic Field — Beam acceleration

Constant of the motion:

$$p_z = \frac{\partial L}{\partial \dot{z}} = m\dot{z} - qA_z(x,y)$$

Without field:

$$\dot{z} = const$$

Dipole:

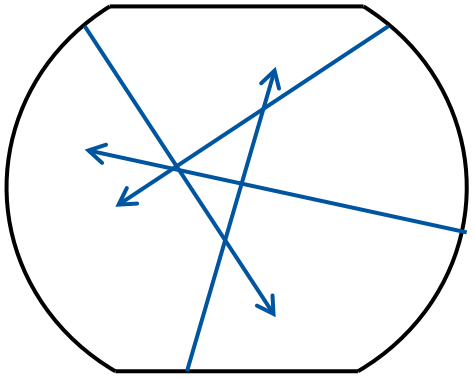
$$m\dot{z} - qBx = const$$

Quadrupole:

$$m\dot{z} - qK(x^2 - y^2) = const$$

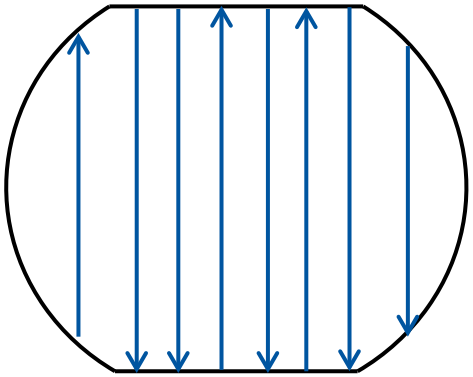
ECLOUD: Trajectories

Without field:



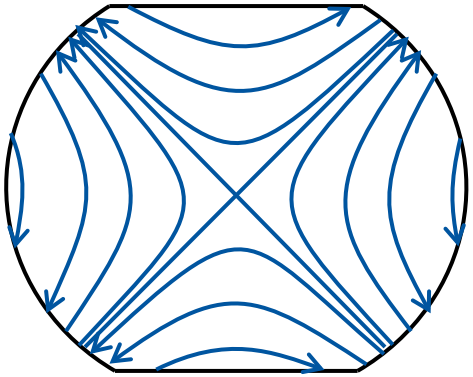
$\dot{z} = const$

Dipole:



$m\dot{z} - qBx = const$

Quadrupole:



$m\dot{z} - qK(x^2 - y^2) = const$

Accelerating field does not change axis of the curve around which electron oscilate!

ECLOUD: Effect of Magnetic Field

Period of oscilations:

$$\mathrm{T} = \frac{2\pi m}{qB}$$

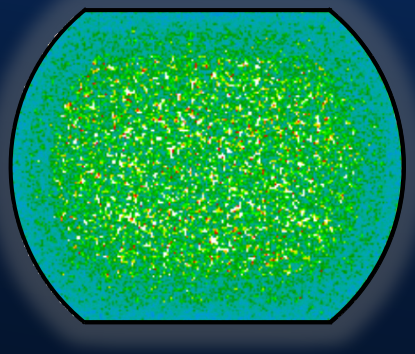
If $T \ll \tau_{beam}$ (1ns) accelerating only in the direction of the field lines

- true for main LHC dipoles and D1, D2 as well

If it is comparable (B≈20mT) the transverse spiral motion of electron is boosted

- Some orbit correctors in LHC, Area in Quadrupoles close to optical axis

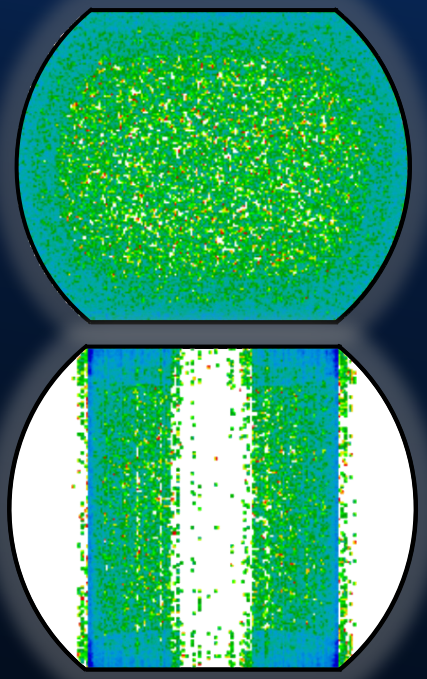
ECLOUD: Summary



Without Field:

- High treshold SEY
- Influenced by synchrotron radiation

ECLOUD: Summary



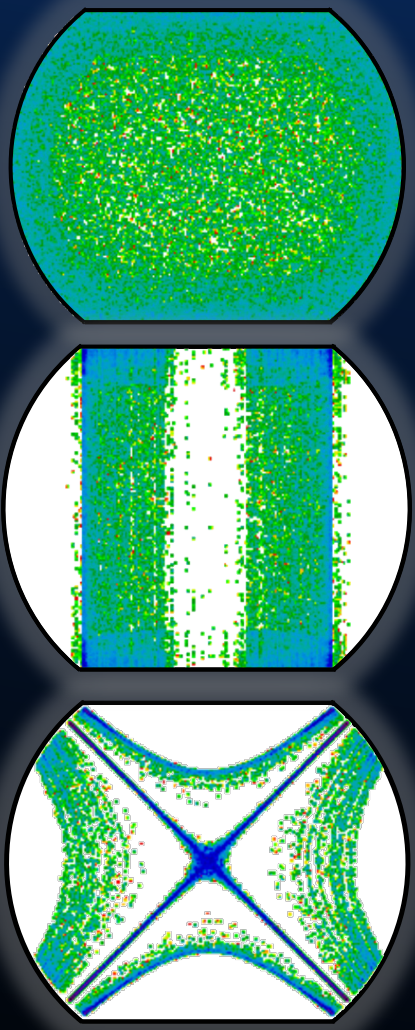
Without Field:

- High treshold SEY
- Influenced by synchrotron radiation

Dipole Field:

- No variation with magnetic field (if B»20mT)
- Main dipoles can be almost totally scrubbed

ECLOUD: Summary



Without Field:

- High treshold SEY
- Influenced by synchrotron radiation

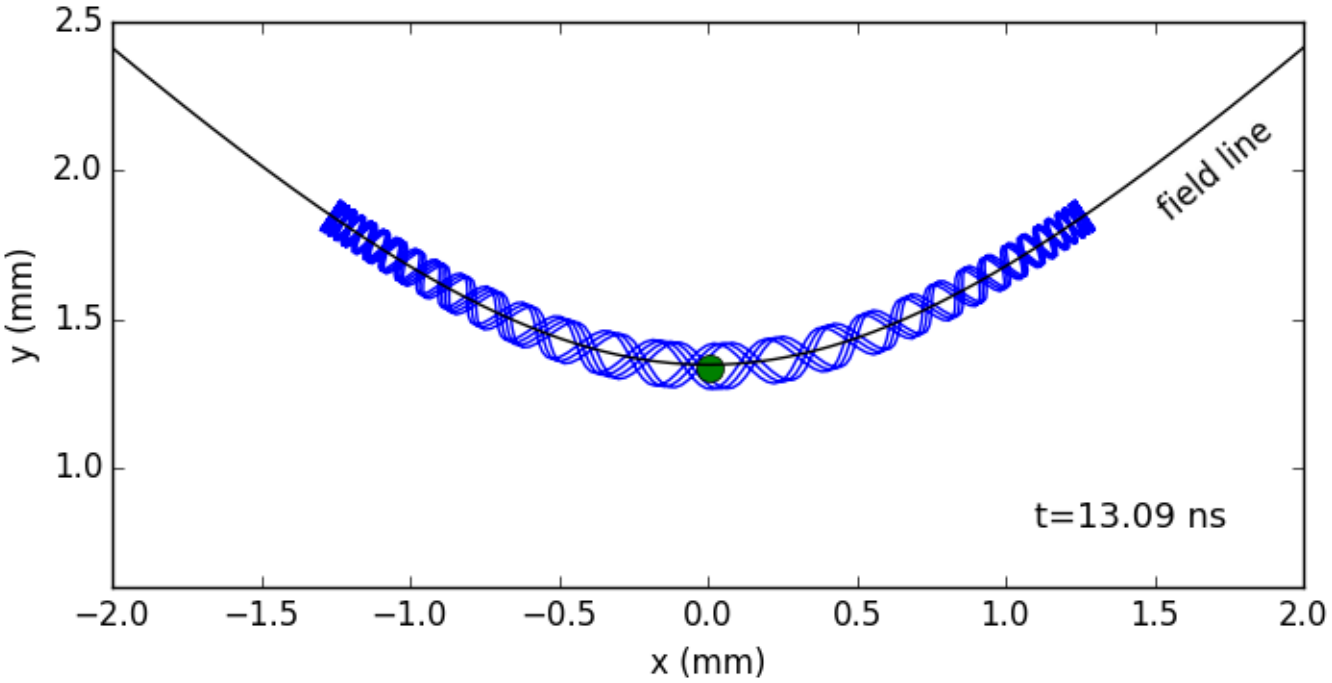
Dipole Field:

- No variation with magnetic field (if B»20mT)
- Main dipoles can be almost totally scrubbed

Quadrupole Field:

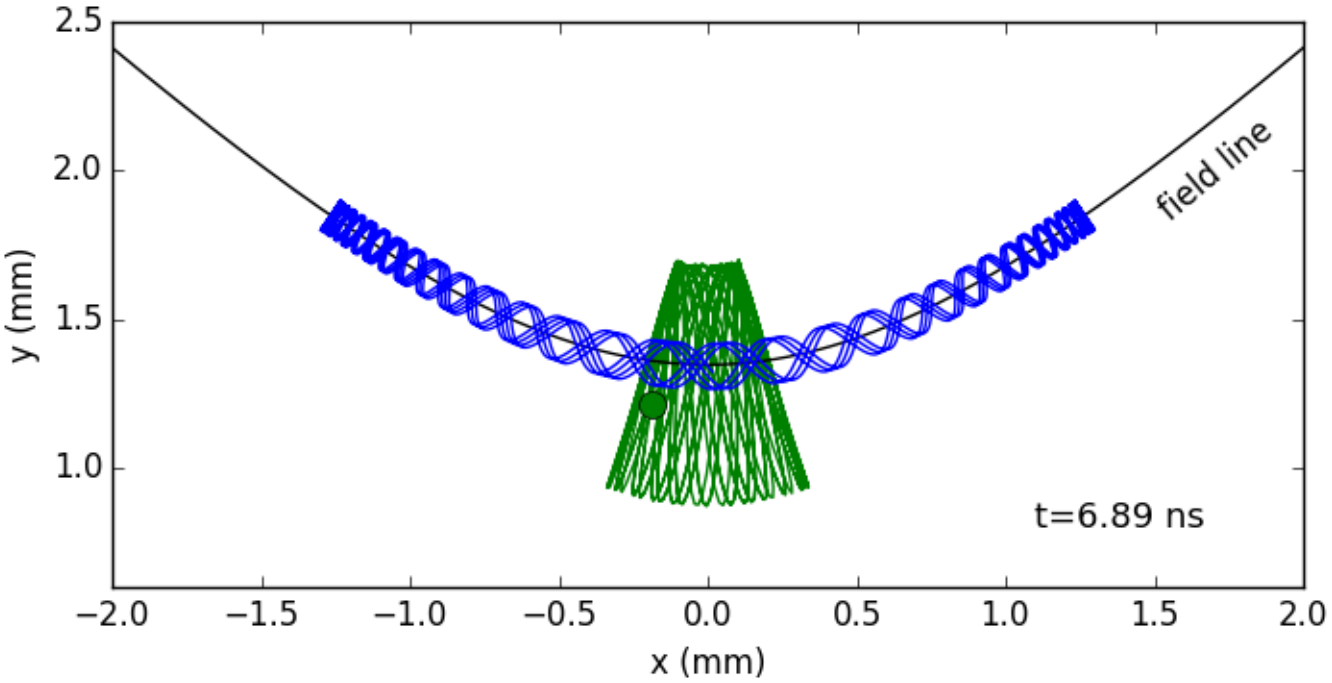
- Slow decay process of ECLOUD
- Trapping effect, area dependent on magnetic field

ECLOUD: Trapping effect



Quadrupole Field 40 T/m, Energy of electron 10 eV

ECLOUD: Trapping effect



Quadrupole Field 40 T/m, Energy of electron 110 eV