Status of LHC heavy ion collimation

- Intro and quick recap
- ICOSIM: latest updates and preliminary studies
- Loss maps for several scenarios
- Suggested locations for BLMs (IR7)
- What next

Ion collimation: why an issue?

Nominal ion beam has 100 times less beam power than proton beam, but particle-collimator physics very different:

Physics process	Proton	^{208}Pb
$\frac{dE}{Edx}$ due to ionisation	-0.12 %/m -0.0088 %/m	-9.57 %/m -0.73%/m
Mult. Scattering (projected r.m.s. angle)	$73.5\mu rad/m^{1/2}$ $4.72\mu rad/m^{1/2}$	$73.5\mu rad/m^{1/2}$ $4.72\mu rad/m^{1/2}$
Nucl. Interaction length ≈fragment. length for ions	38.1cm 38.1cm	2.5cm 2.5cm
Electromagnetic dissociation length	-	33cm 19cm

(HB, EPAC'04)

Daughter nuclei:

$$\left(\frac{\Delta P}{P}\right)_{eff} = \frac{Z_1}{A_1}\frac{A_2}{Z_2} - 1$$

can be bigger than 1% acceptance of LHC arcs

For 2-stage collimation:

$$\delta x' >> \sqrt{\frac{(N_2^{\,2} - N_1^{\,2})\varepsilon_N}{\gamma_{REL}\,\beta_{TWISS}}}$$

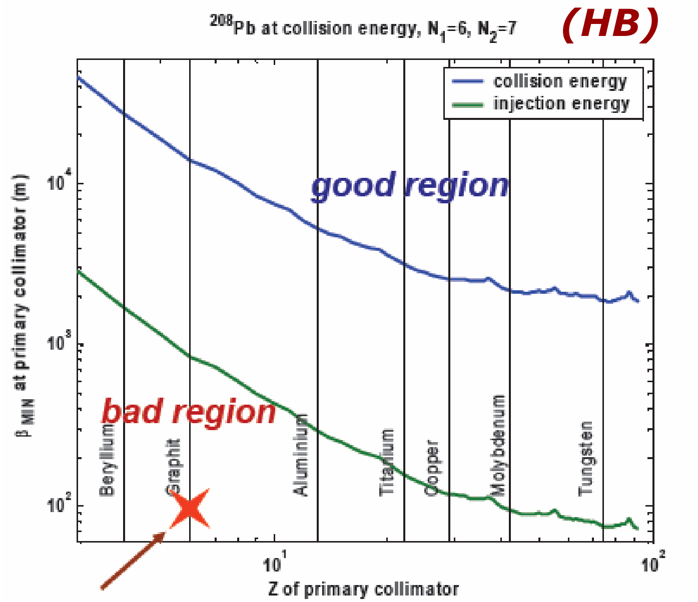
Multiple scattering at TCPs:

$$<\delta x'^2> \sim L,$$

for

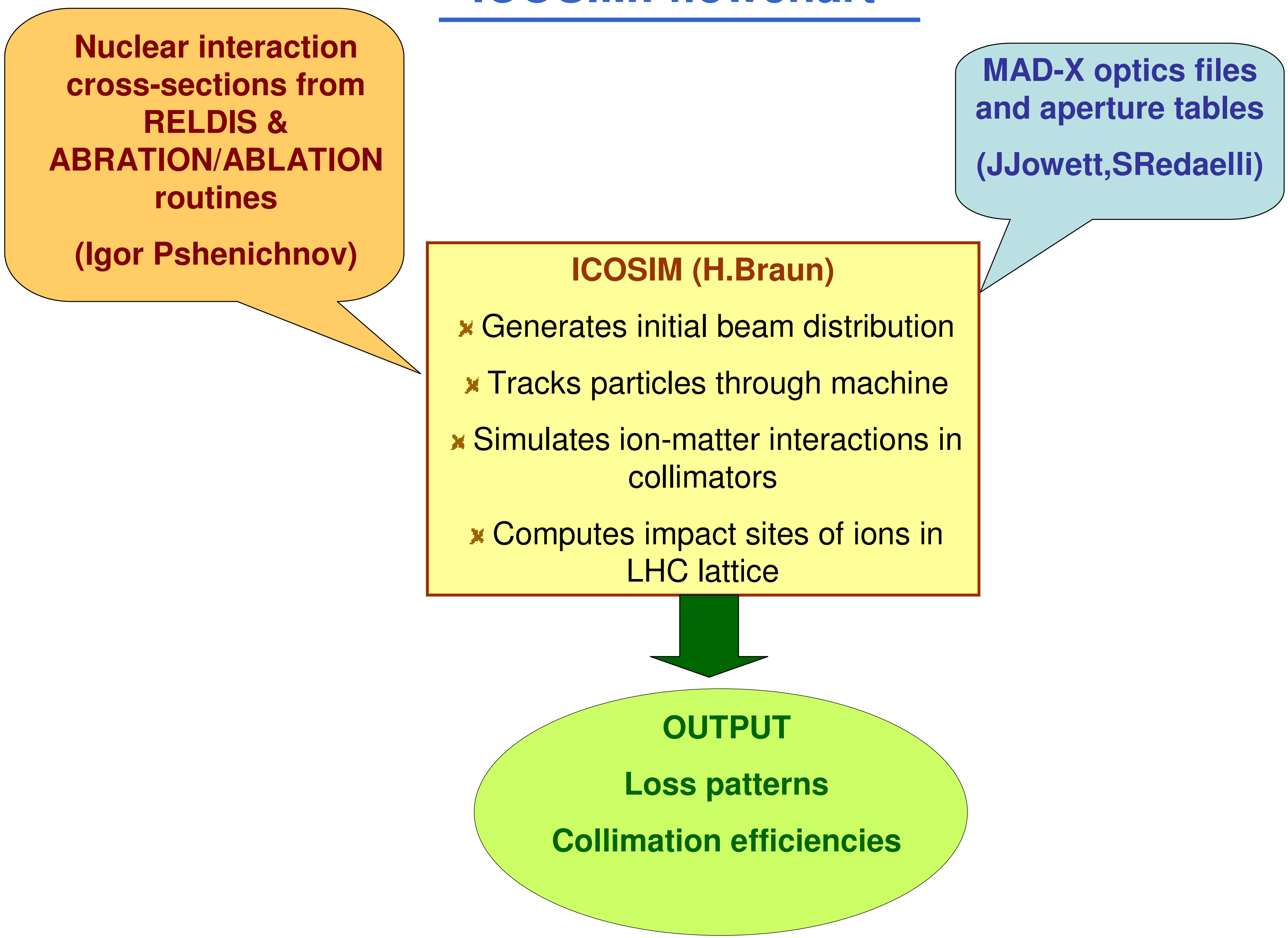
$$L \approx L_{\text{int}} = \frac{A_{coll}}{N_A \rho(\sigma_{had} + \sigma_{emd})}$$

(HB)



IR7 primary collimators

ICOSIM: flowchart



i) Generation of first impact distribution

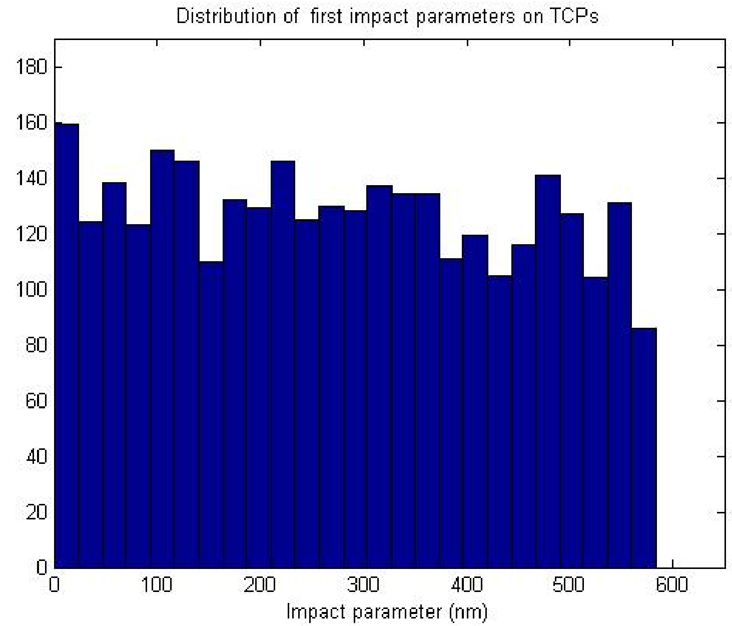
ICOSIM generates randomly populated KV beam distribution in 4D with 'skin depth' parameter:

$$\varepsilon = 36 \times \varepsilon_{nom}$$

Linear tracking from TCP to TCP with slow increase of amplitude dA/dt (~diffusion velocity, every 100 turns) until all particles have hit a TCP. Initial hit position of particles saved for later tracking.

Skin depth parameter and dA/dt determine the average impact parameter of particles onto primary collimators.

<*b*>~ 280 nm



ii) Tracking

Typically 10^4-10^5 particles are tracked for ~250 turns of the LHC, with particle coordinates transformed element by element.

Linear transfer matrices in

$$x, x', y, y', \delta p / p$$

+

Linear dispersion in bending magnets

Chromaticity in quadrupoles to leading order

Sextupoles in thin element kick approximation

No acceleration ($1/Q_s$ <<100)

Check on aperture hits at the end of each element ; in case of hit the exact impact position within the element is found by interpolation.

Aperture cross sections are approximated by ellipses, except for collimators, where full geometry is taken into account.

If hit location is inside a collimator then call is made to fragmentation routines.

iii) Particle interactions

Cross-section tables for NF and EMD generated by I.Pshenichnov's abration/ablation and RELDIS codes.

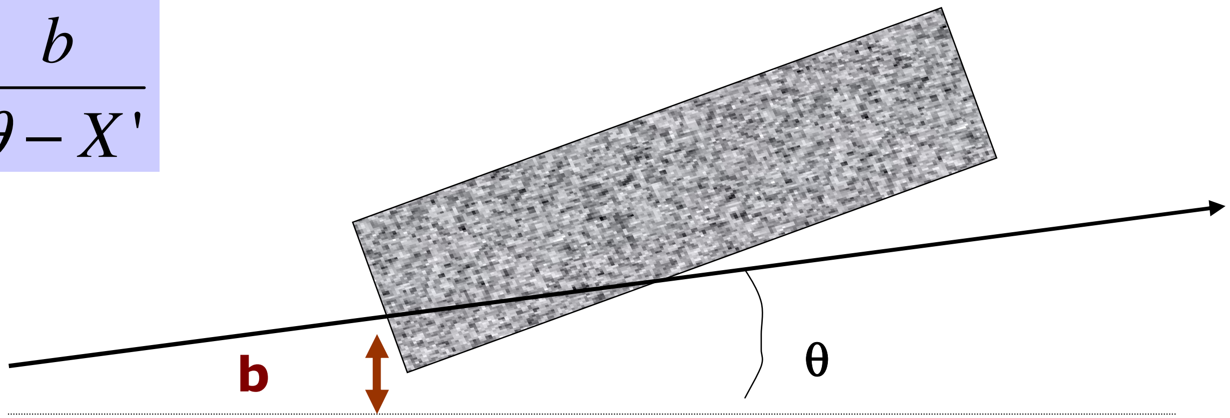
Ionisation energy loss modelled by Bethe-Bloch formula for heavy ions with shell and density corrections.

Multiple scattering is described using a Gaussian approximation of the scattering distribution

The effective particle path is calculated at impact time for each particle.

If **$L_{eff} > 10\ L_{int}$** the particle is assumed to be stopped and absorbed, otherwise the probability for a fragmentation process is randomly computed using the look-up cross-section tables.

$$L_{eff} = \frac{b}{\theta - X'}$$



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ICOSIM: latest updates

Introduced **latest LHC optics** -> files from JJowett

Injection

	β_x (m)	β_y (m)
IP1	17	17
IP2	10	10
IP5	17	17
IP8	10	10

Early Ion Collisions:

	β_x (m)	β_y (m)
IP1	2	2
IP2	1	1
IP5	2	2
IP8	10	10

Nominal Ion Collisions:

	β_x (m)	β_y (m)
IP1	0.55	0.55
IP2	0.5	0.5
IP5	0.55	0.55
IP8	10	10

Np/bunch = 7x10⁷

Nb=592

E/nucleon = 177.4 GeV

$\beta\gamma = 190.47$

$\mathcal{E}x = \mathcal{E}y = 1.5/\beta\gamma = 7.88\times10^{-3}$ mm mrad

Np/bunch=7x10⁷

Nb=592

E/nucleon=2.76 TeV

$\beta\gamma = 2962.9$

$\mathcal{E}x = \mathcal{E}y = 1.5/\beta\gamma \sim 5\times10^{-4}$ mm mrad

New aperture files provided by S Redaelli (but will need further update to fix some wrong specifications)

Collimators

List of collimators updated to include full list of TCPs, TCSGs, TCTVs, TCTHs (TCLIs and TCLAs not yet included); also changed denominations to be in line with those adopted in the LHC optics database. Complete list:

8 TCPs: 8/IR7, 2/IR3 (A6L7, A6R7 deactivated)

42 TCSGs: 32/IR7, 8/IR3, 2/IR6

8 TCTH: 2/IR1, 2/IR2, 2/IR5, 2/IR8

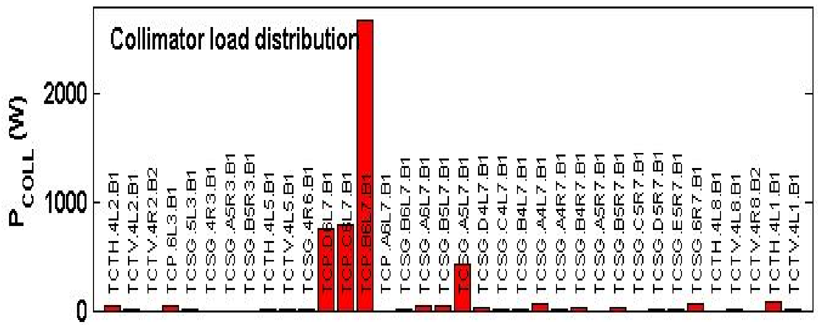
8 TCTV: 2/IR1, 2/IR2, 2/IR5, 2/IR8

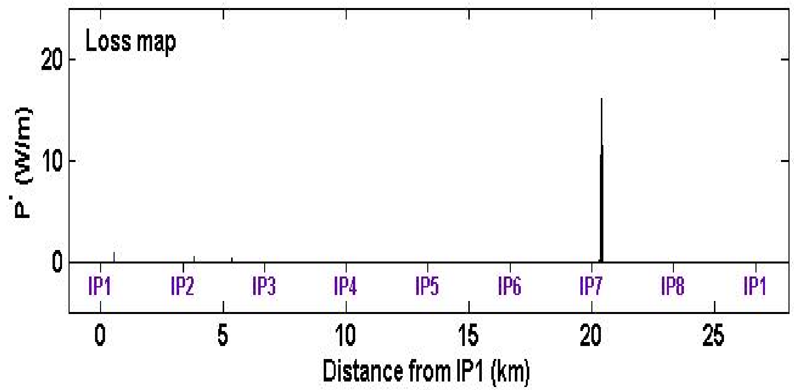
Standard aperture settings:

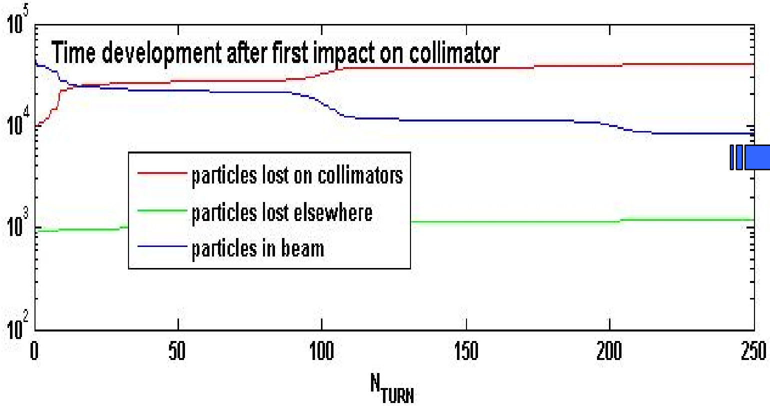
	n1	n2	n3
Injection IR3	8	9.3	10
Injection IR7	6	7	10
Collision IR3	15	18	10
Collision IR7	6	7	10

Changed ρ **(C-C)= 2.25** → **1.7 g/cm3** (R. Chamizo)

Nominal ILHC beam 1 at collision

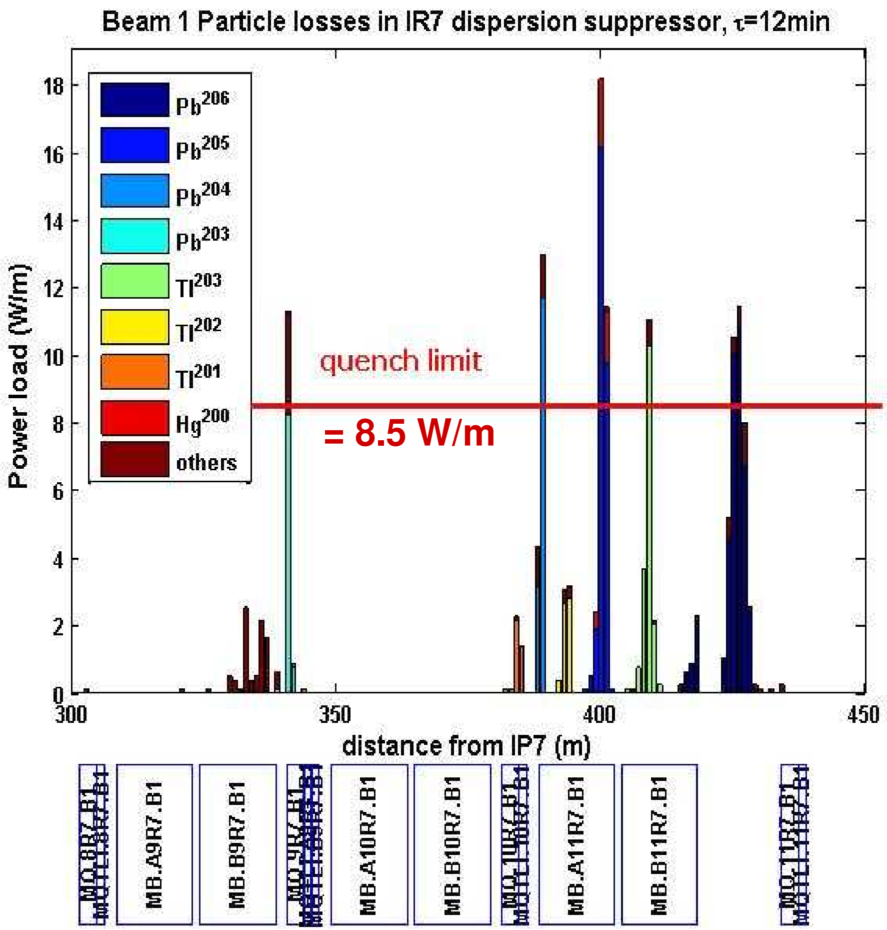






Collimation inefficiency:

η=0.0294

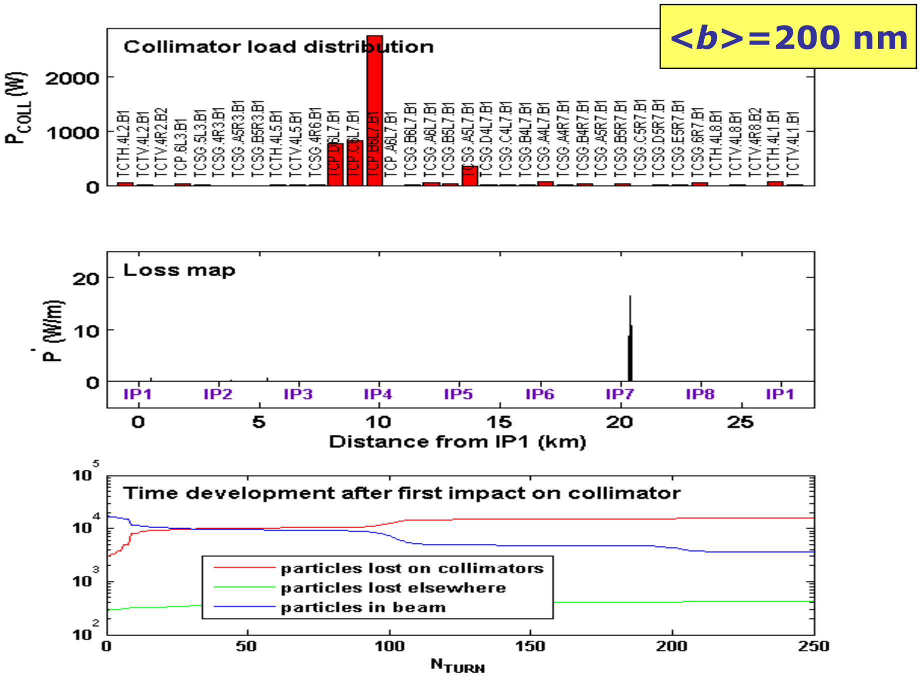


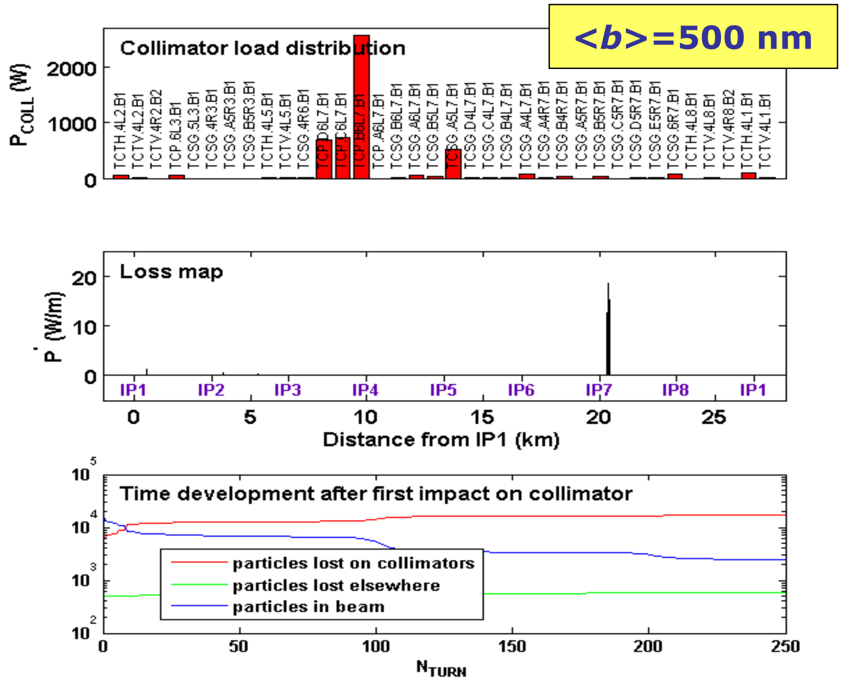
N_p =50k

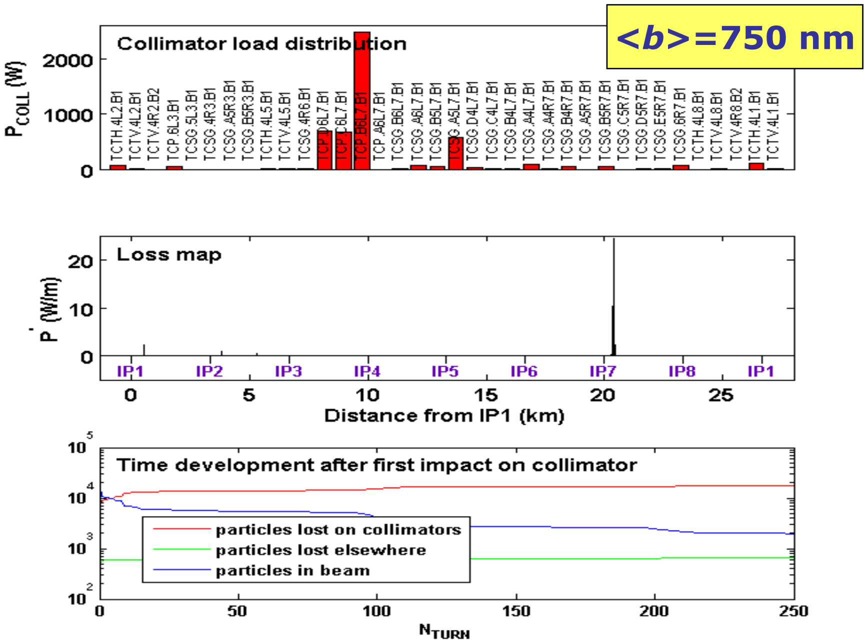
Nrev = 250

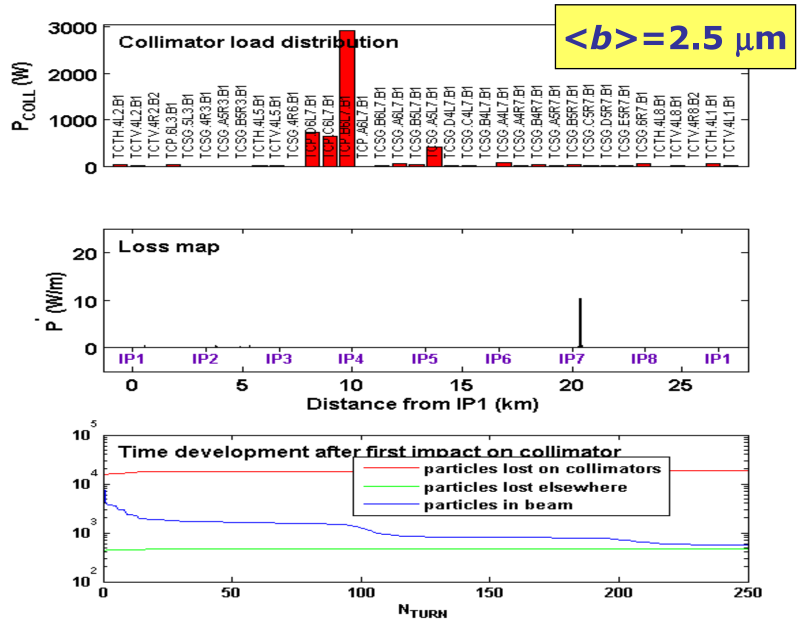
<*b*> = 280 nm

ρ=1.7 g/cm^3

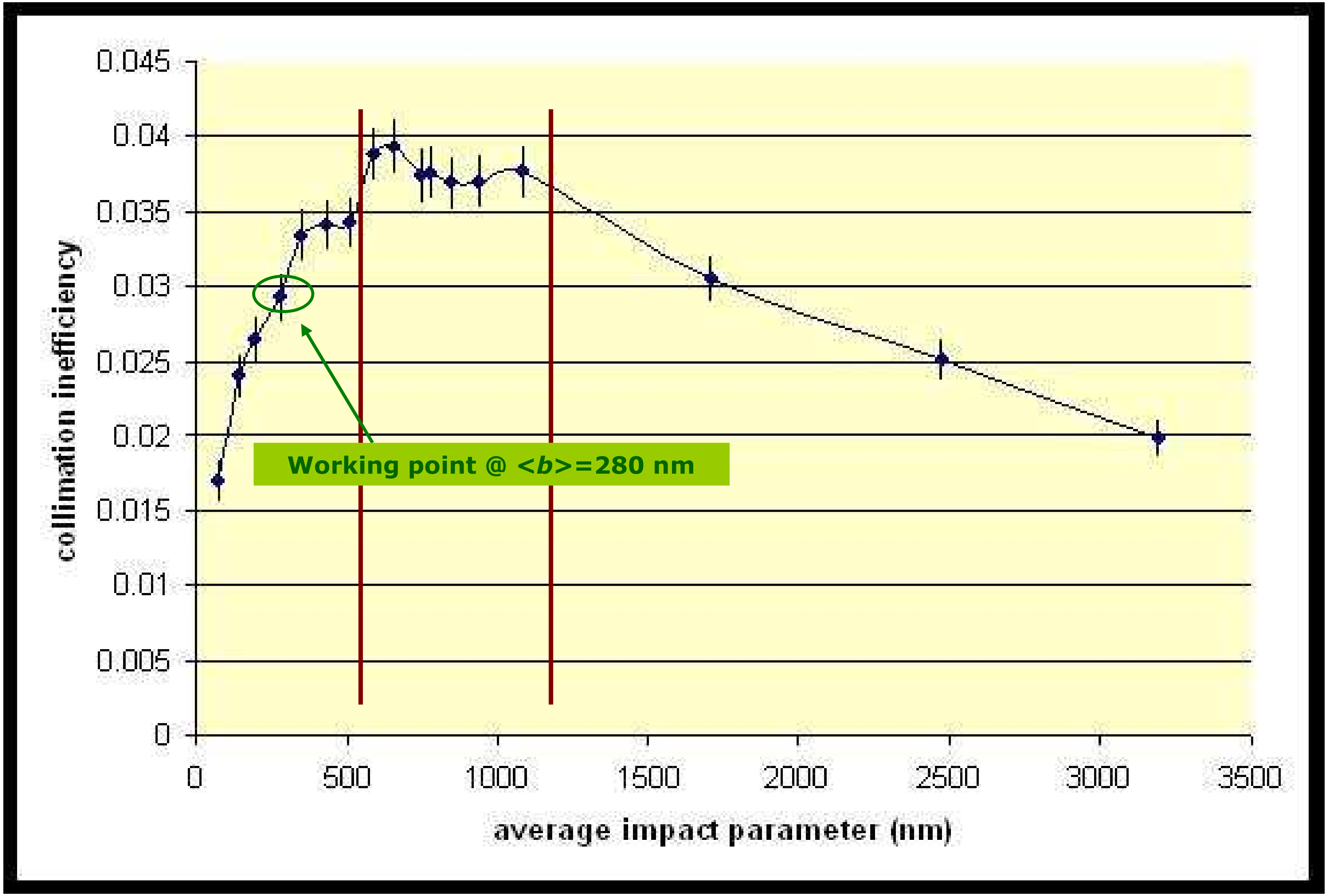

<b>=200 nm
Collimator load distribution
P_{COLL} (W)
Loss map
P' (W/m)
IP1 IP2 IP3 IP4 IP5 IP6 IP7 IP8 IP1
Distance from IP1 (km)
Time development after first impact on collimator
particles lost on collimators
particles lost elsewhere
particles in beam
N_{TURN}


<b>=500 nm
Collimator load distribution
P_{COLL} (W)
Loss map
P' (W/m)
IP1 IP2 IP3 IP4 IP5 IP6 IP7 IP8 IP1
Distance from IP1 (km)
Time development after first impact on collimator
particles lost on collimators
particles lost elsewhere
particles in beam
N_{TURN}


<b>=750 nm
Collimator load distribution
P_{COLL} (W)
Loss map
P' (W/m)
IP1 IP2 IP3 IP4 IP5 IP6 IP7 IP8 IP1
Distance from IP1 (km)
Time development after first impact on collimator
particles lost on collimators
particles lost elsewhere
particles in beam
N_{TURN}

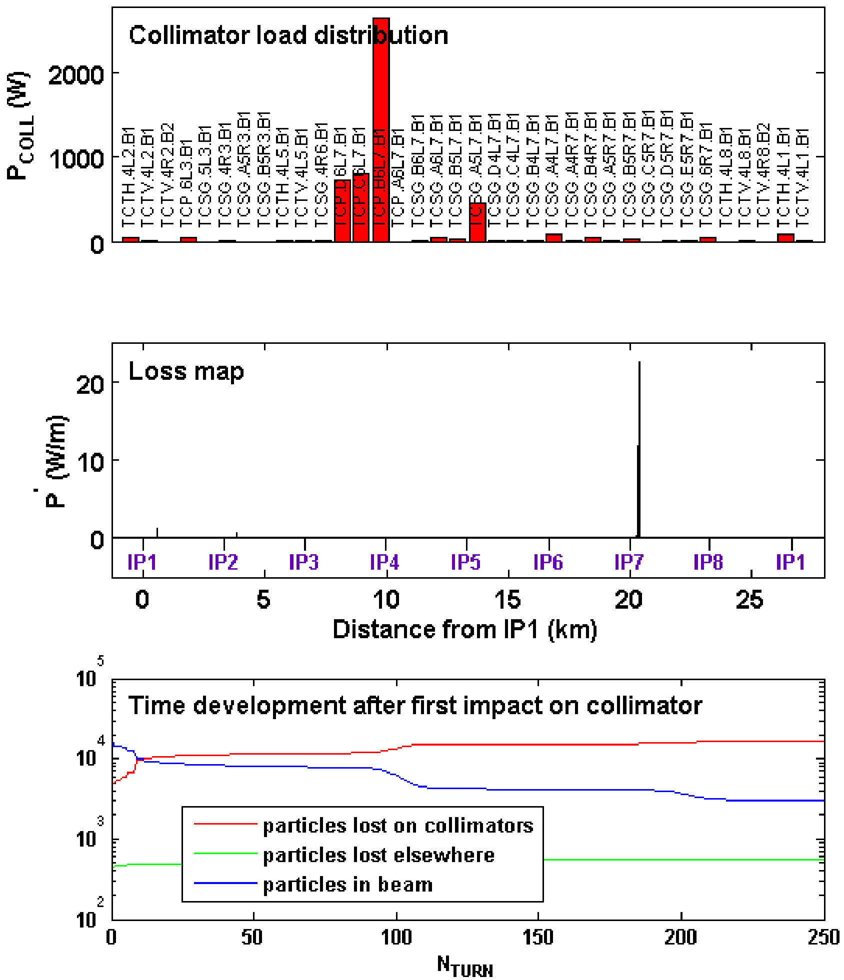

<b>=2.5 μm
Collimator load distribution
P_{COLL} (W)
Loss map
P' (W/m)
IP1 IP2 IP3 IP4 IP5 IP6 IP7 IP8 IP1
Distance from IP1 (km)
Time development after first impact on collimator
particles lost on collimators
particles lost elsewhere
particles in beam
N_{TURN}

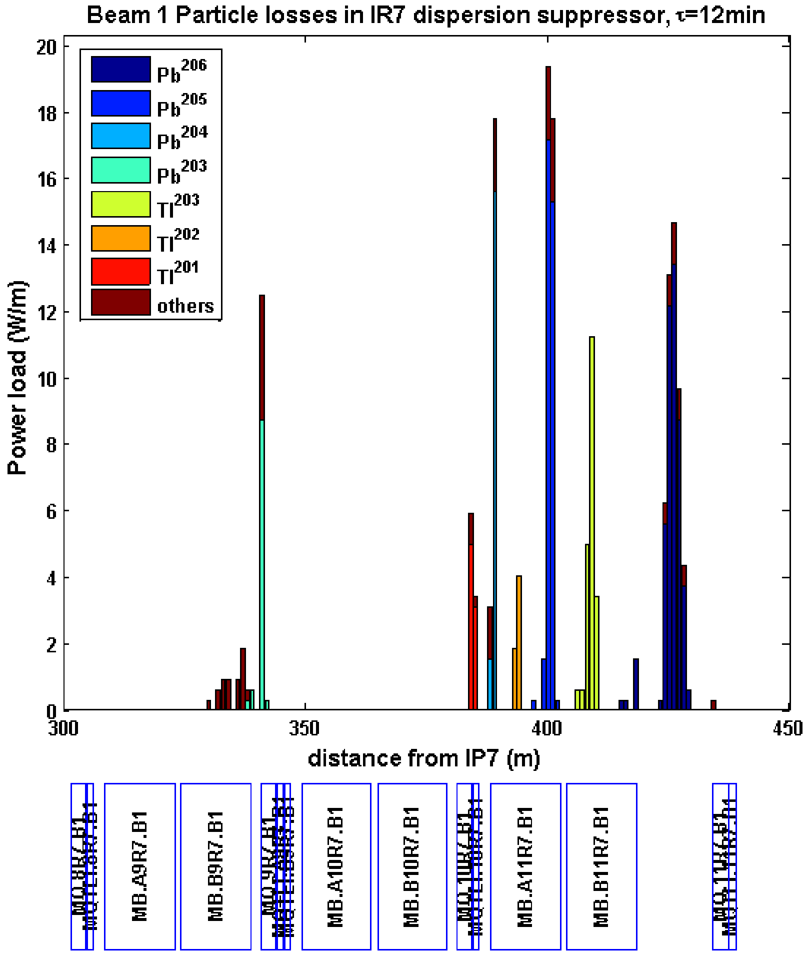
Impact parameter study



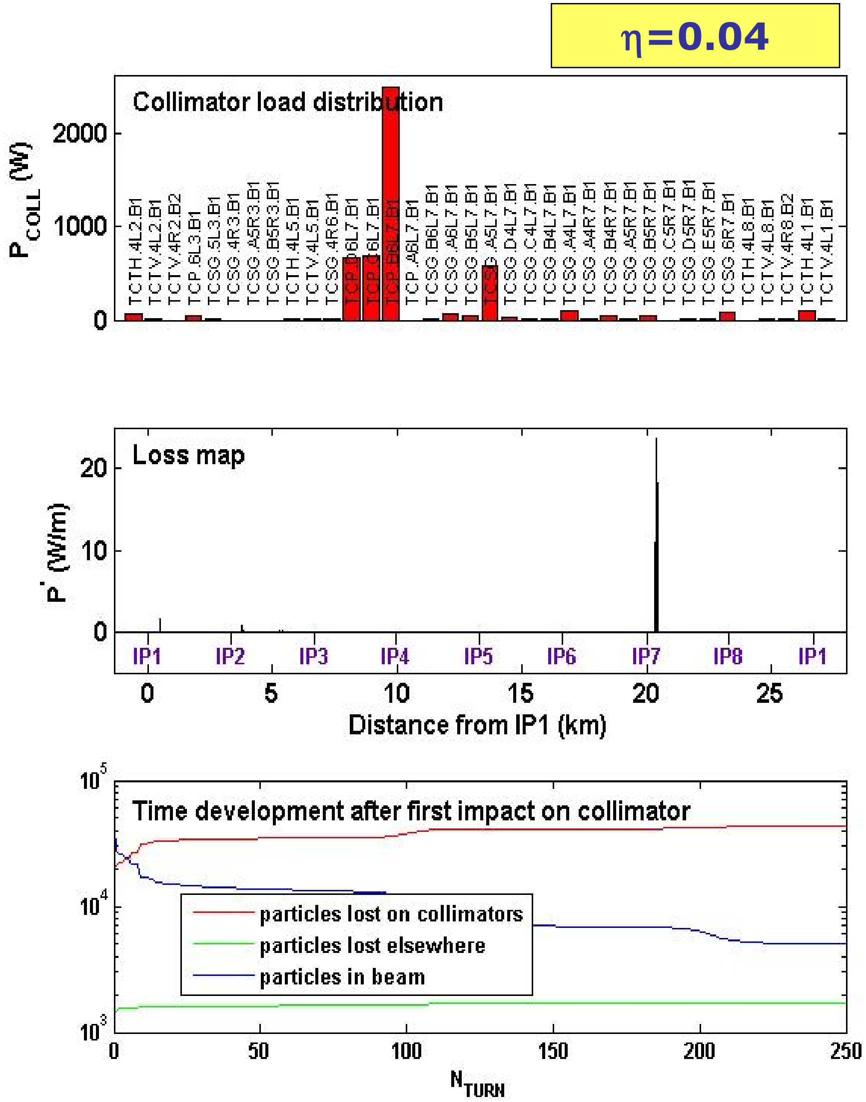
Effect of change in ρ

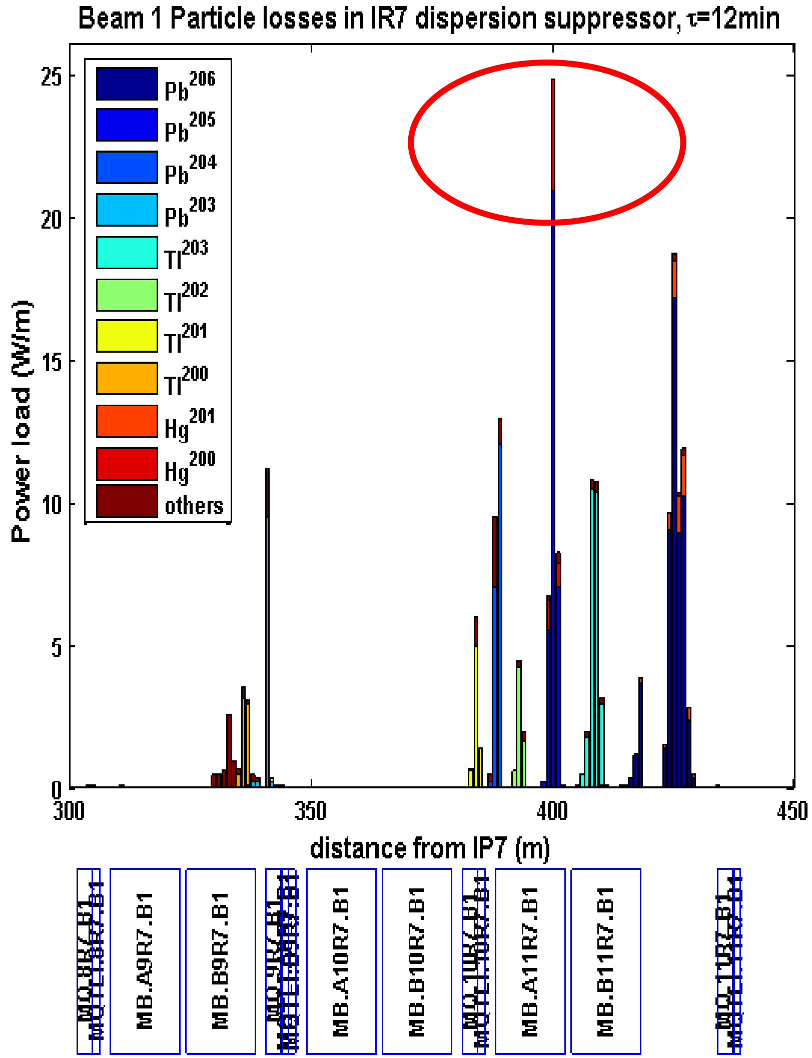
Going back to ρ **= 2.25 g/cm³** for <*b*>~280 nm ⇒ **η increases to 0.0339**





Now taking ρ=**1.7 g/cm³** and **<*b*>~ 750 nm** (plateau region):





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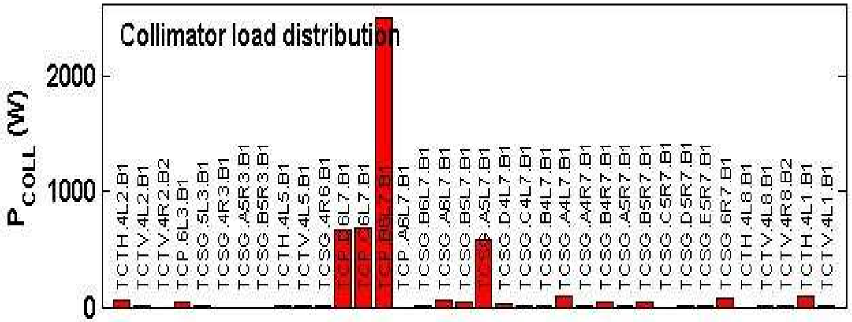
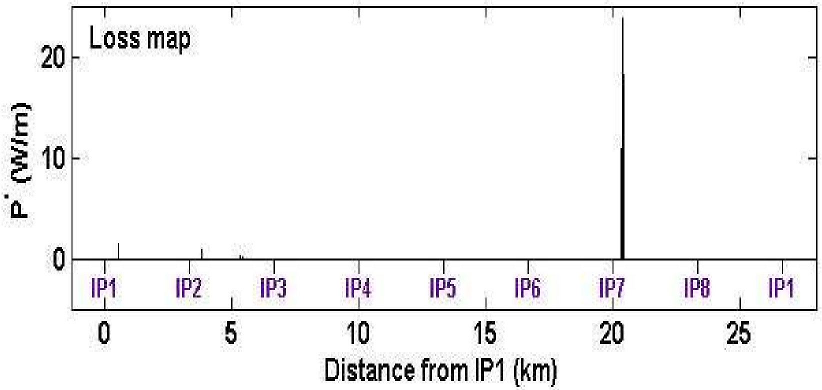
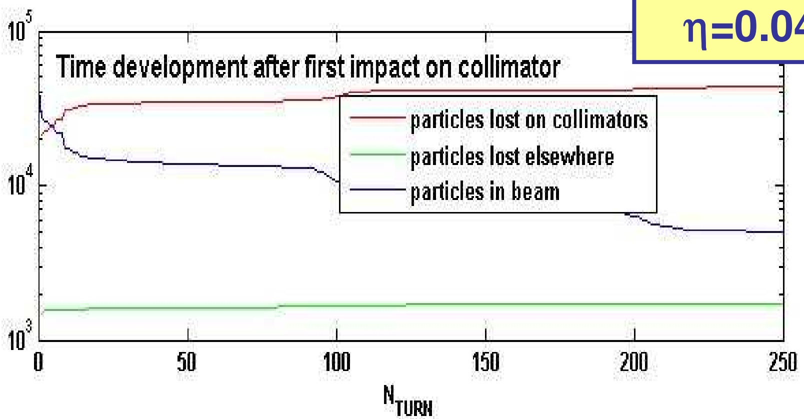
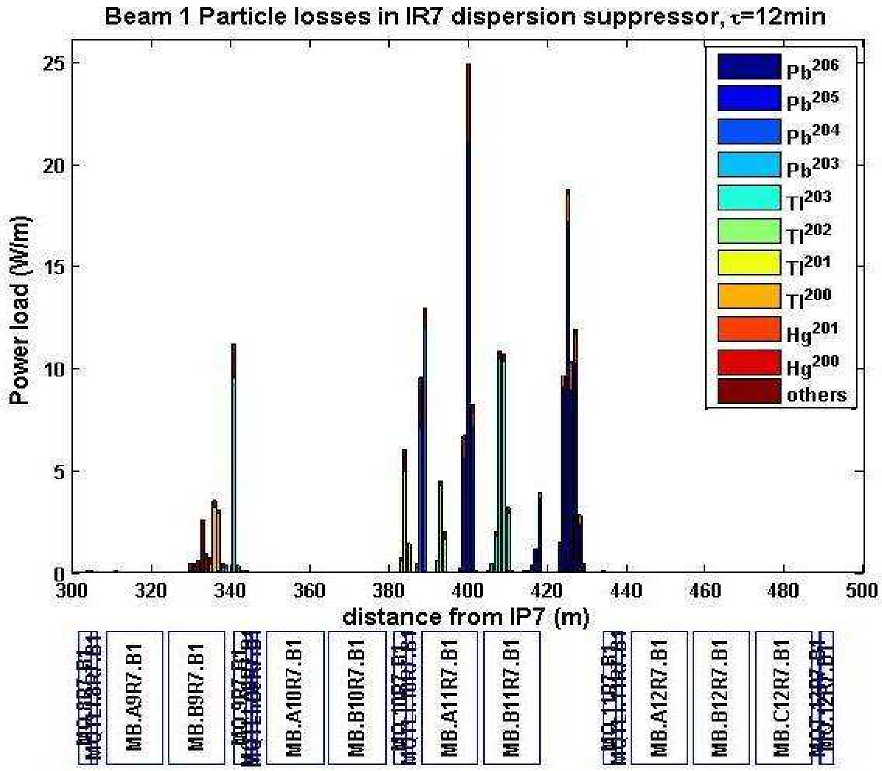
Beam1 @ nominal collision







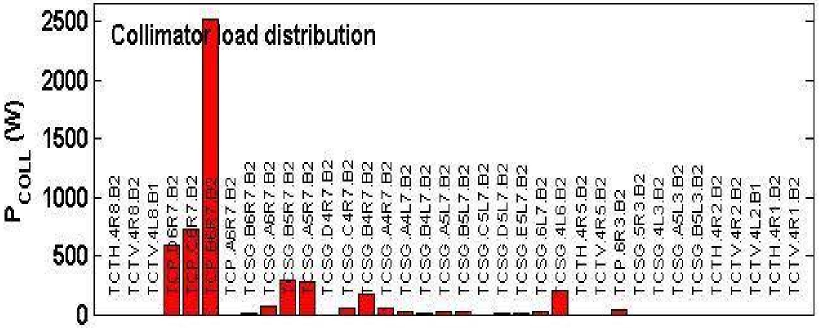
η=0.040

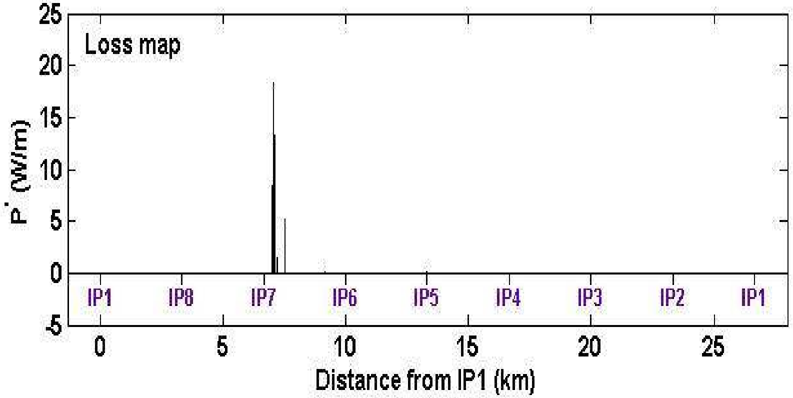


Losses confined to IR7 dispersion suppressor, cells 9 & 11

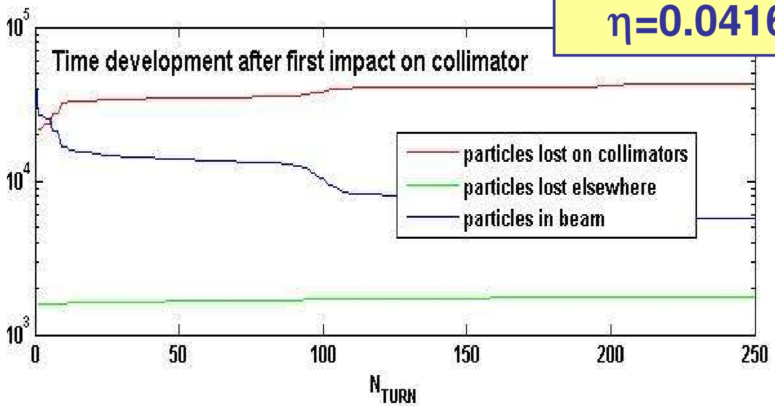
Few small losses in IR2 (mainly blocked by tertiaries)

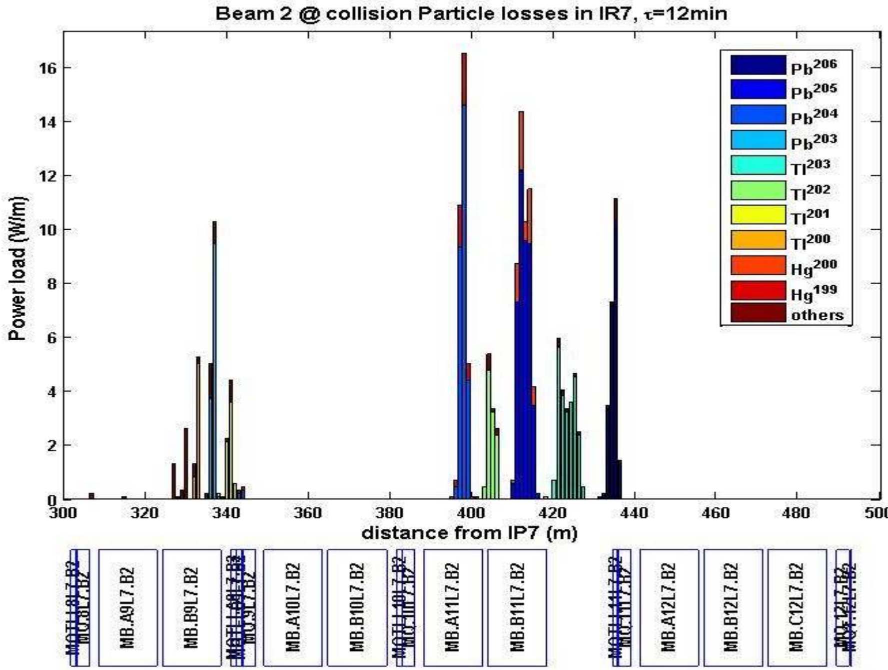
Beam2 @ nominal collision

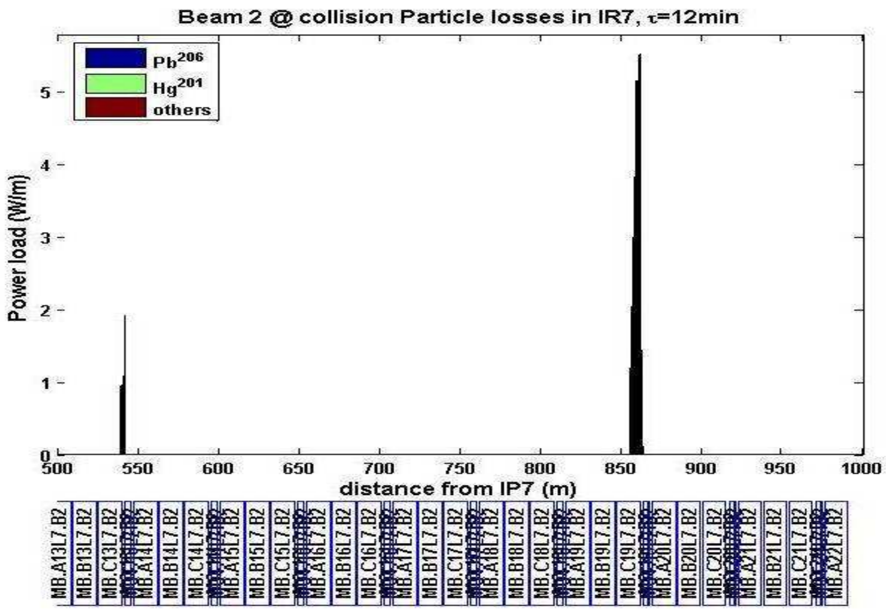




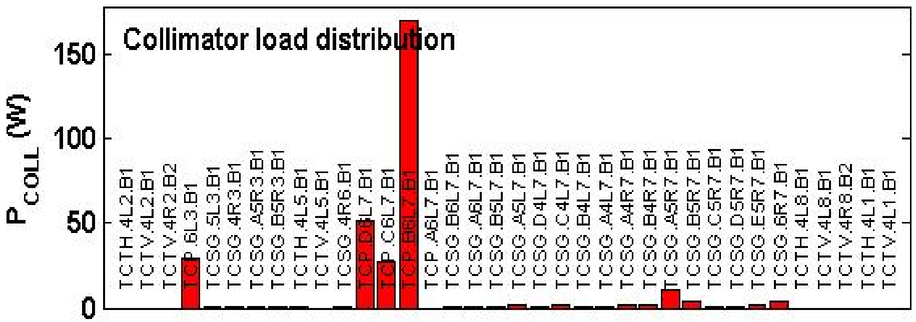
η=0.0416

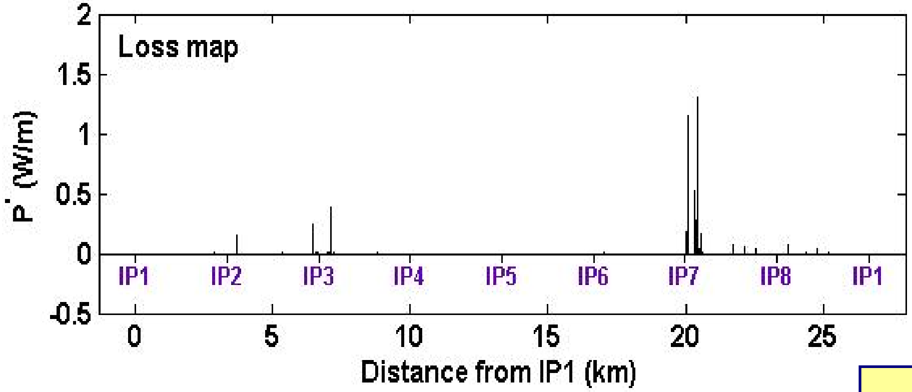


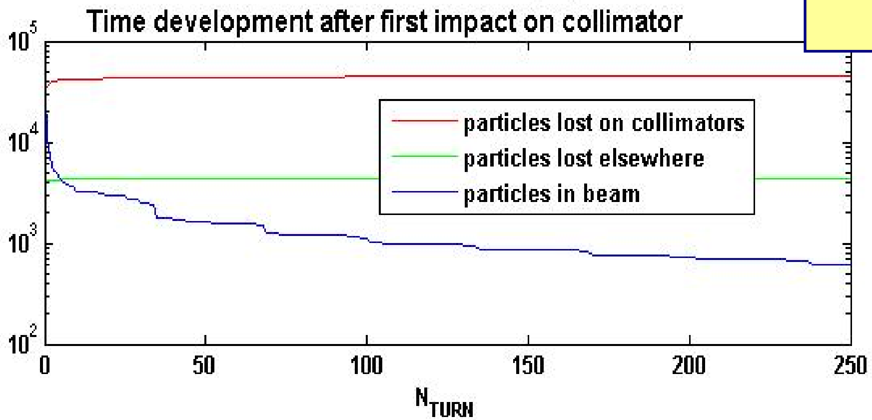


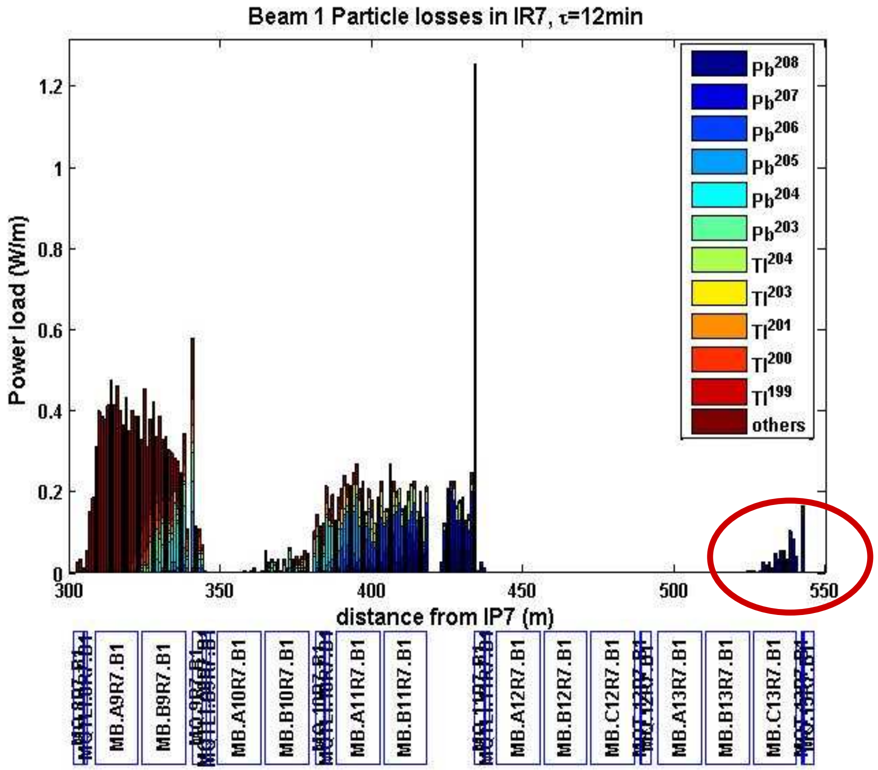


Beam1 @ injection



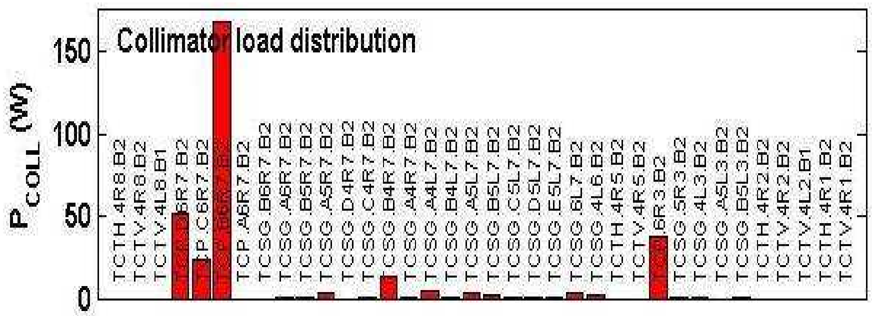


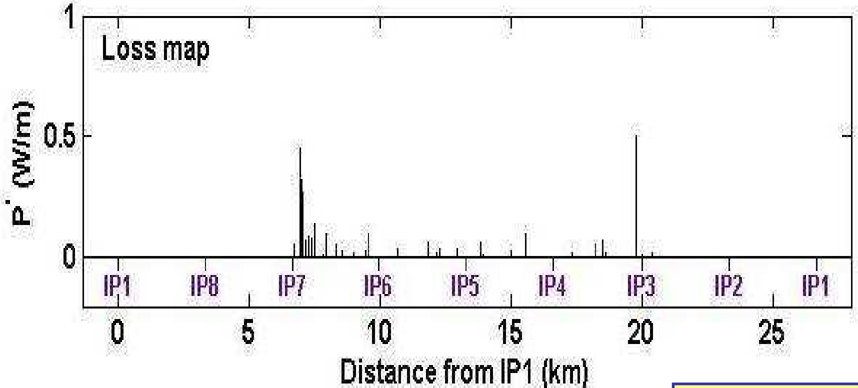


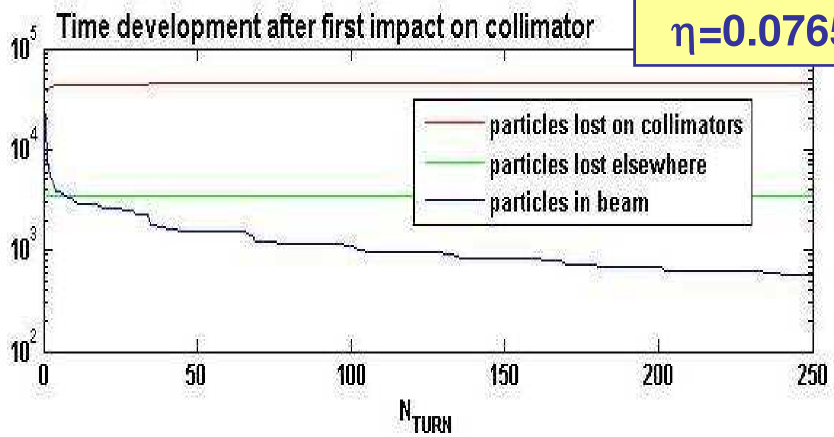


$\eta=0.0964$

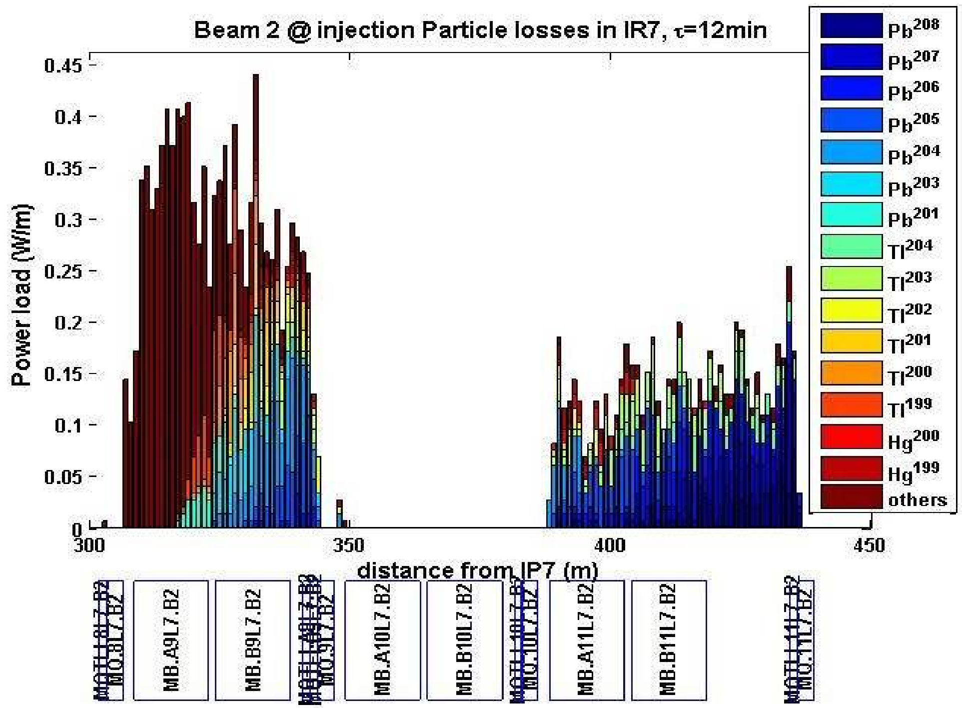
Beam 2 @ injection

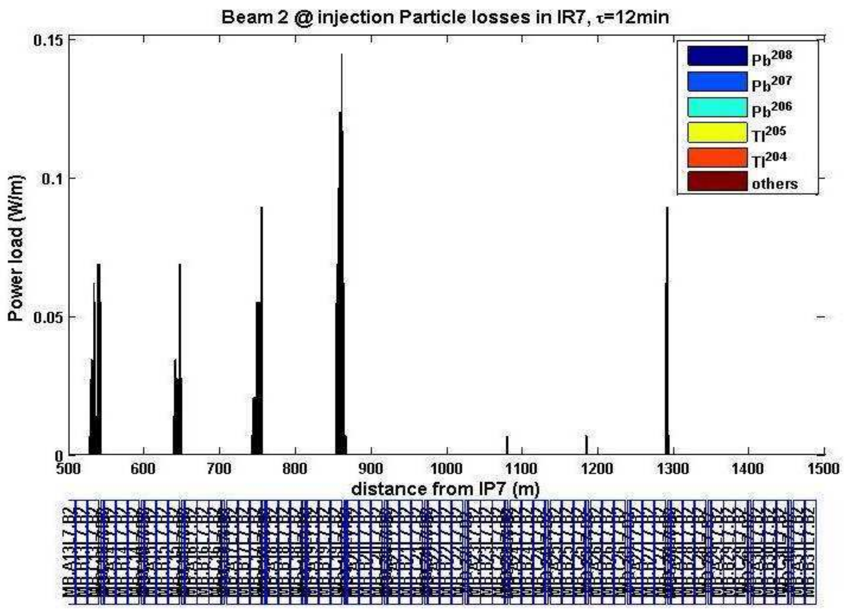






η=0.0765





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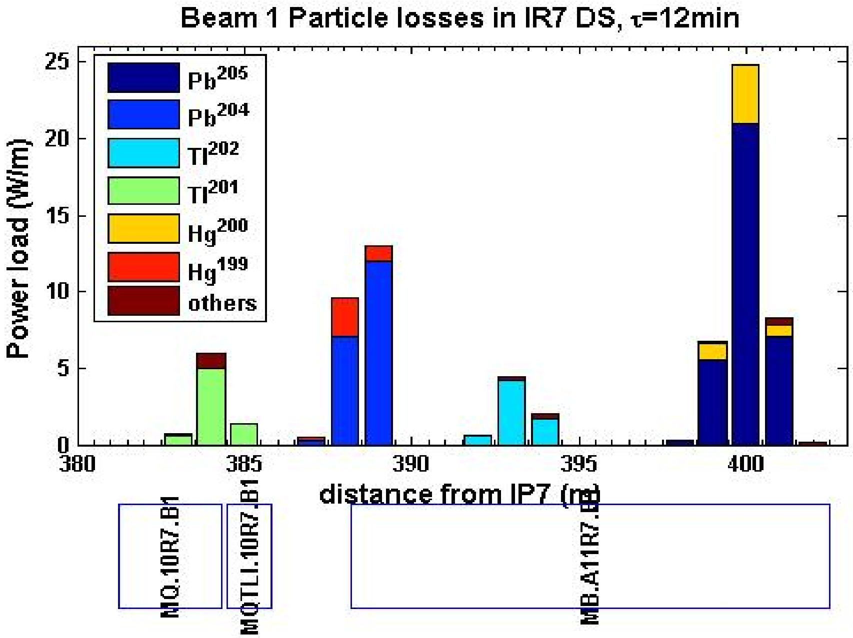
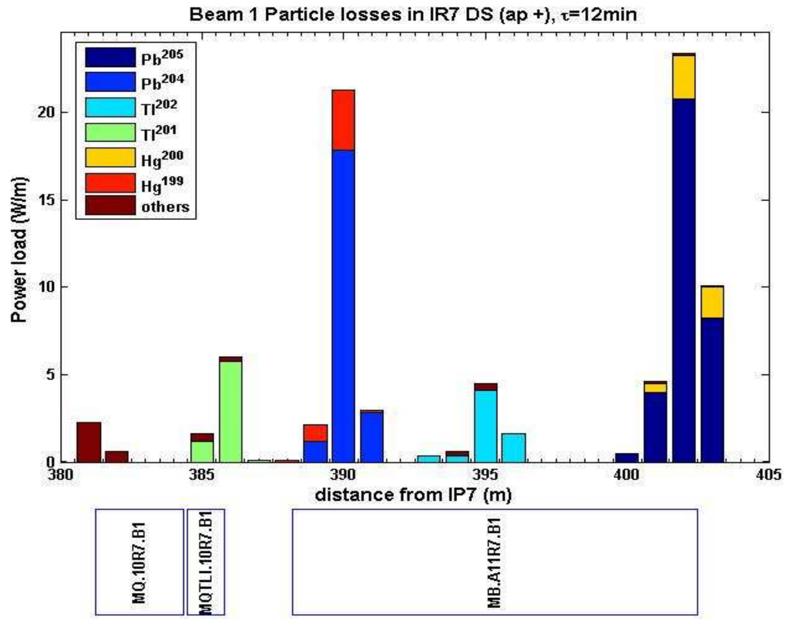
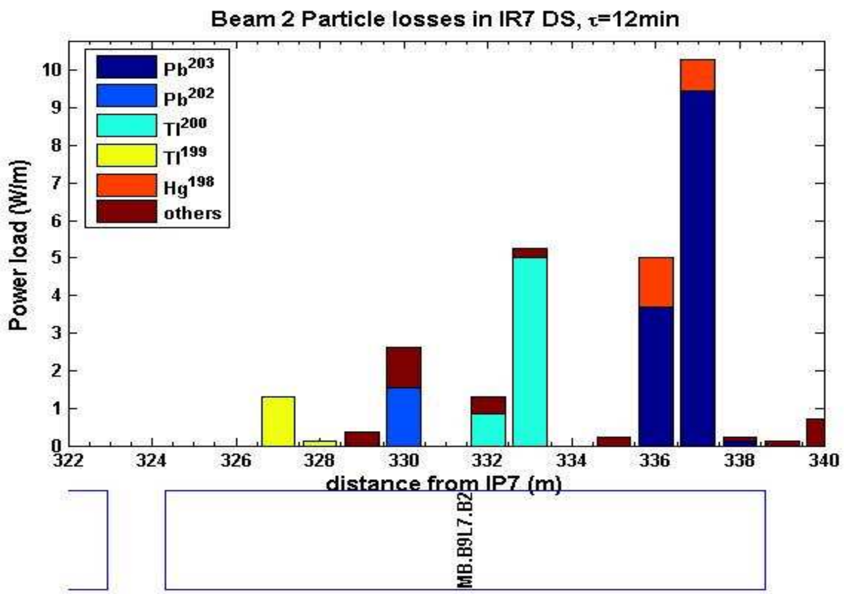
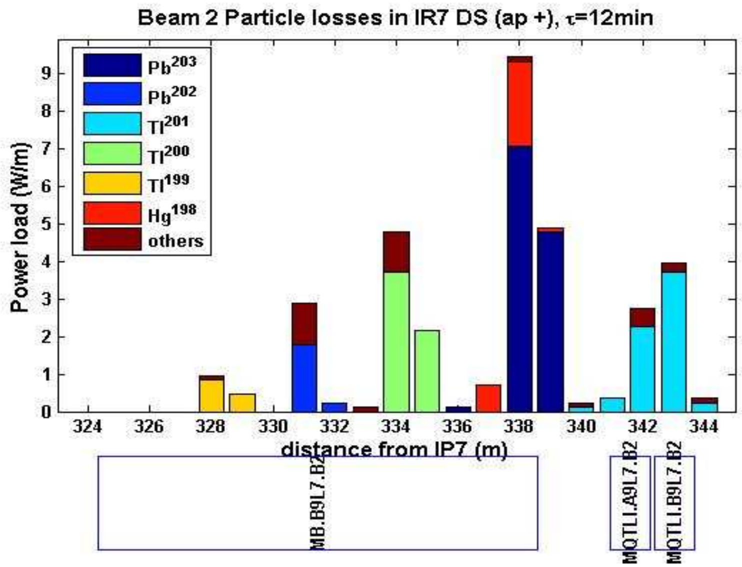
Aperture sensitivity : nominal +1 mm









BLMs coverage:

Philosophy :

Adding 1mm to aperture (all elements) causes a shift in the beam loss peaks by up to 2m

BLMs coverage of IR7:
3 patches available in cells 8,9,11 (dipoles) X 8 channels (max) X 2 BLMs

2 channels available on quad patches (regions 8,9,10,11,13)

Need partial coverage of cell 9 and 13, full coverage of cell 11

Numbers:

BLM active length = 40 cm

Dipole length = 14.3 m (x2)

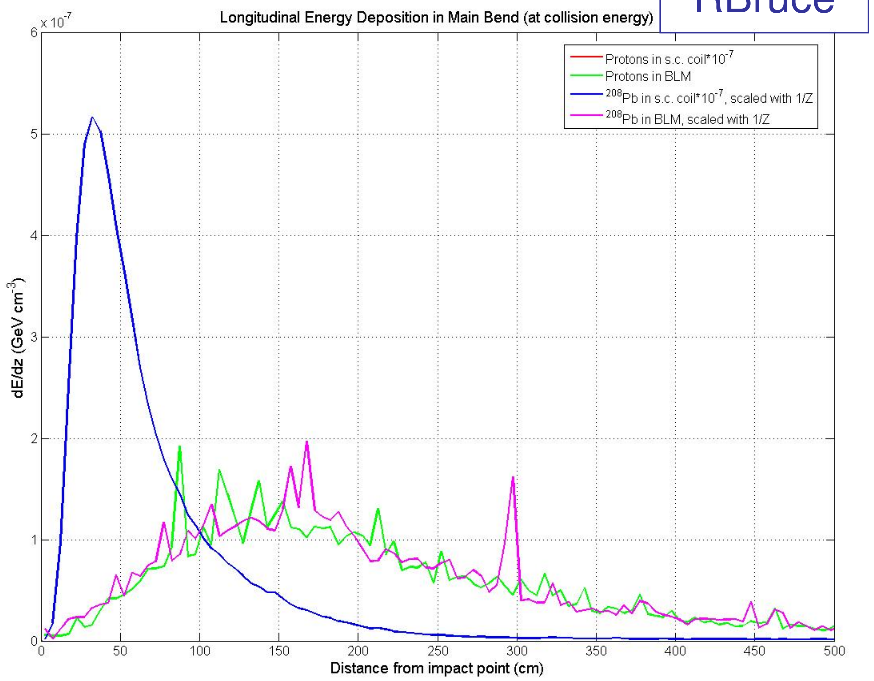
Long. Spread of energy deposition=

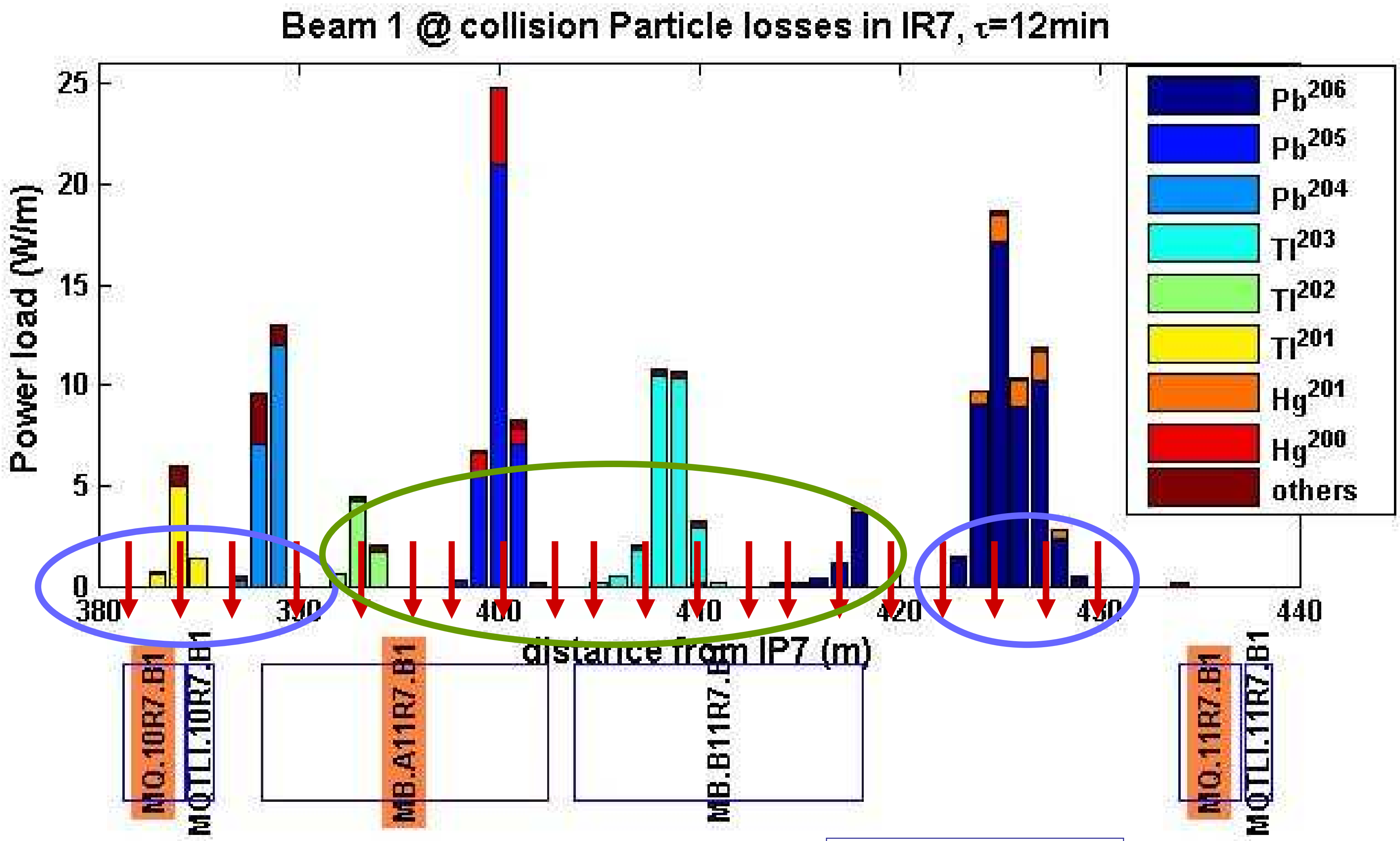
2.5 m FWHM

peak @ 1.5 m from impact

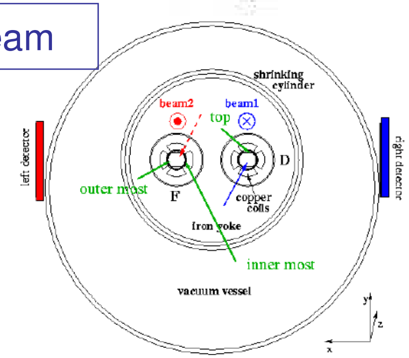
For coil deposition peak @ 30cm from impact point

RBruce





B. Dehning's team



-2.5 m spacing

-Transverse position: inside (left) for beam2, outside (right) for beam1

What next ?

Next few days:

Produce list of locations for BLM installation in IR7/IR3

Longer term :

move in parallel with proton collimation working group :

Use common setup (optics/aperture model/collimator list)

Adopt similar study approaches for better comparison of results: next priority

Study sensitivity to orbit oscillations using same perturbation model (GRD's talk at last Chamonix)

Specific issues:

- Code benchmarking for protons (ICOSIM/Sixtrack, ICOSIM/SPS data)
- Study loss distributions (uniform loss assumption *vs* losses concentrated on a single collimator jaw)
- Improve physical model of particle/collimator interactions