Simulation of Radiation monitors

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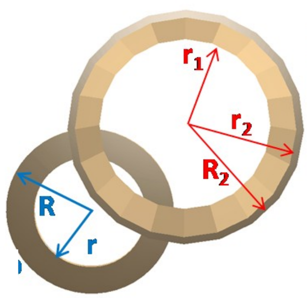
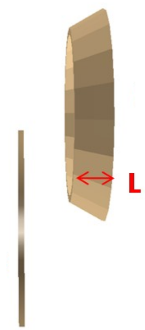
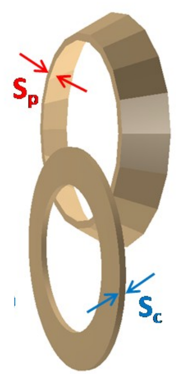
Introduction

- Goal is to monitor the beam conditions in a region as close as possible to BP and IP
  - Must face a very tough environment, from the point of view of total dose and rate
- Several detector configurations being presently investigated
  - before a choice is made, one must have an idea of the precise requirements
- Aim of this study is to look at what happens in some possible locations for such a detector, and give feedback to detector design
  - See R. Cardarelli's presentation in this session

Implementation





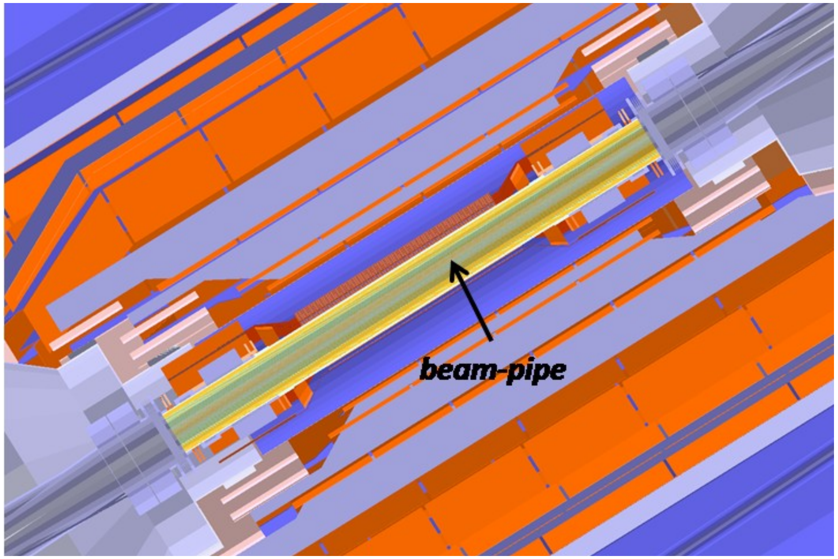


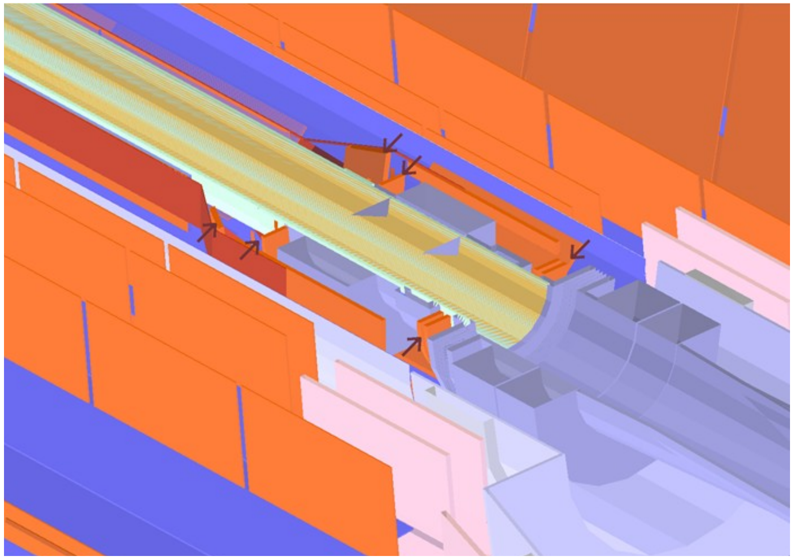
Tube
r=12 mm
R=18 mm
Sc=1 mm
Area=565.49 mm2

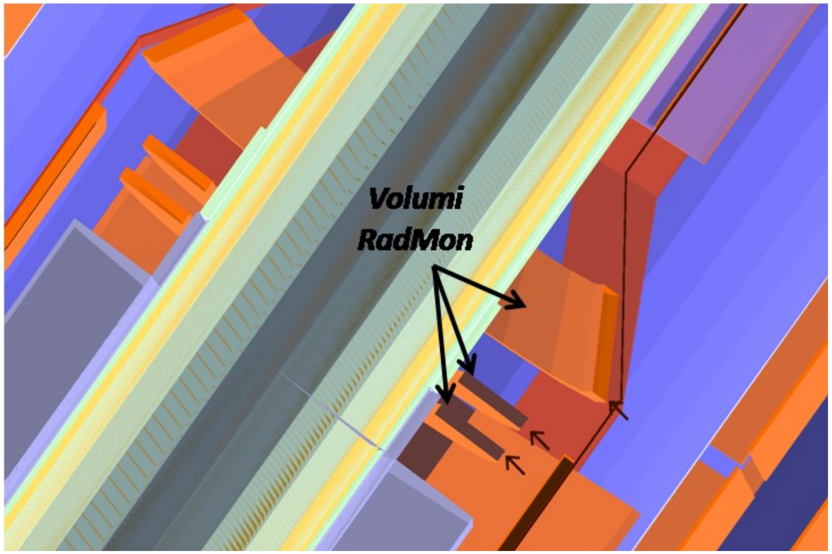
Polycone
r1=16.8 mm
R1=18.2 mm
r2=20.8 mm
R2=22.2 mm
L=7 mm
Sp=1.4 mm
Volume=3431 mm3

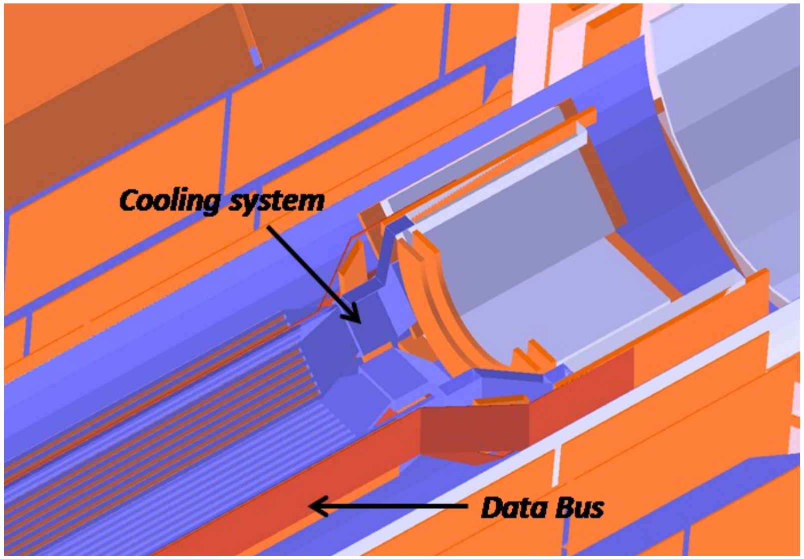
Only very limited space availability in the region we are interested in. Had to devise some general shapes, as small as possible, to optimize limited clearances between existing components

Implementation

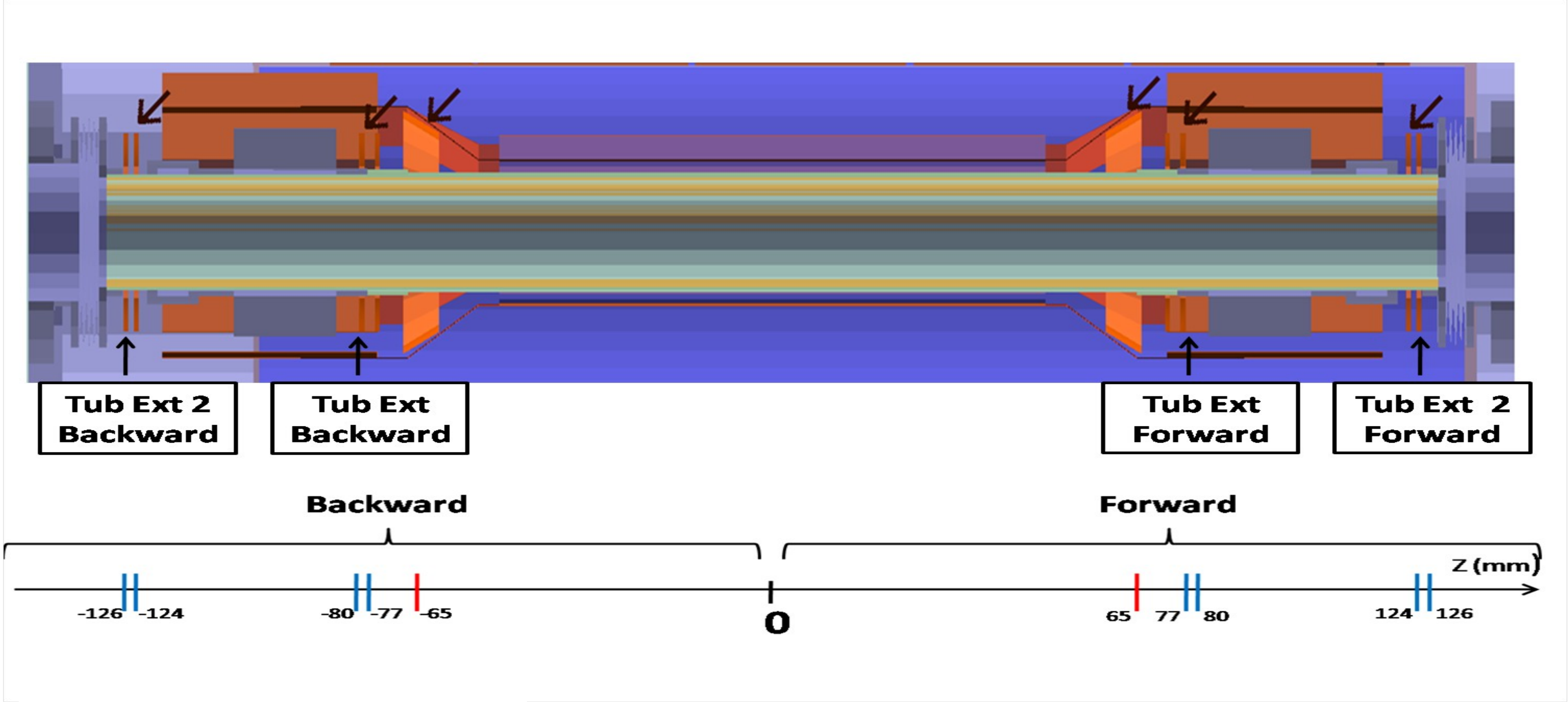








Implementation



Simulation

- Studies done on 130k RadBhabha events (largest cross section)
  - Home-made, following A. Perez's prescriptions for official-like production
  - Plan to use officially produced data asap, including more background sources
- Analysis is presently limited to feasibility studies
  - Hit rates
  - Deposited energy
  - Arrival times
  - Using R. Cenci's instructions for dose evaluation on electronics
- Will present here some preliminary results, on the ring-like volumes

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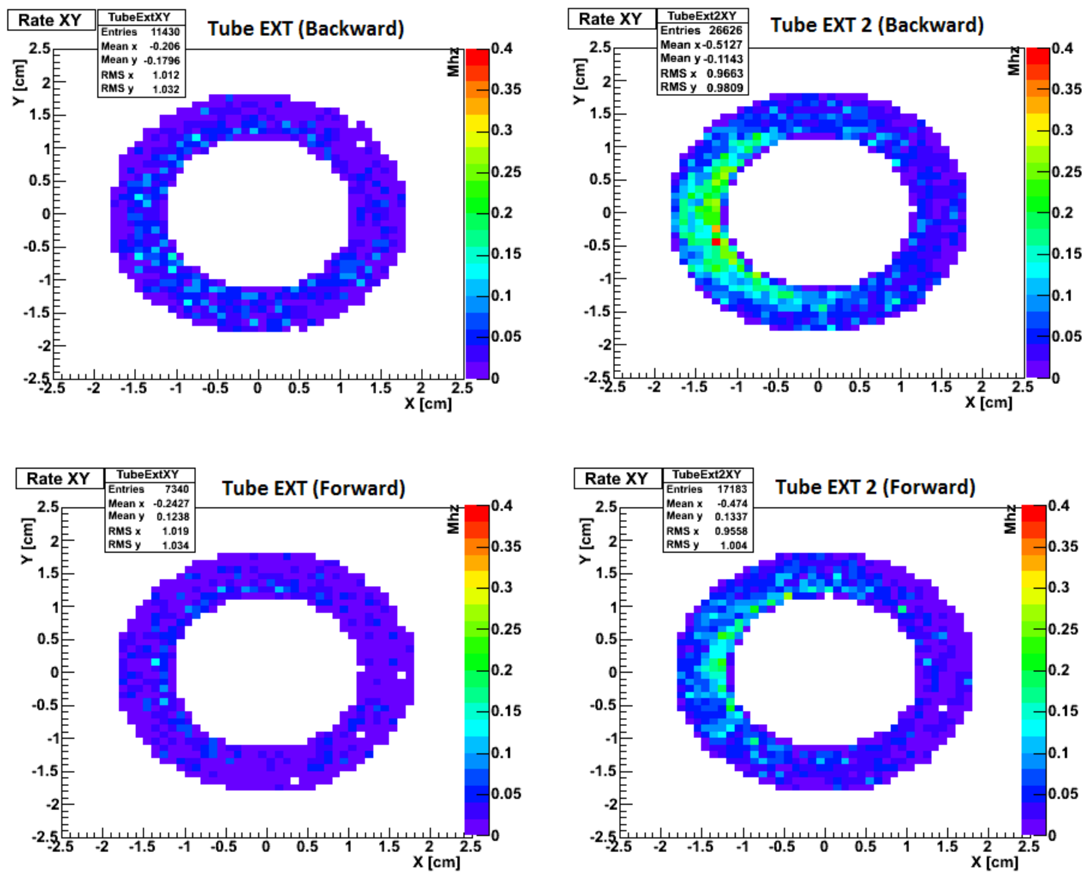
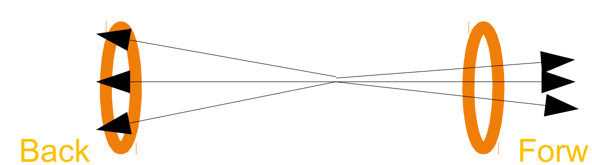
Hit rates



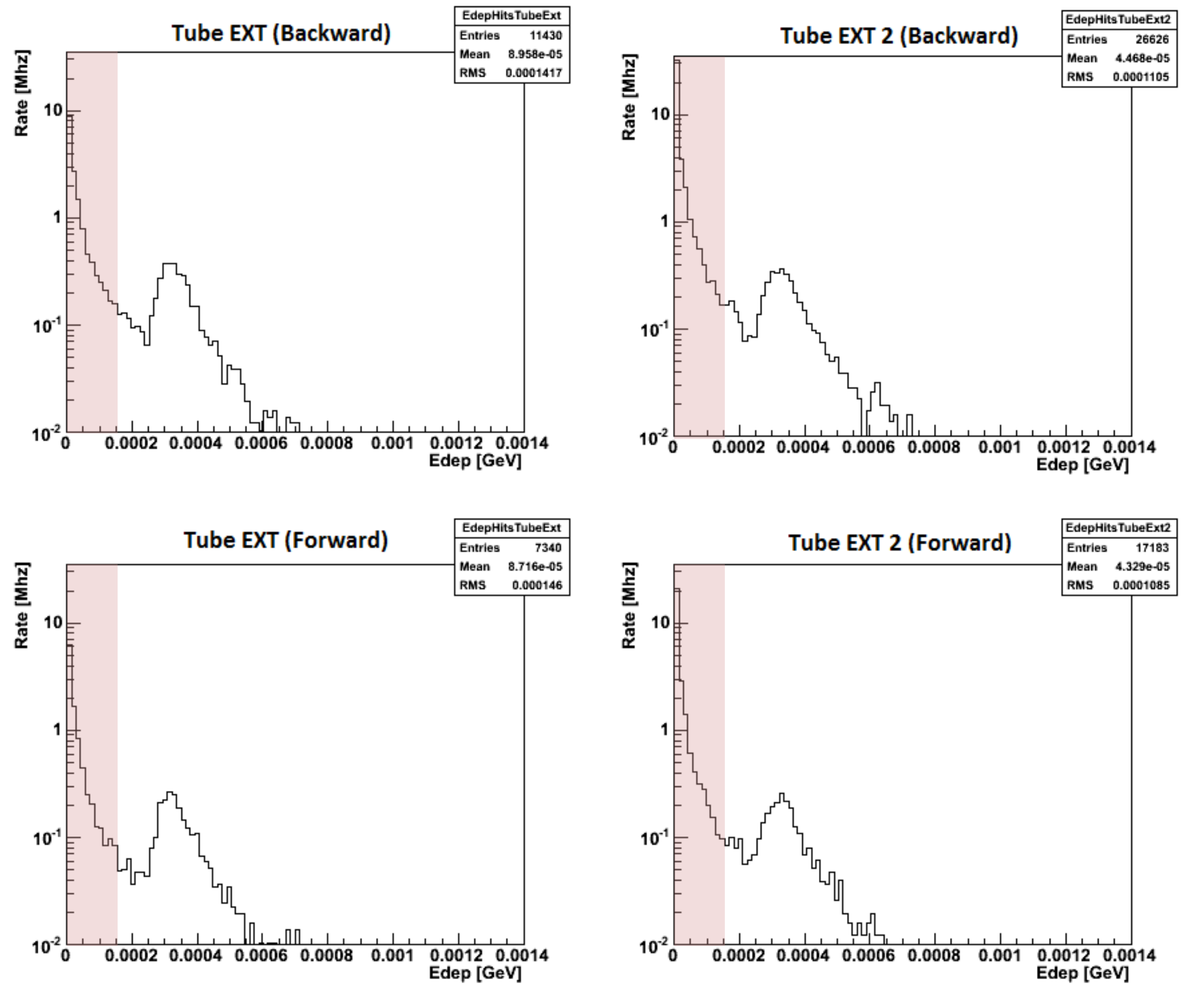
- Plot shows global hit rates, integrated in time, edep, particle type
  - Left: layer closer to IP
  - Right: layer farther from IP
  - Top: backward
  - Bottom: Forward
- Bin size is 1mmx1mm
  - Note that most of this rate comes from very-low-energy particles, hence it would not map directly to occupancy

- In general, bwd volumes more populated
  - Probably an effect of the boost
- Points farther from IP have larger hit rate
  - Under investigation. Possible correlation with proximity of some dead material

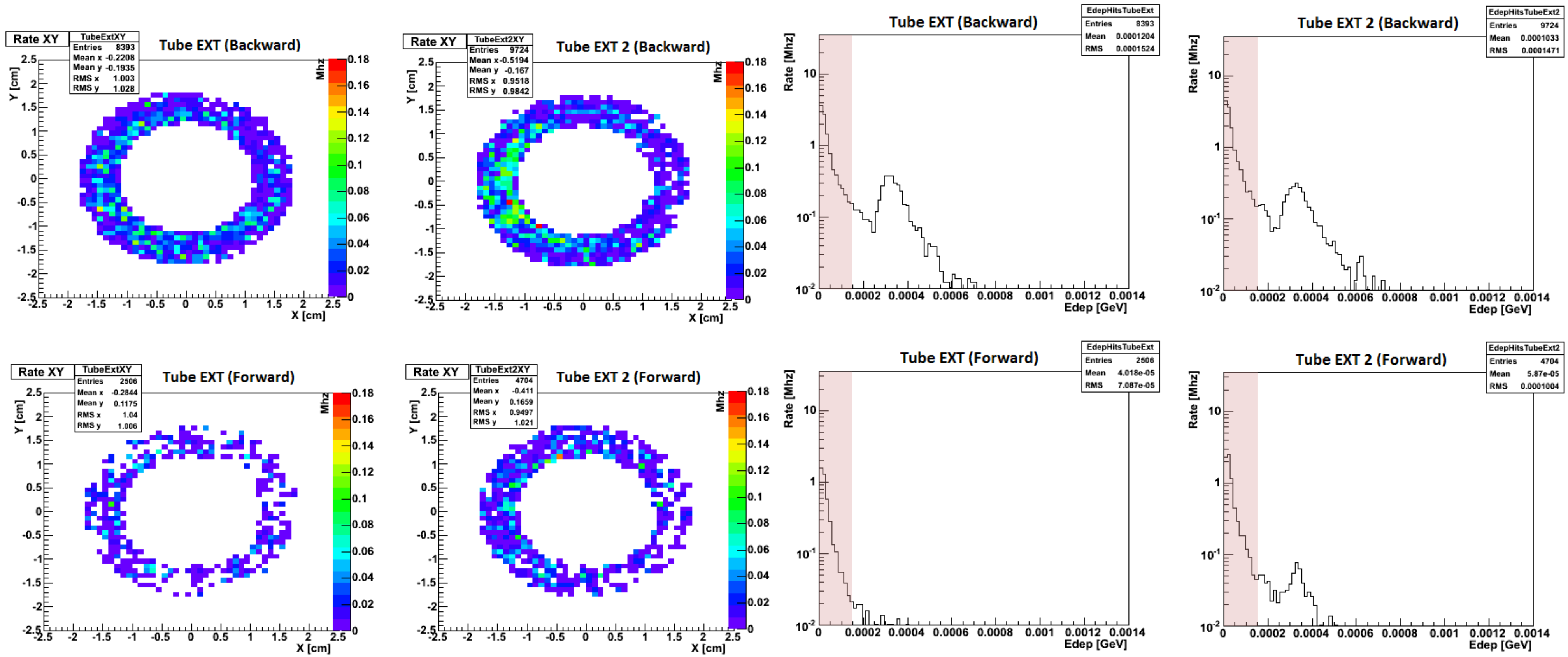


Energy depositions

- Plot shows the expected rate, in bins of deposited energy
- Red band shows zone where a typical diamond-based sensor is NOT sensitive
- Small peaks at larger energies correspond to MIPs

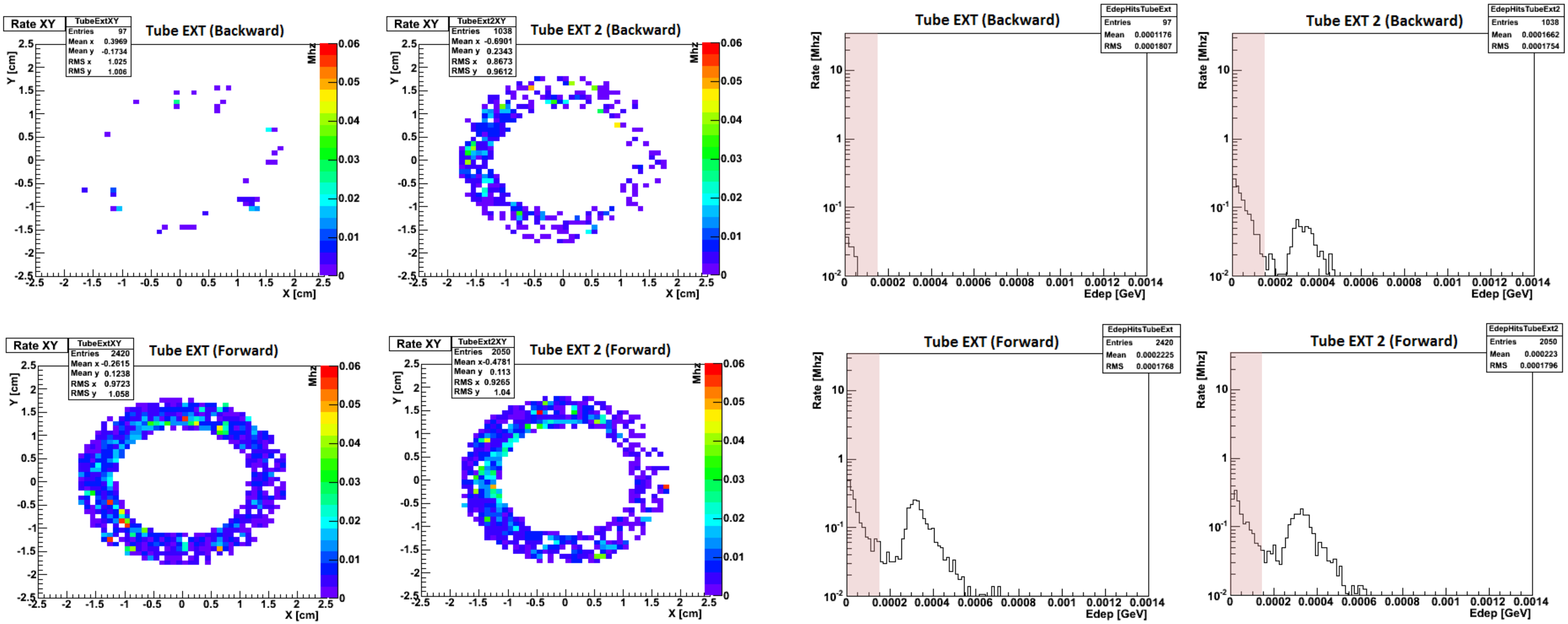


Results - electrons



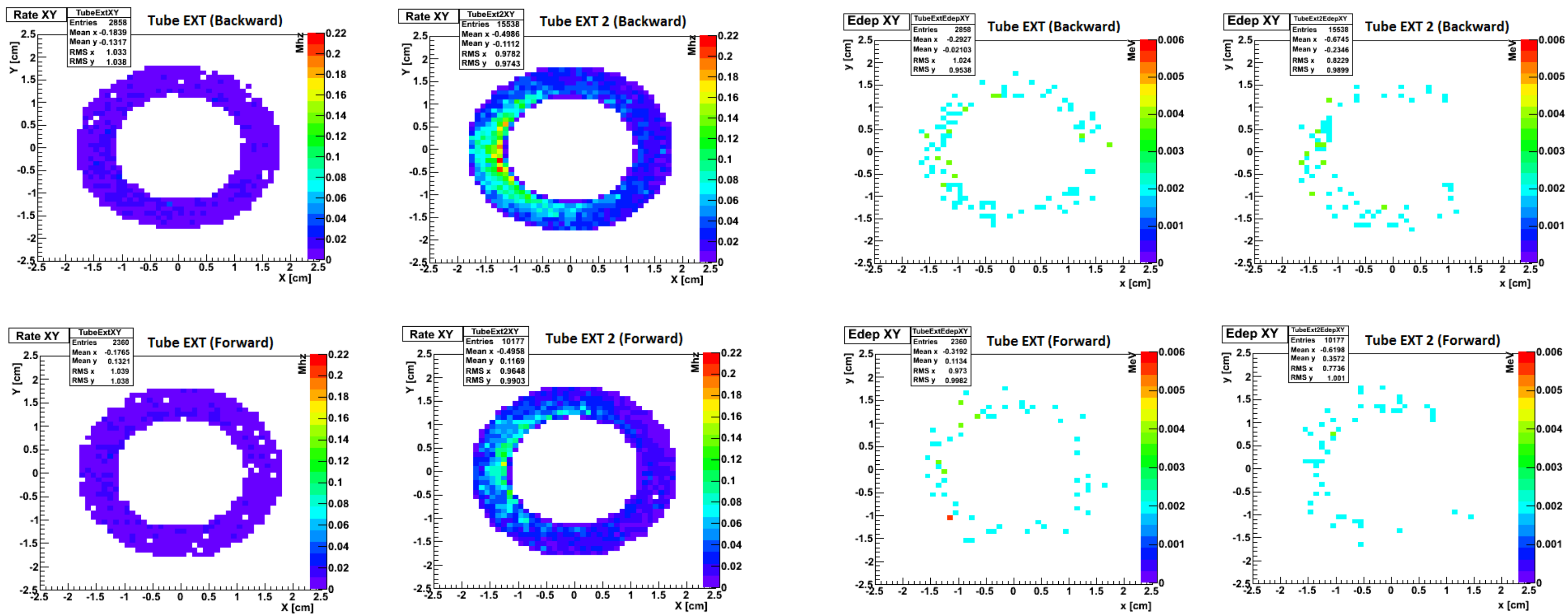
- Similar features as already seen in the global plots
- Note bwd volumes more populated, as expected by machine configuration

Results - positrons



- Specular wrt electrons.
  - Overall less populated, probably due to the boost

Results - photons



- Most of the observed rate comes from photons
  - Which, however, are all of very low energy, hence mostly undetectable

Results

All particles	Rate (MHz)	Edep/sec (GeV/s)	nHits/Event	Edep/Hit (GeV)	Rate/mm2 (MHz/mm2)	Z (mm)	% Hits (>150KeV)
Tube Ext (Back)	19.9	1780	0.09	9.0x10-5	0.035	-80	22%
Tube Ext 2 (Back)	46.4	2080	0.20	4.5x10-5	0.082	-126	10%
Tube Ext (Forw)	12.8	1115	0.06	8.7x10-5	0.023	80	21%
Tube Ext 2 (Forw)	30.0	1305	0.13	4.3x10-5	0.053	126	10%

	Rate all (MHz)	**Rate Electrons (MHz)**	**Rate Positrons (MHz)**	**Rate photons (MHz)**	**Rate others (MHz)**
Tube Ext (Back)	19.9	14.6	0.2	5.0	~0.1
Tube Ext 2 (Back)	46.4	17.0	1.8	27.1	~0.5
Tube Ext (Forw)	12.8	4.4	4.2	4.1	~0.1
Tube Ext 2 (Forw)	30.0	8.2	3.6	17.8	~0.5

Impact on detector design

- We can use rate information to calculate the expected current with beam operation
- Let's focus on a particular technology
  - Diamond
- Ingredients are
  - Average energy deposition (worst case 2080GeV/s)
  - Area (565mm2)
  - Threshold for pair production in diamond (~14eV)

$$\frac{2080}{565} \times 10^9 \frac{eV}{s \cdot mm^2} = 3.68 \times 10^9 \frac{eV}{s \cdot mm^2}$$ Edep/s/mm2

$$\frac{3.68}{14eV} \times 10^9 \frac{eV}{s \cdot mm^2} = 0.26 \times \frac{10^9}{s \cdot mm^2}$$ #electrons/s/mm2

$$0.26 \times \frac{10^9}{s \cdot mm^2} \cdot 1.6 \times 10^{-19} C = 0.420 \times 10^{-10} \frac{A}{mm^2}$$ current/mm2

For a 16mm2 sensor one gets a “beam-on” current of **6.7×10^{-10} A**

Impact on detector design

- The "beam-on" current must be compared with the leakage current (i.e. the "beam-off" current)
- The latter can be easily calculated from Ohm's law
  - Resistivity of 10^{11}Ohmcm @ 500V

$$\rho = 10^{11}\Omega \cdot cm \rightarrow R = \rho\frac{l}{S} = 10^{11}\Omega \cdot cm\frac{0.1cm}{0.01cm^2} = 10^{12}\Omega$$

Sensor resistance (per mm2)

$$I = \frac{V}{R} = \frac{500V}{10^{12}\Omega} = 0.5 \times 10^{-9} = 0.5nA$$

Sensor current (per mm2)

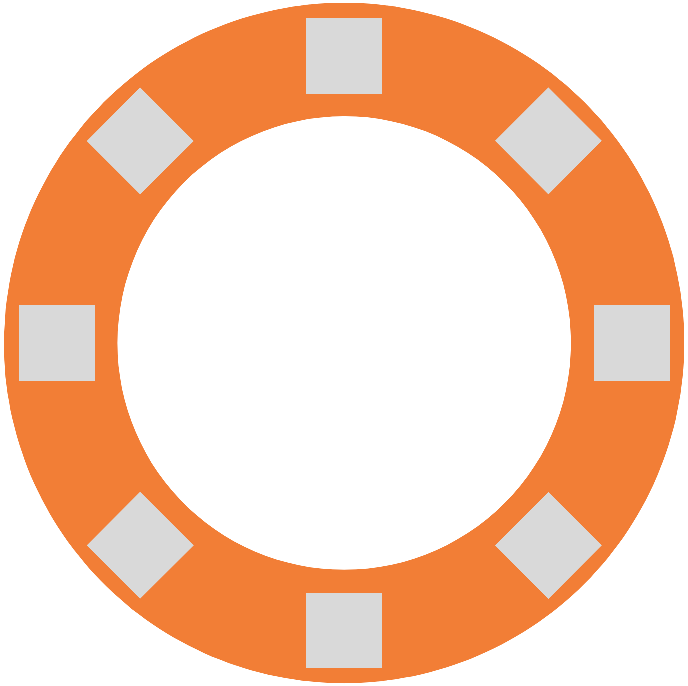
  - This corresponds to 8nA on a 16mm2 sensor, i.e. about 10 times larger than the "beam-on" current

Counting single hits

- Apart from measuring the current, would we be able to count the hit rate?
  - Collection time: 20ns
  - Integration time of the readout: 30ns
  - Readout threshold: 150keV
- The “hottest” volume has a hit rate of 82kHz/mm2, which means 1.3MHz on a 16mm2 sensor
  - Once the 150keV threshold is taken into account this drops to 130kHz
    - Average time distance between hits is 8us

Detector summary

Sensor dimensions	8 X16 mm2
Leakage current per sensor	8nA
“Beam on” current per sensor	0.67nA
Hit rate per sensor	130KHz
Collection time	20 ns
Integration time	30 ns
Sensor resistivity	10^{11} Ωcm
Detection threshold	150KeV



Conclusions

- Very first simulation of radiation monitor has provided a wealth of valuable information
  - Much more than we can digest in such a short time...
  - Discussion ongoing with detector/electronics experts on how to use these results to drive the technological choices
- Must look at more background events
- Must understand the source of the particles
  - Primaries? Secondaries?
- We will be able to do much more than just measuring current
  - Hit rates will most likely be measurable
  - What about coincidences? TOF?
- Must update the studies using more up-to-date geometry description

Backup

Results

Electrons	Rate (MHz)	Edep/sec (GeV/s)	nHits/Event	Edep/Hit (GeV)	Rate/mm2 (MHz/mm2)	Z (mm)
Tube Ext (Back)	14.6	1760	0.06	1.2x10-4	0.026	-80
Tube Ext 2 (Back)	17.0	1750	0.07	1.0x10-4	0.030	-126
Tube Ext (Forw)	4.4	175	0.02	0.4x10-4	0.008	80
Tube Ext 2 (Forw)	8.2	480	0.04	0.6x10-4	0.015	126

Positrons	Rate (MHz)	Edep/sec (GeV/s)	nHits/Event	Edep/Hit (GeV)	Rate/mm2 (MHz/mm2)	Z (mm)
Tube Ext (Back)	0.2	20	0.001	1.1x10-4	3.5x10-4	-80
Tube Ext 2 (Back)	1.8	300	0.008	1.7x10-4	0.003	-126
Tube Ext (Forw)	4.2	940	0.018	2.2x10-4	0.007	80
Tube Ext 2 (Forw)	3.6	795	0.016	2.2x10-4	0.006	126

Photons	Rate (MHz)	Edep/sec (GeV/s)	nHits/Event	Edep/Hit (GeV)	Rate/mm2 (MHz/mm2)	Z (mm)
Tube Ext (Back)	5.0	0.35	0.02	7.2x10-8	0.009	-80
Tube Ext 2 (Back)	27.1	0.24	0.12	0.9x10-8	0.048	-126
Tube Ext (Forw)	4.1	0.19	0.02	4.8x10-8	0.007	80
Tube Ext 2 (Forw)	17.8	0.16	0.08	0.9x10-8	0.031	126