BEAM-RELATED BACKGROUND STUDIES FOR THE EIC INTERACTION REGION

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Exploring the Nature of Matter

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GENERIC DETECTOR R&D FOR AN ELECTRON ION COLLIDER

eRD21 Participants

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6.	Mike Sullivan:	SLAC physics
7.	Yulia Furletova:	JLab physics
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12.	Nick Markov:	JLab physics
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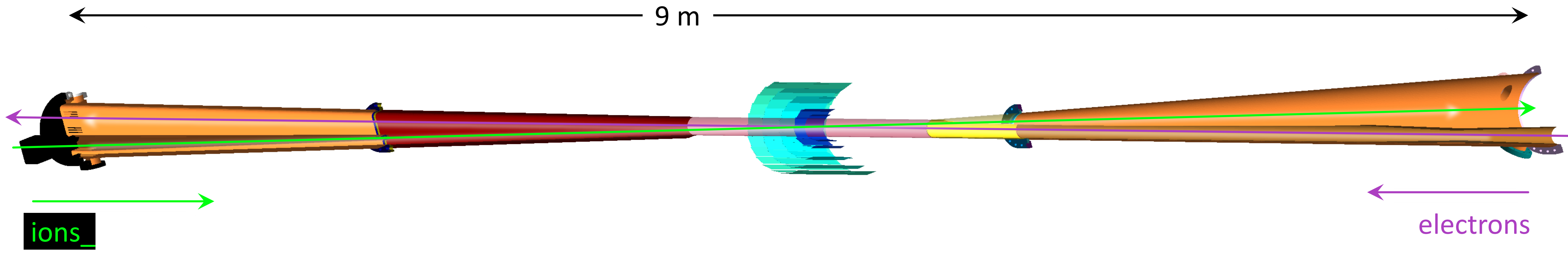
14.	Pavel Degtiarenko:	JLab RadCon
15.	Frank Marhauser:	JLab RF
16.	Alexander Kiselev:	BNL Physics

* partially funded by eRD21 project

METHODOLOGY & GOALS

- Synchrotron Radiation impact on central detector
  - X-rays generated by SYNRAD (CERN) code, propagated through IP:
    - Fun4All EIC framework (Jin Huang, BNL)
    - custom GEANT4 model (C.Ploen, A.Kim)
  - X-rays generated by Sync_Bgd (SLAC) code and propagated through IP with same custom GEANT4
- Ion Beam ⊗ Residual gas interactions
  - Direct and cascading secondaries computed in FLUKA
  - Full propagation through beamline magnets, tunnel, walls, detector
- Calibrate any concerns regarding component lifetimes
- Longer term goal to quantify detector occupancy from background hits.

SYNCHROTRON PHOTONS IN EIC IR1

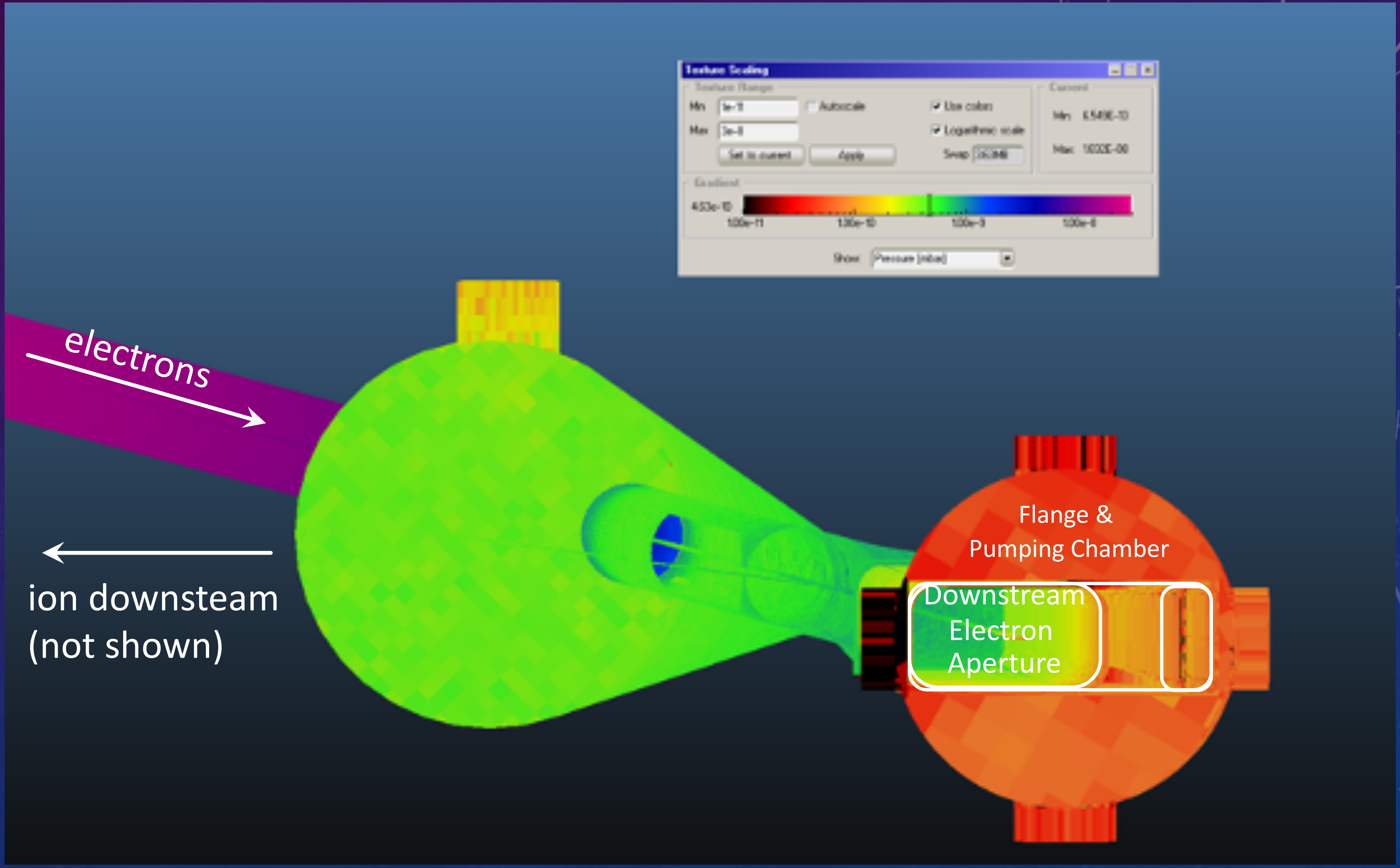


- GEANT4 stand-alone Model of IP
- Extension in progress to include full beamline, Dipole-upstream to Dipole-downstream

STATIC VACUUM CALCULATION (MOLFLOW)

M. STUTZMAN (JLAB)

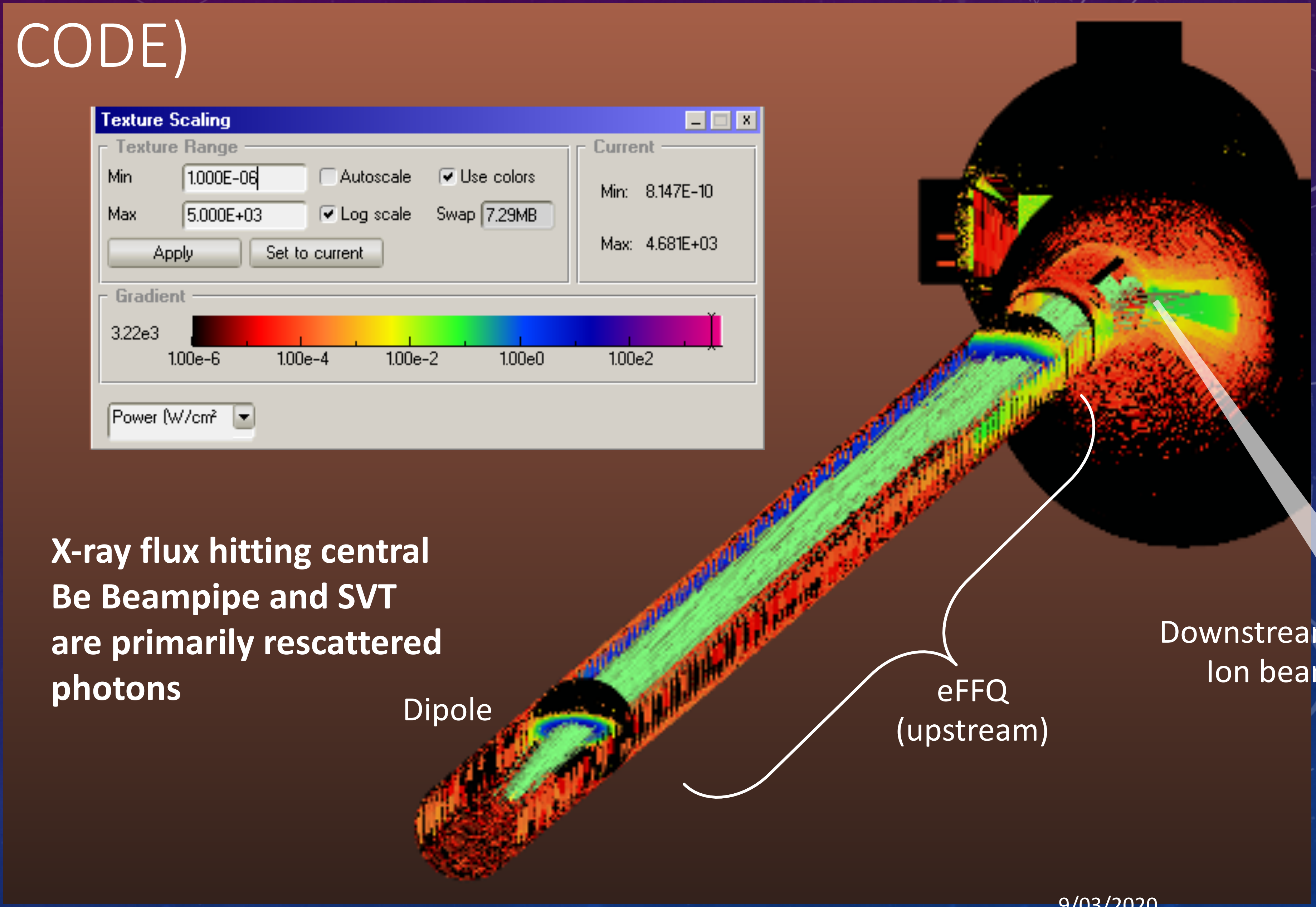
- Pumping at ~±5m achieves 10^{-9} mBar in IP.
- Calculations of synchrotron radiation induced desorption pending.



SYNRAD (CERN CODE)

M. STUTZMAN, C.HETZEL

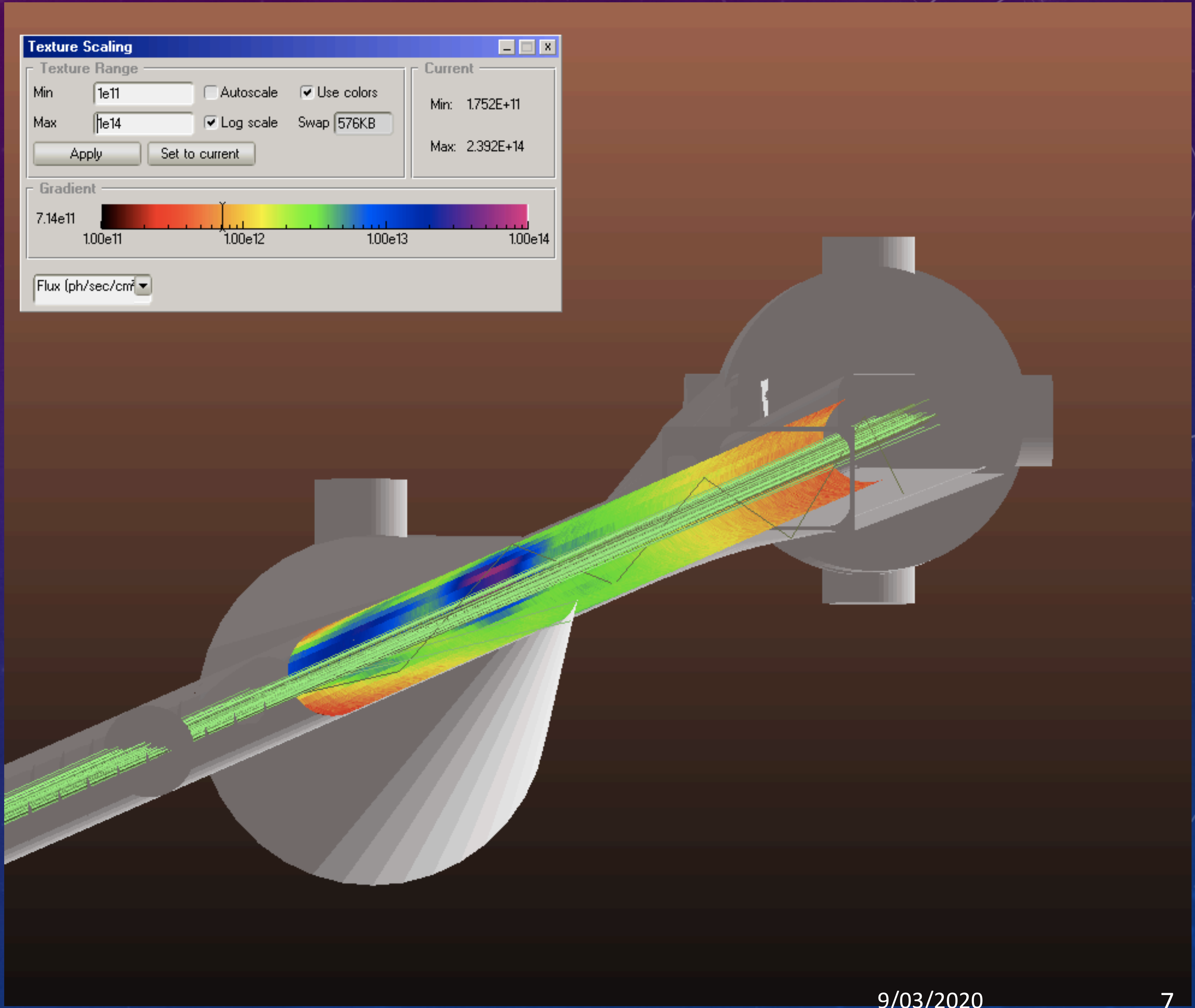
- **Sawtooth beam pipe reduces scattering from walls**
- **Virtual planes at exit of Dipole and FFQ visualize Flux**
- **Photon flux imported into Fun4All simulation by Jin Huang (BNL).**
- **Smooth absorber at entrance to IP beampipe creates strong scattering**
    - **Design of sawtooth absorber in progress**



X-ray flux hitting central Be Beampipe and SVT are primarily rescattered photons

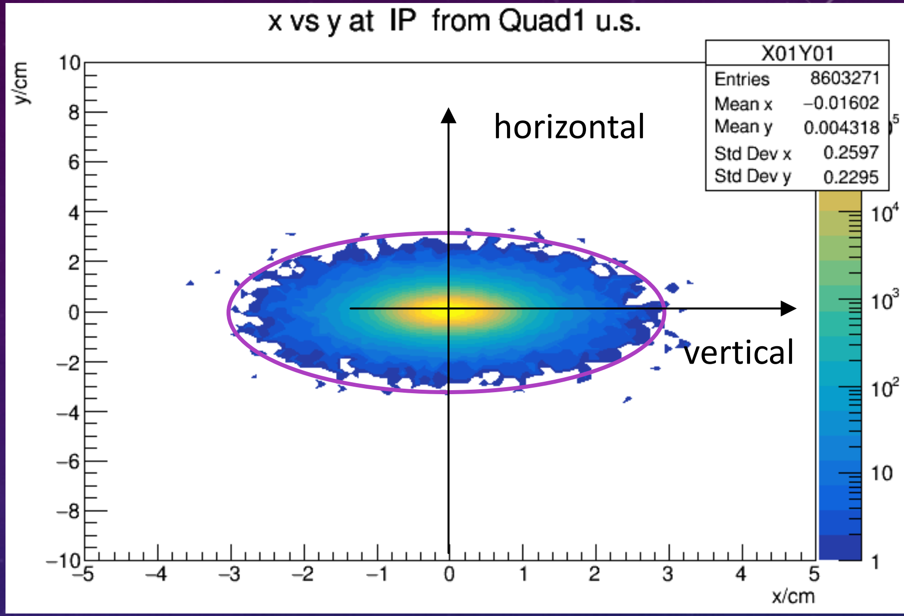
SYNRAD FLUX IN CENTRAL REGION

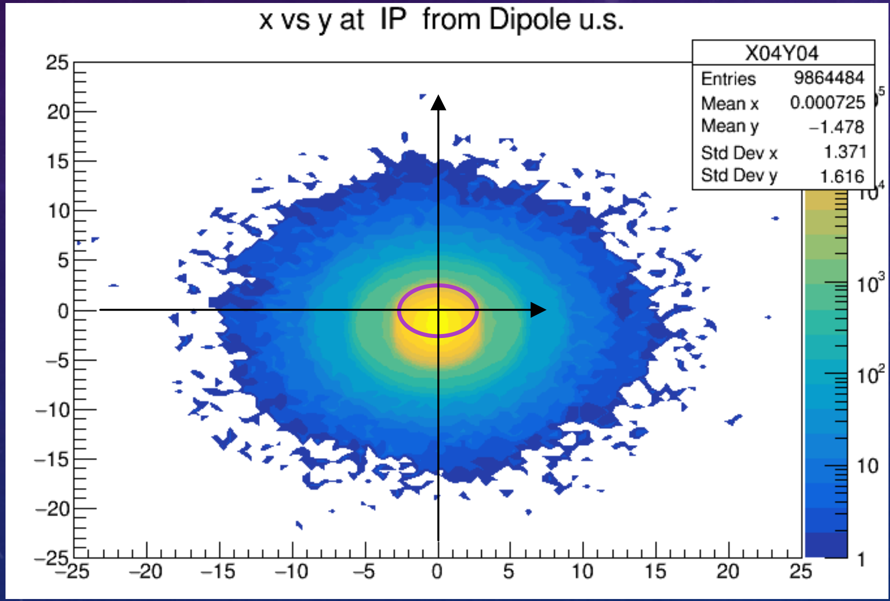
- Hot spots induced by scattering from “photon absorber” at entrance to common pipe.
- Only photons passing through virtual cylinder are passed through to Fun4All or GEANT4 simulation
  - Reduces computation by ~10^5

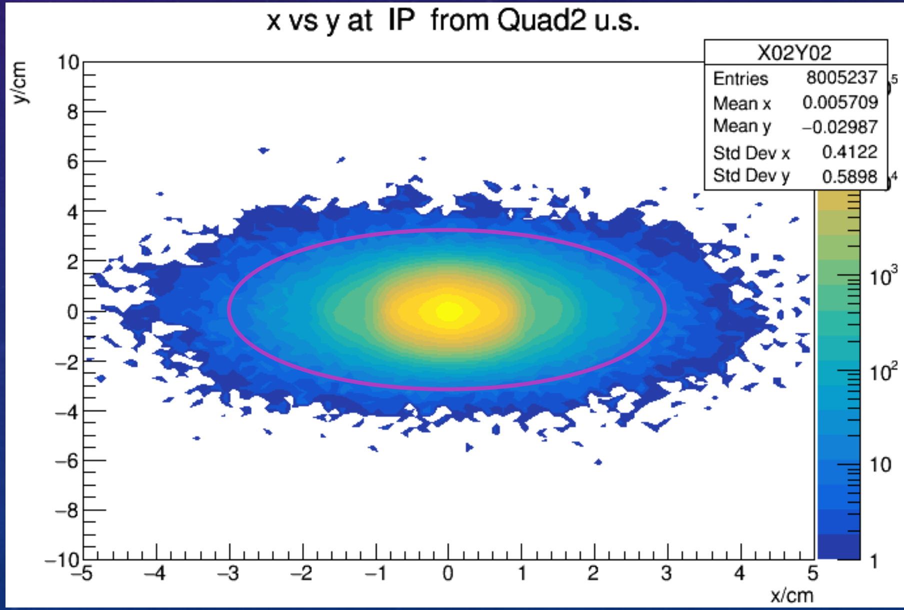


STATUS OF SYNC_RAD PHOTON FLUX CALCULATIONS

- Updated July electron IR1 optics
- Updated BELLE-II beam halo
- Full angular spread of emission
- Propagation through IP in progress







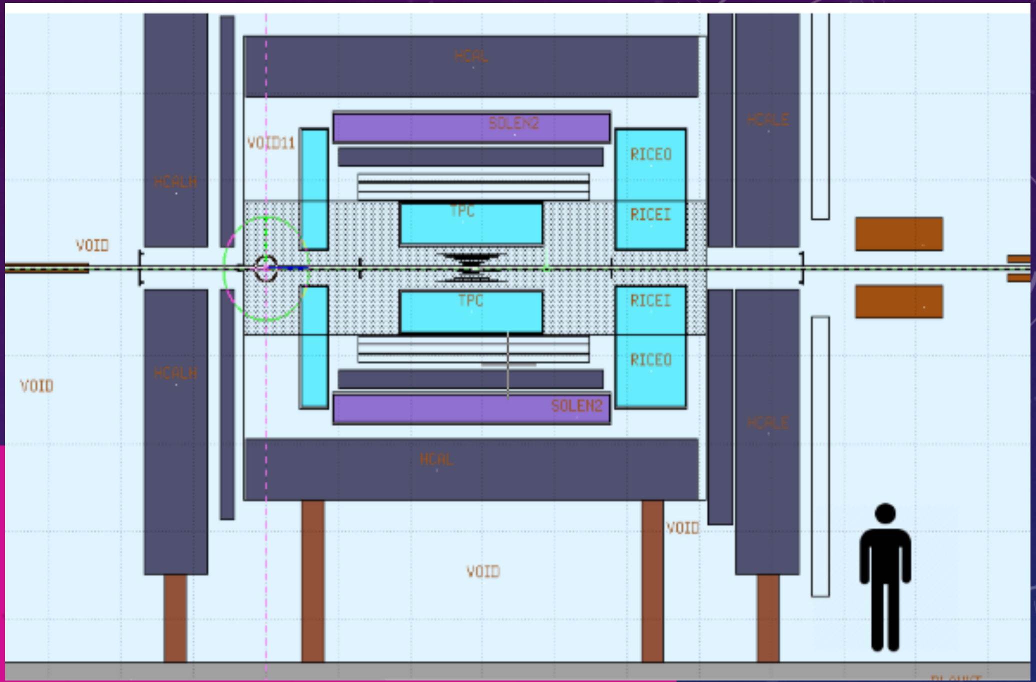
STATUS OF SYNCHROTRON STUDIES

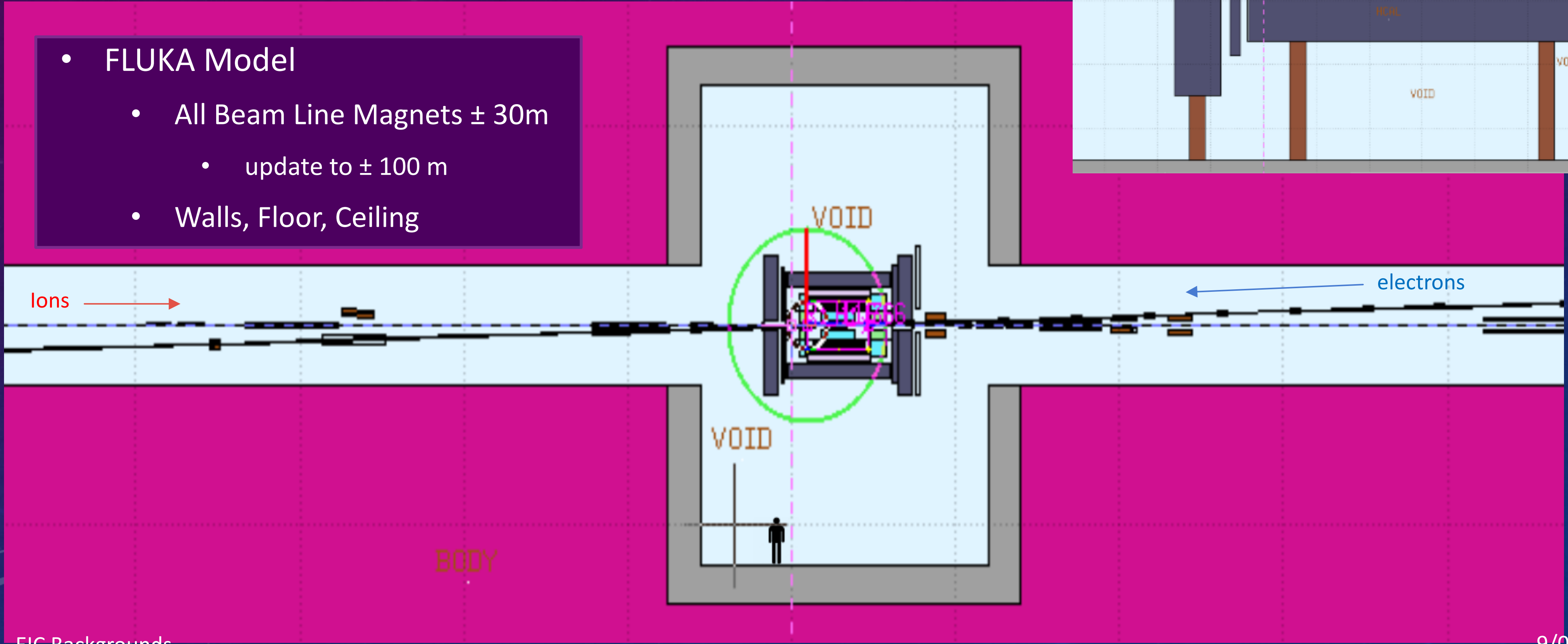
- The problem is very dynamic:
  - Monthly updates to magnetic optics
  - Monthly updates to electron beam halo estimates, based on BELLE-II experience (Mike Sullivan, SLAC)
  - Active revision of Beampipe and Photon collimator design (upstream and downstream) in progress at BNL
- Working hard to keep up-to-date with design status, cross-reference different simulation approaches
  - SYNRAD+fun4all *vs.* Sync_rad + GEANT4
  - Absolute normalization of flux is still a work-in-progress

BEAM GAS INTERACTIONS

V. Baturin, et al.

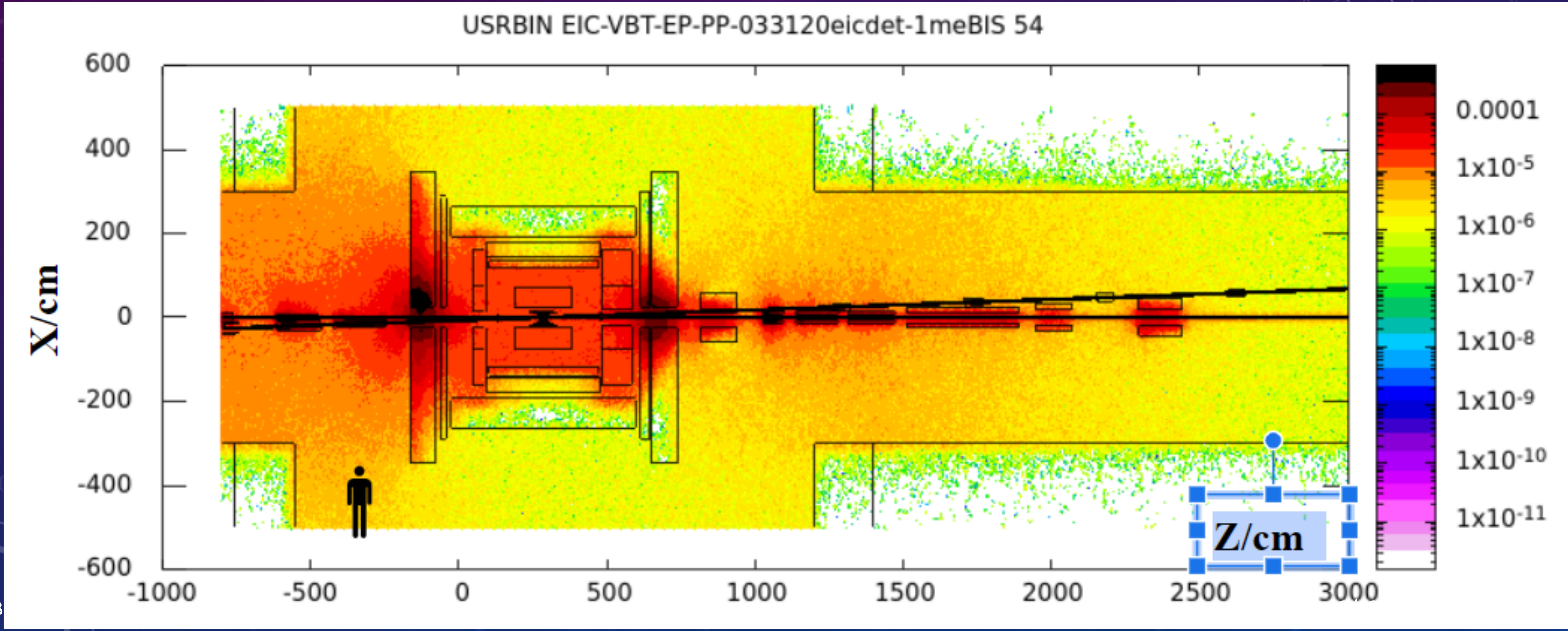
- FLUKA Model
  - All Beam Line Magnets ± 30m
    - update to ± 100 m
  - Walls, Floor, Ceiling





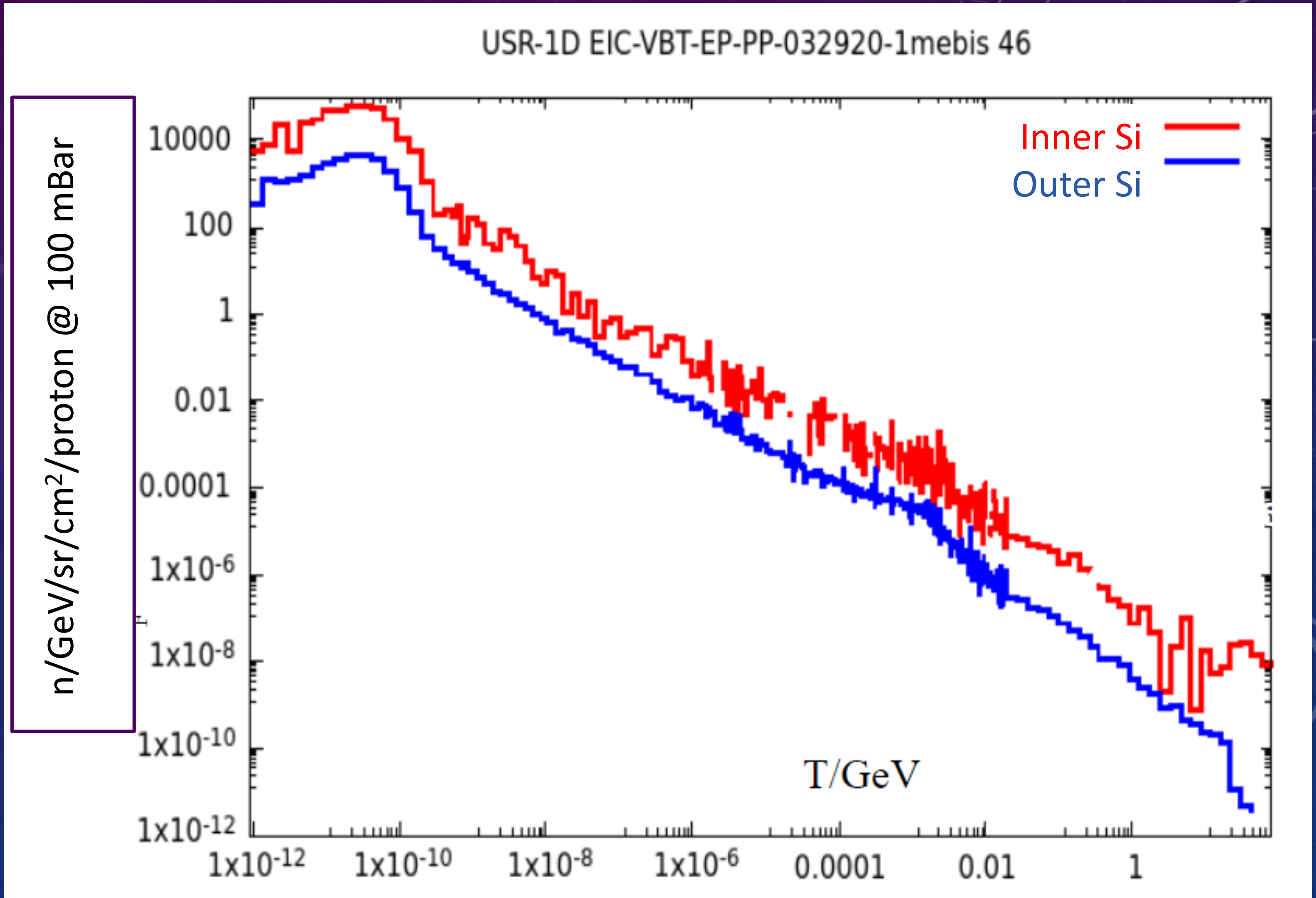
NEUTRON FLUENCE,
275 GEV PROTONS INCIDENT

Color scale is
Neutrons/cm²/proton @ 100 mBar Air
Scale by 6.25•10⁷/sec for
n/cm²/sec for 1 Amp protons @ 10⁻⁹ mBar



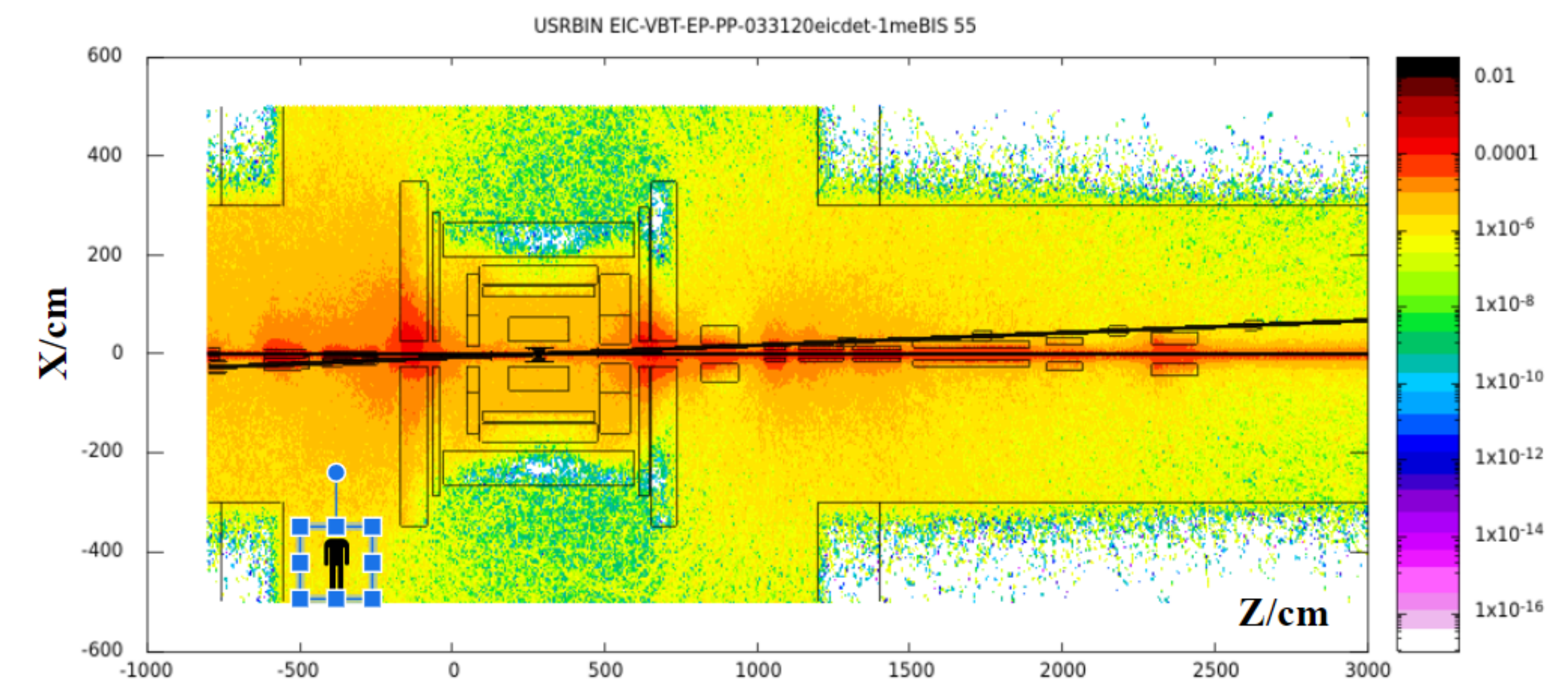
NEUTRON SPECTRA

- Illustrates extensive "thermalization" by FLUKA in 30 m propagation to IP



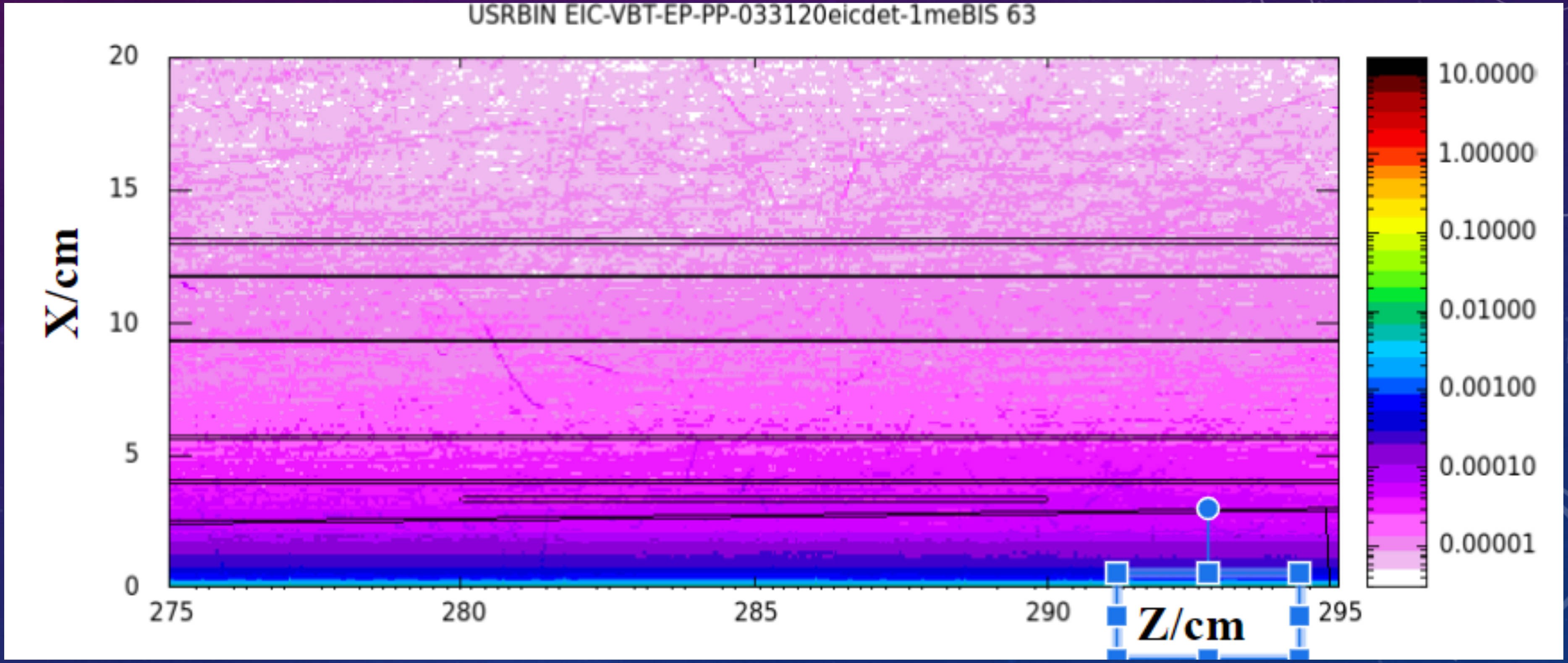
EQUIVALENT 1 MEV NEUTRON FLUENCE

- **Equivalent n/cm² per proton @ 100 mbar Air**
- **Scale by 6.25•10⁷/sec for 1 Amp beam and 10⁻⁹ mBar vacuum**



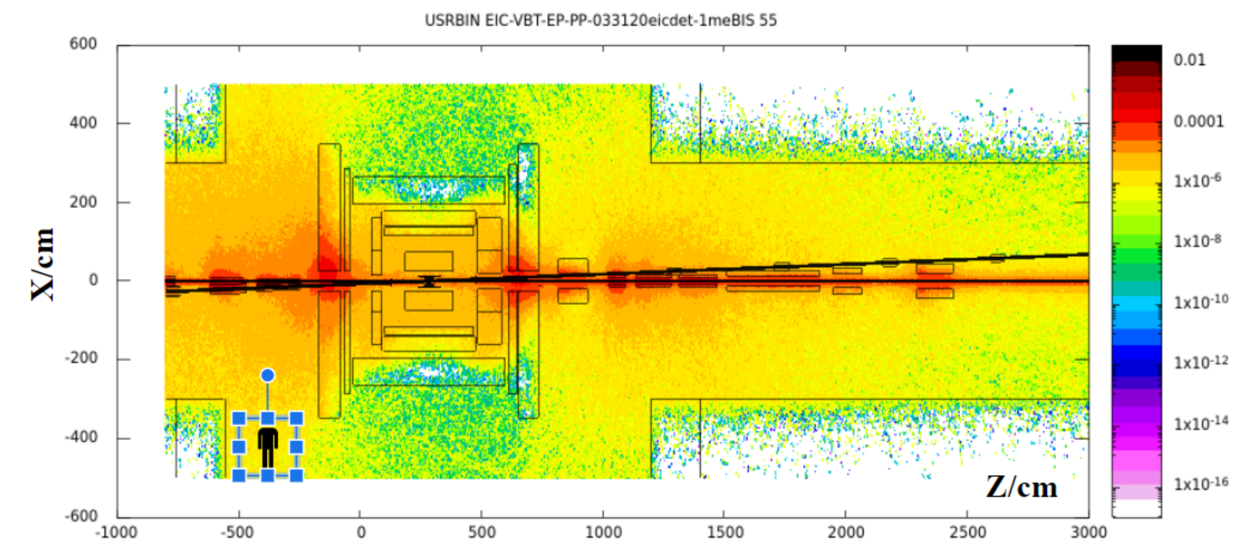
Si VERTEX TRACKER: EQUIVALENT 1MEV NEUTRON FLUENCE

- **Equivalent 1 MeV n/cm²/proton @ 100 mbar**
- **Scale by $6.25 \bullet 10^{7}$/sec for 1 Amp beam and 10^{-9} mBar vacuum**
- **1 year = 10^{7} sec: Deep magenta color (inner most Si layer) ~ 10^{11} n/cm²/year**



EQUIVALENT NEUTRON FLUENCE SUMMARY

- Normalized to:
  - Residual gas pressure 1.e-9 mBar
  - 1 Year ➔ (1 Amp)(10^7 sec)
  - Rates scale with molecular mass of gas



Location	Color value	n/cm²/Year	n/cm²/Year (backup slide)
Residual Gas (at 10^{-9} mBar)		Air	95% H_2 + 5%CO_2
SVT	$1.6 \bullet 10^{-4}$	10^{11}	$6 \bullet 10^{9}$
Central Tracker, PID	10^{-5}	$6 \bullet 10^{10}$	
Forward beamline	10^{-4} — 10^{-3}	$6 \bullet 10^{10}$ — $6 \bullet 10^{11}$	

ONGOING BACKGROUND STUDIES

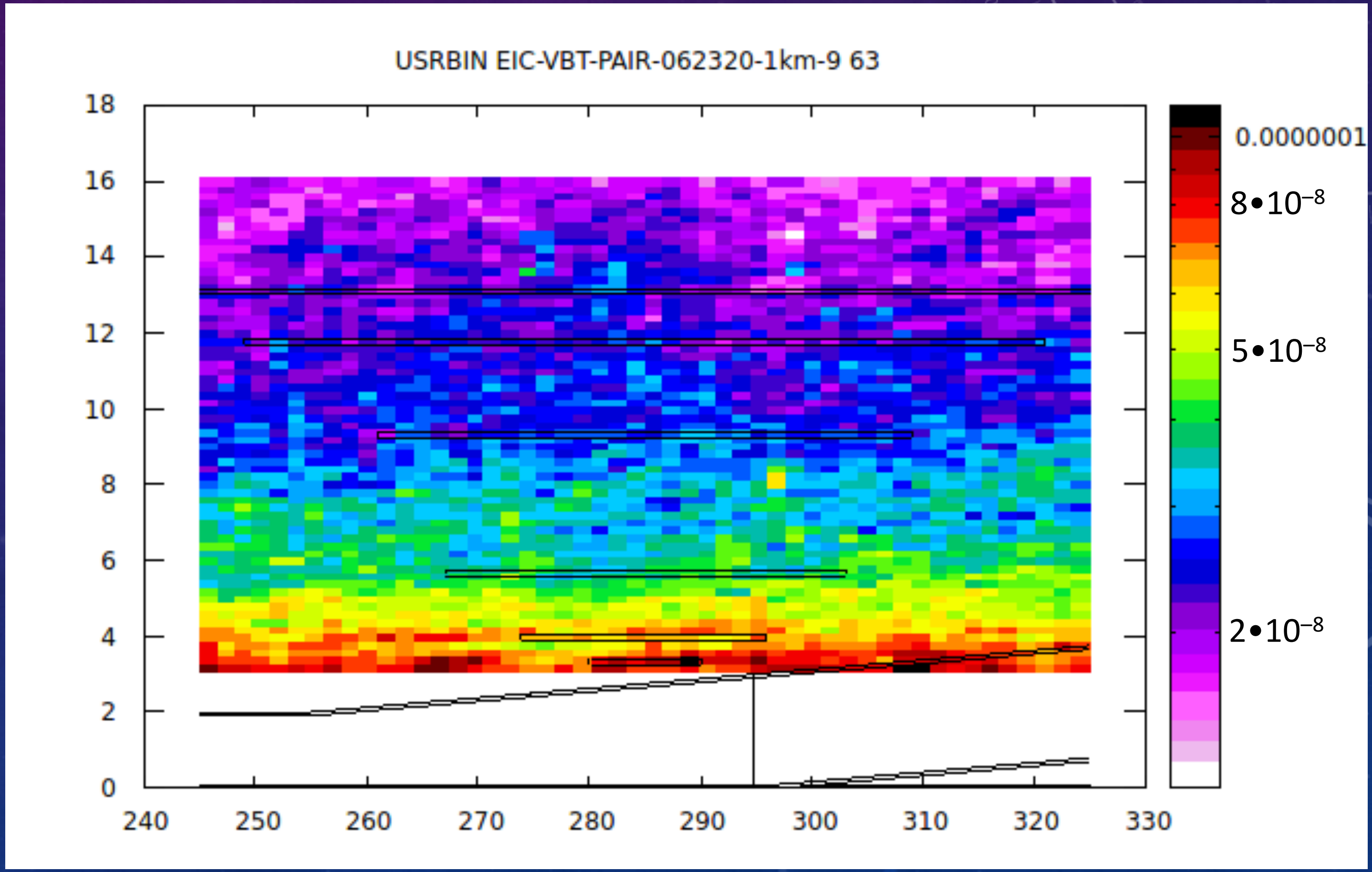
- Beam-Gas
  - Realistic vacuum profile
  - Energy spectra → Occupancy of key detectors
- Synchrotron:
  - Direct comparison of SYNRAD and Sync_Bgd photon generation and GEANT4 model and Fun4All hit rates and doses
  - Recalculate for expected iterations of IR design, upstream photon absorber
  - Implement IR2 concept, when available
- Occupancy of SVT and other key detectors

LOTS OF WORK STILL TO DO!

BACKUP SLIDES

BEAM-GAS INTERACTIONS WITH 95% H_2, 5% CO_2

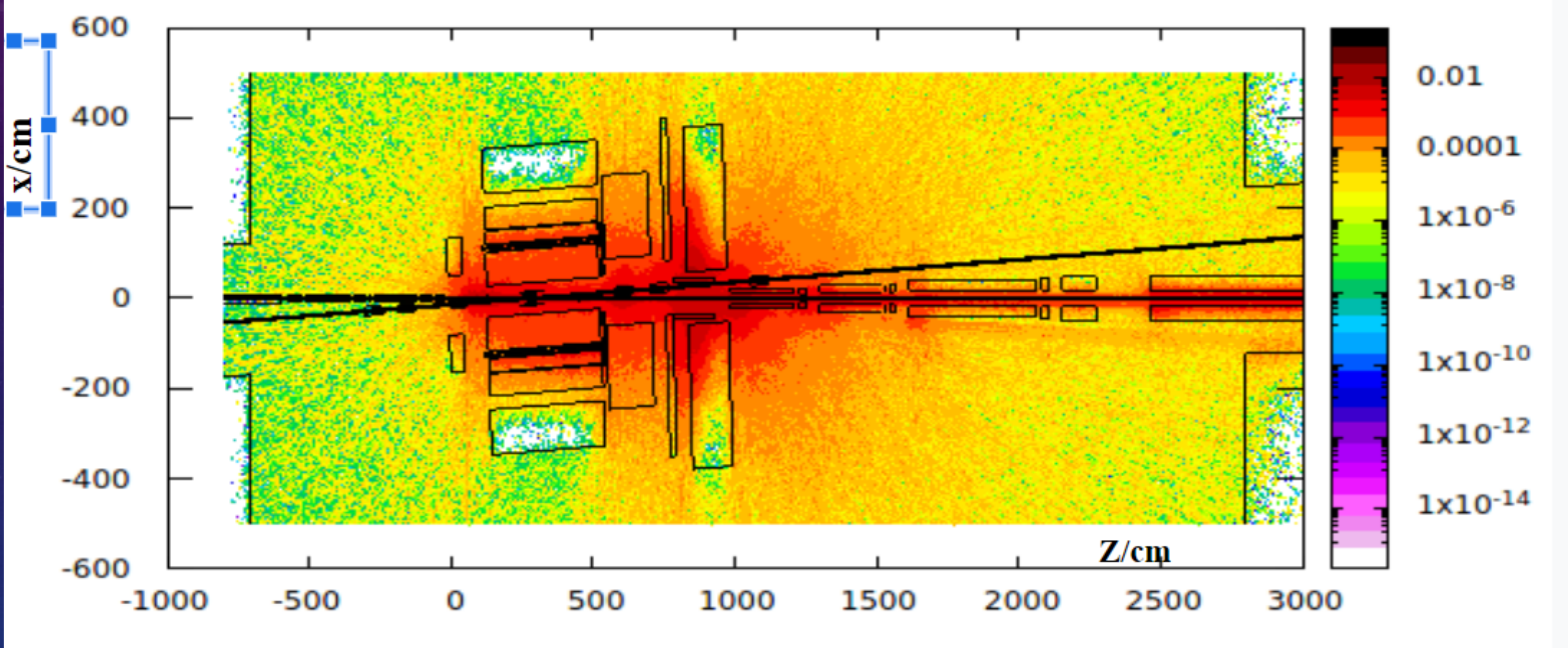
- Map of 1 MeV equivalent fluence in the SVT area in units of n/cm^2/proton/mBar.
- From the point (285cm,3.5cm) near the innermost SVT layer we read the fluence = $0.9 \bullet 10^{-7}$ n/cm^2/proton/mBar
- 570 n/cm^2 @ 1 Amp & 10^{-9} mBar
- $6 \bullet 10^9$ n/cm^2 /yr



BEAM LOSS ACCIDENT NEAR IP

1 MeV Equiv
n/cm^2/proton

- 100 GeV proton beam lost just upstream of IP
- Fluence to SVT ~ 0.02 n/cm^2/proton
- Stored beam = 8•10^{13} protons
- Total beam loss → 1.6•10^{12} n/cm^2
- 60 total beam loss events before destruction of SVT

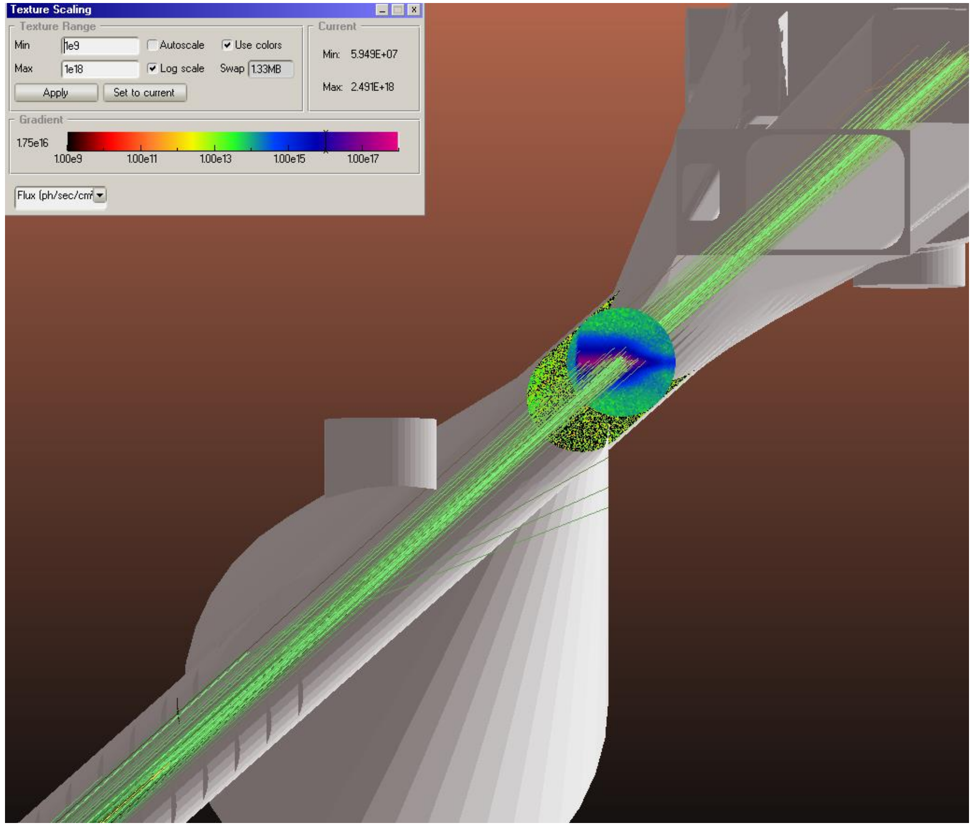


SYNRAD:

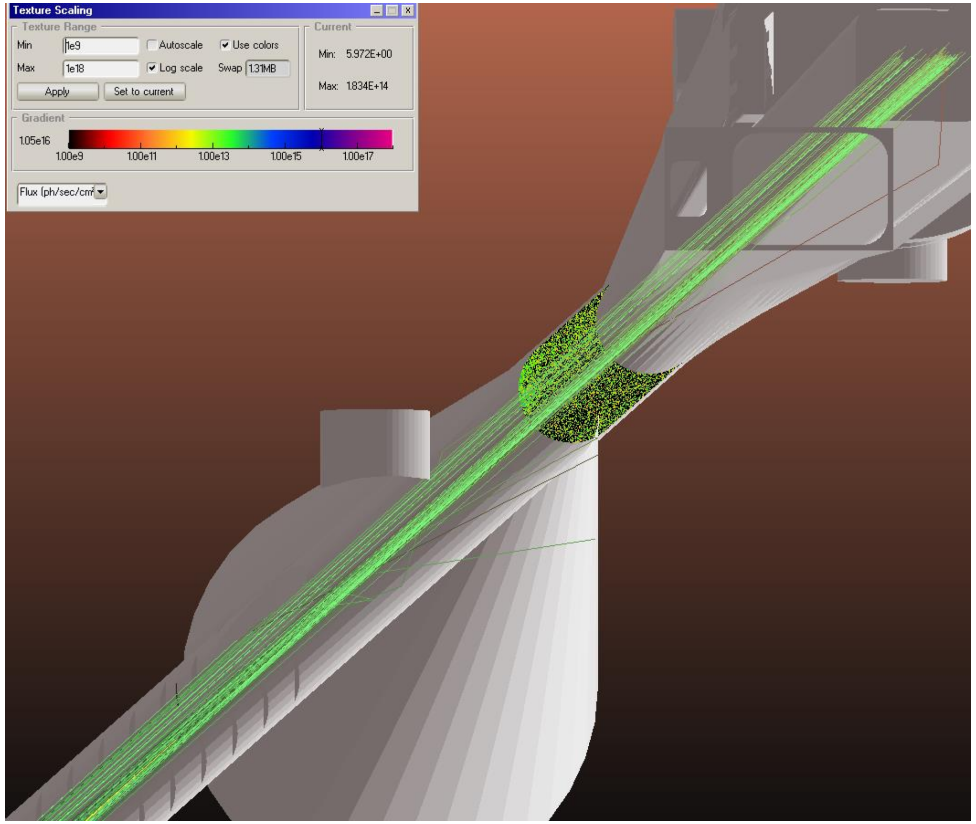
- Central flux through IP: $10^{18}\,\gamma/\mathrm{cm}^2/\mathrm{sec}$
- Peak flux striking Be pipe: $10^{13}\,\gamma/\,\mathrm{cm}^2/\mathrm{sec}$ in small horizontal band

Test plane normal to beam: 10^18 max flux.
Very small percentage of hits will hit Be

~1 per 10^5

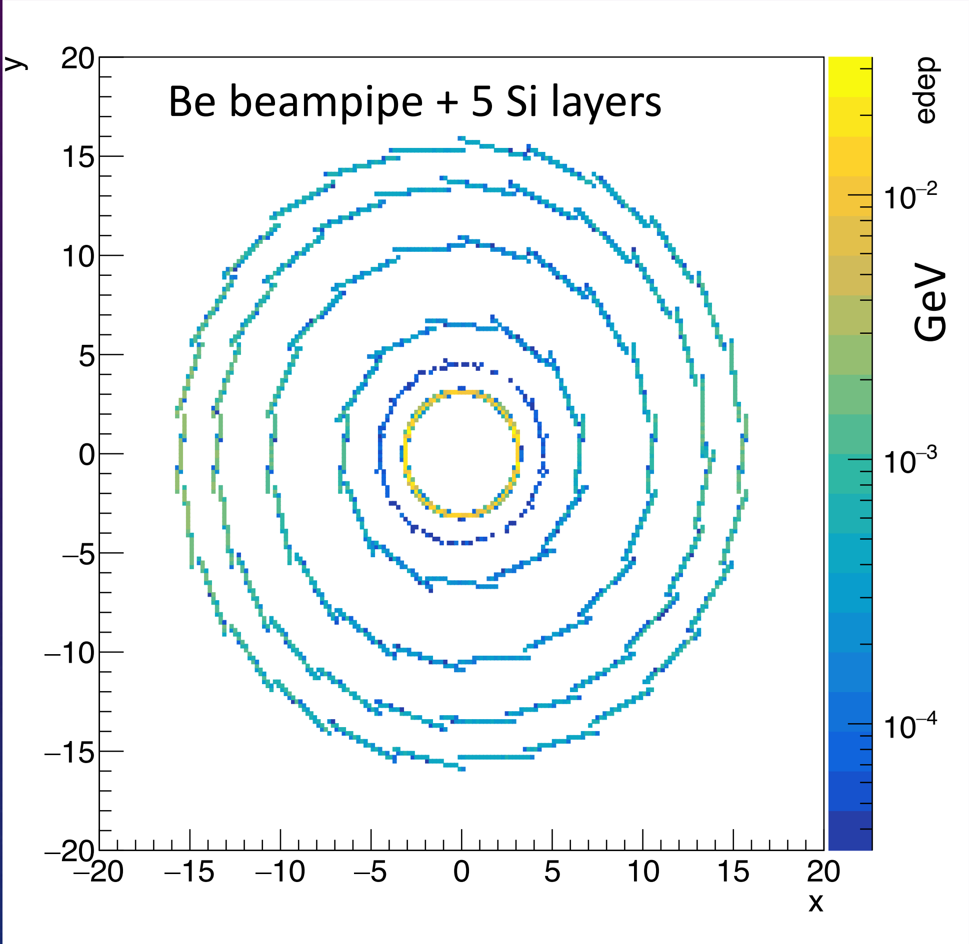


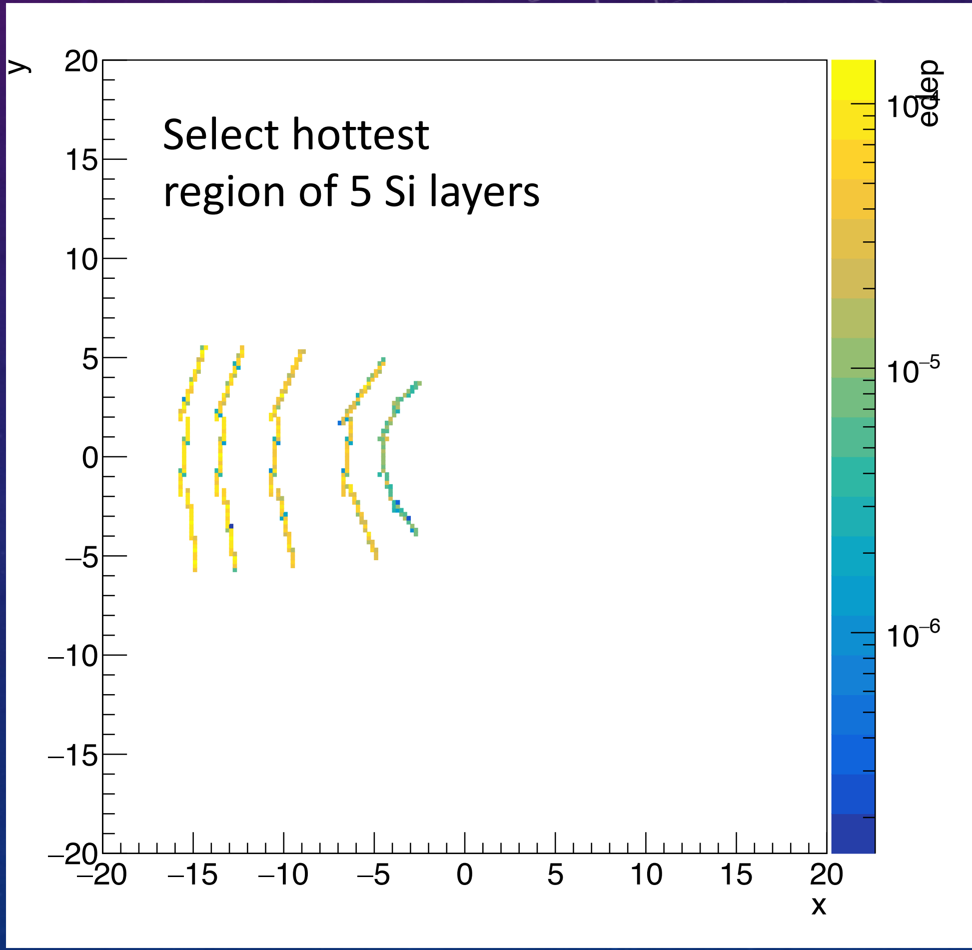
Test plane is a cylinder at 95% Be diameter
10^13 max flux.
Most hits on test plane will also hit Be



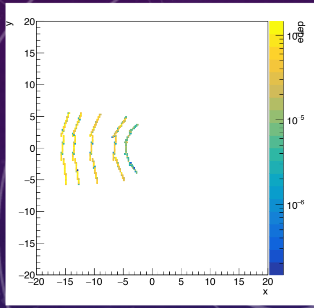
SYNRAD STUDY: 18 GEV ELECTRON BEAM

- 10^9 photons from ~2μs @ 0.26 Amp. Normalization still TBD





SUMMARY OF HOT-ZONE RESULTS



18 GeV electron beam

- 0.26 Amp, inclusive of beam tail
- $2\mu s$ → 10^9 total synchrotron photons

Inner Si Layer

- Dose = $4 \bullet 10^{-4}$ GeV/g/($2\mu s$) = 200 GeV/g/s
- Dose = $3.2 \bullet 10^{-5}$ J/kg/s
- Dose = 320 Gy/Year
  - 1 year = 10^7 sec
- This estimate predicts modest radiation dose.
  - Updates in progress
- Planned estimate of Event Occupancy in SVT