Generic Detector R&D for an Electron Ion Collider
Committee Meeting 24 July 2020

eRD21 UPDATE: EIC BACKGROUND STUDIES AND THE IMPACT ON THE IR AND DETECTOR

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METHODOLOGY & GOALS

Jan 2020: Switched all efforts to BNL EIC Design

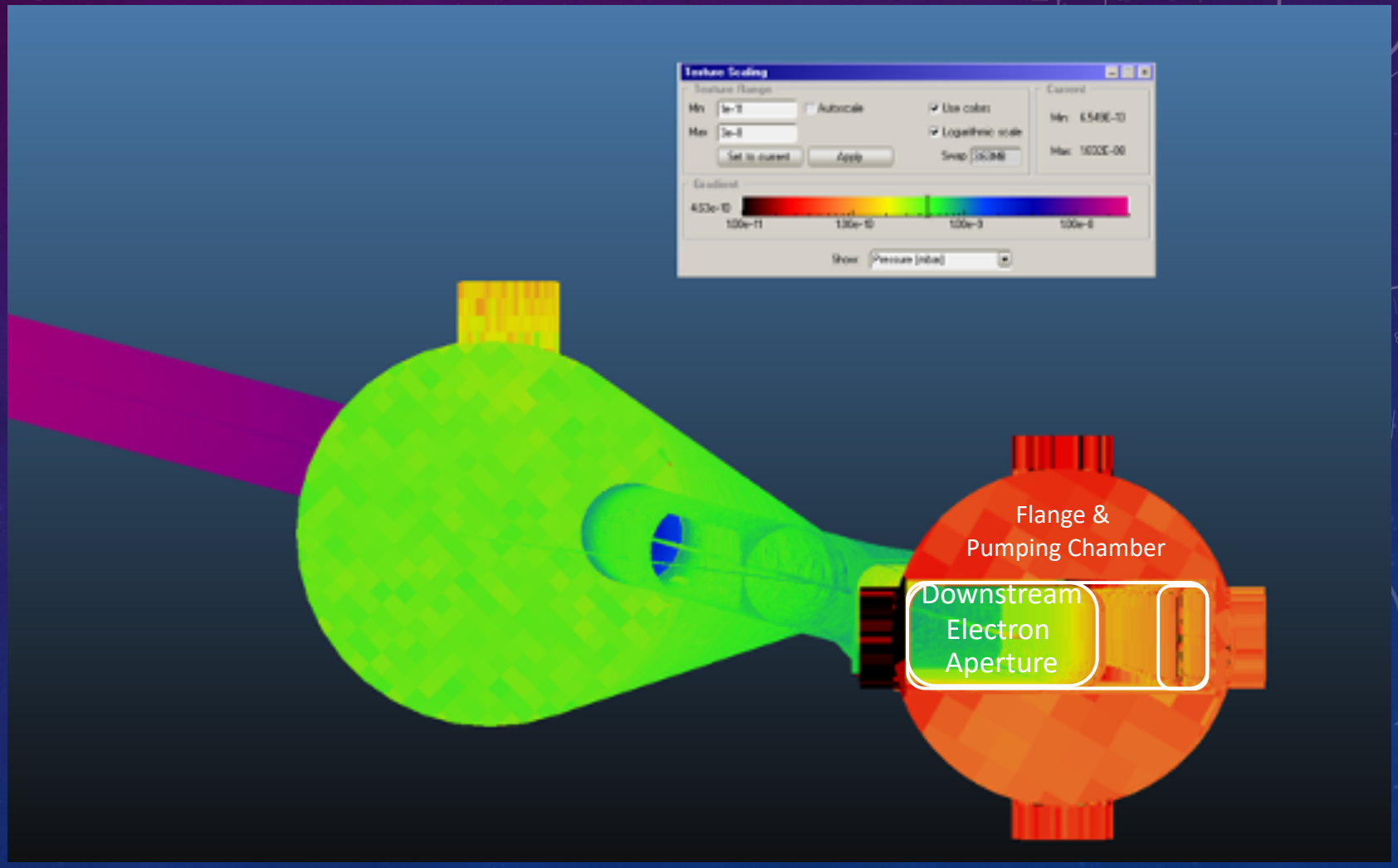
Electron optics from May 2020 BNL IR1 update

- Synchrotron Radiation impact on central detector
  - X-rays generated by SYNRAD and propagated through IP by Fun4All EIC framework or custom GEANT4 model
  - X-rays generated by Sync_Bgd (SLAC) code and propagated through IP by 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.

STATIC VACUUM CALCULATION (MOLFLOW)

M. STUTZMAN (JLAB)

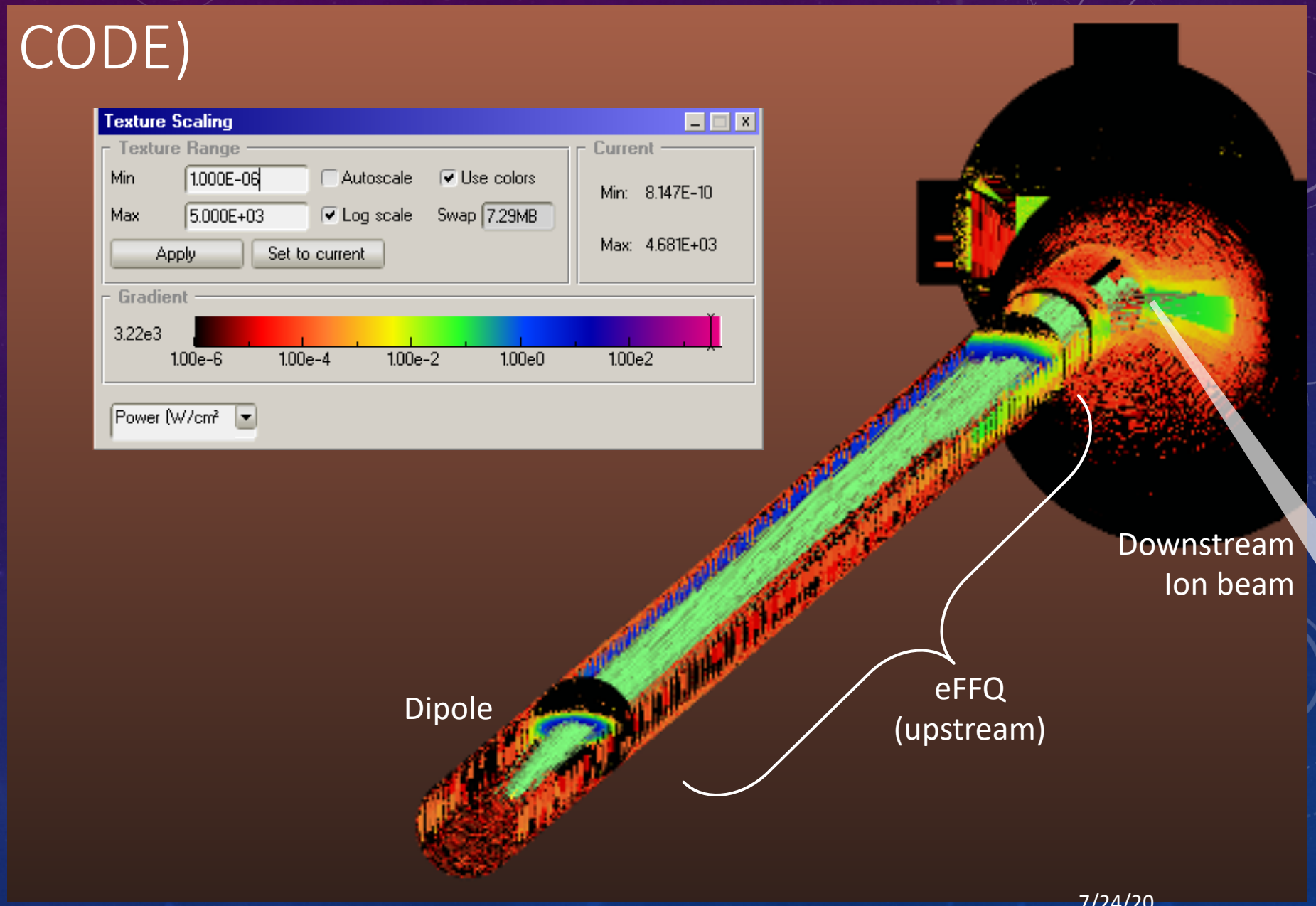
- Pumping achieves 10^{-9} mBar in IP.
- Calculations of synchrotron radiation induced desorption pending.



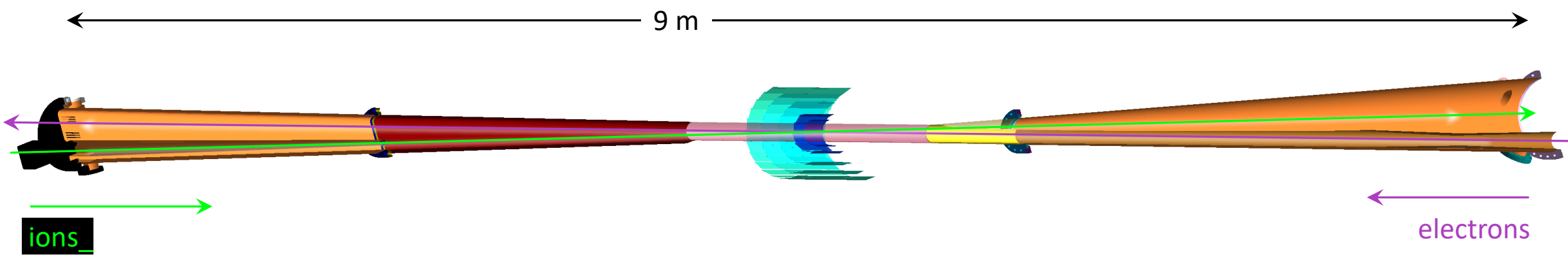
SYNRAD (CERN CODE)

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**



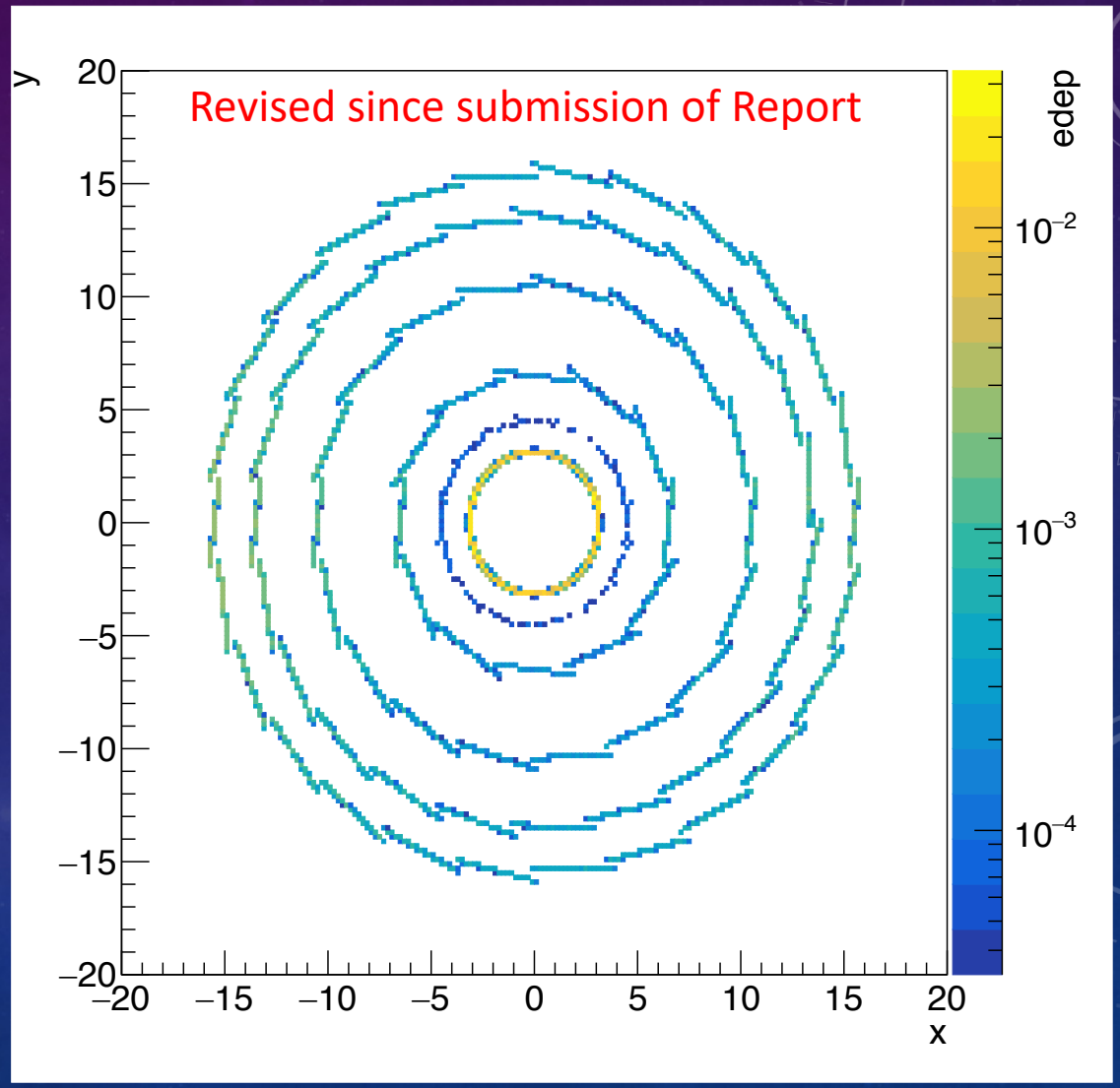
SYNCHROTRON PHOTONS IN EIC IR1



SLAC-JLAB SYNCHROTRON CODE

M. SULLIVAN, V.BATURIN, A.KIM, C.PLOEN

- Photon spectrum generated in FFQ magnets
- Every photon Propagated by GEANT4 from z=+5.2 m through IP model



UPDATED STRATEGY

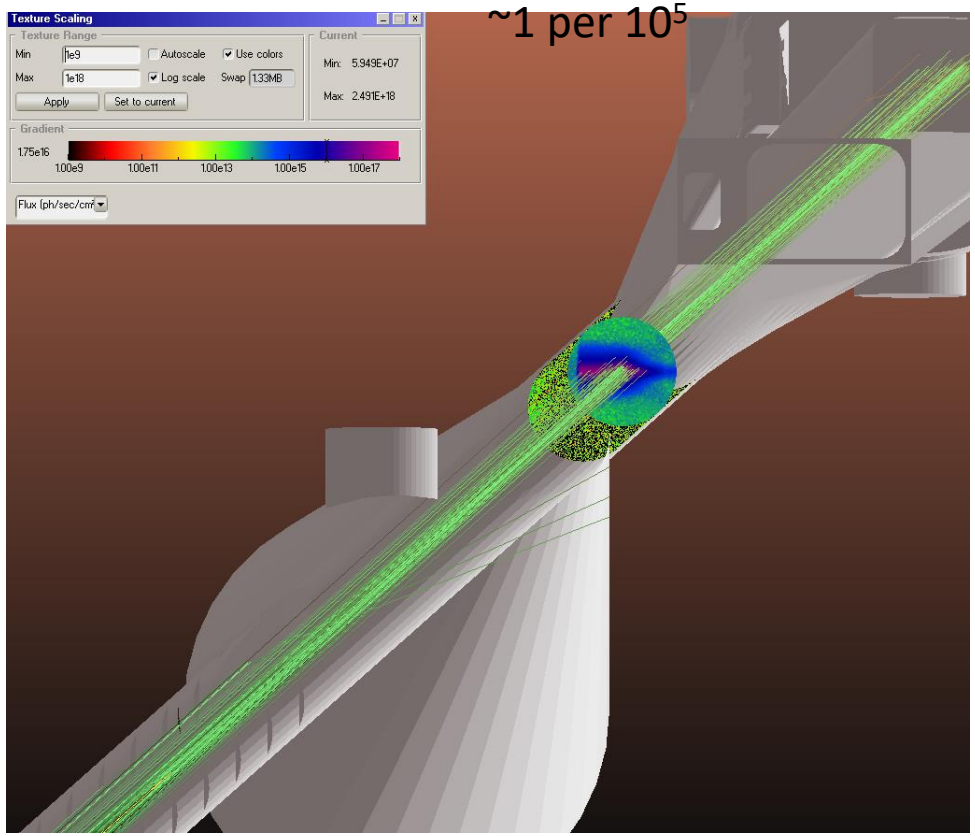
- Our GEANT4 model propagates every single photon through IP.
- SYNRAD/Fun4All strategy only imports to GEANT4 those photons headed towards the beam pipe.
  - Eliminates all but 1 in 10^5 photons.
- Currently we are implementing the SYNRAD/Fun4All strategy with ensembles of both SYNRAD and Sync_Bgd generated photons.
  - SYNRAD results follow

SYNRAD:

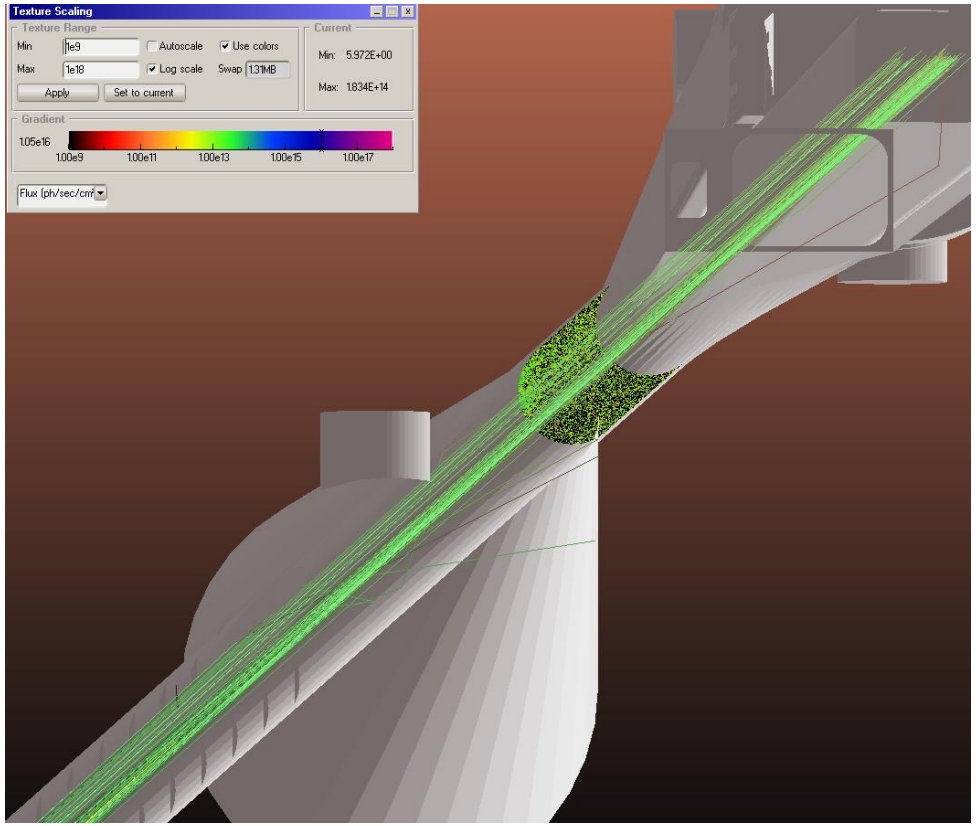
- Central flux through IP: $10^{18}\,\gamma/cm^2/sec$
- Peak flux striking Be pipe: $10^{13}\,\gamma/\,cm^2/sec$ in small horizontal band

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

~1 per 10^5

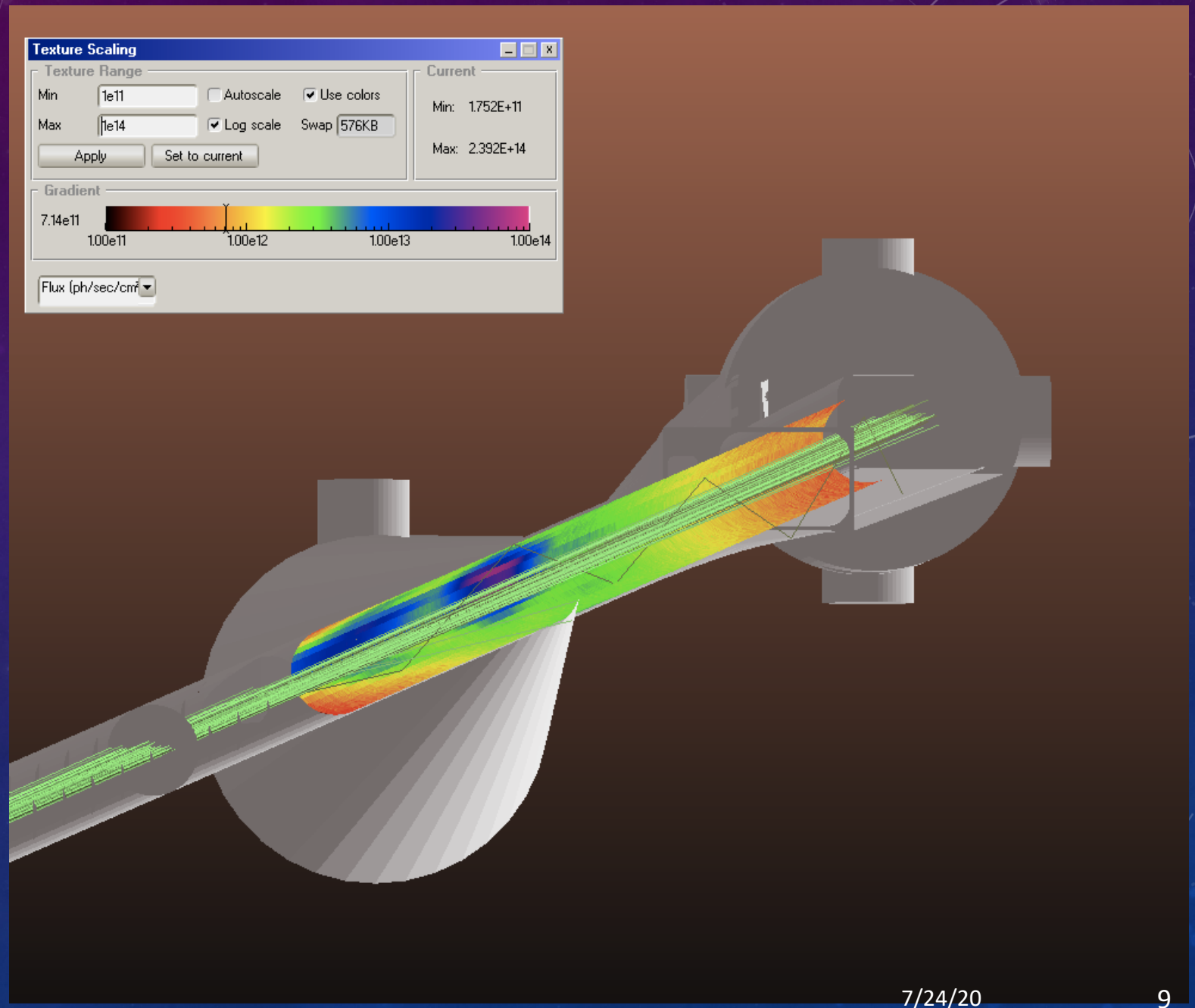


Test plane is a cylinder at 95% Be diameter
10^13 max flux.
Most hits on test plane will also hit Be



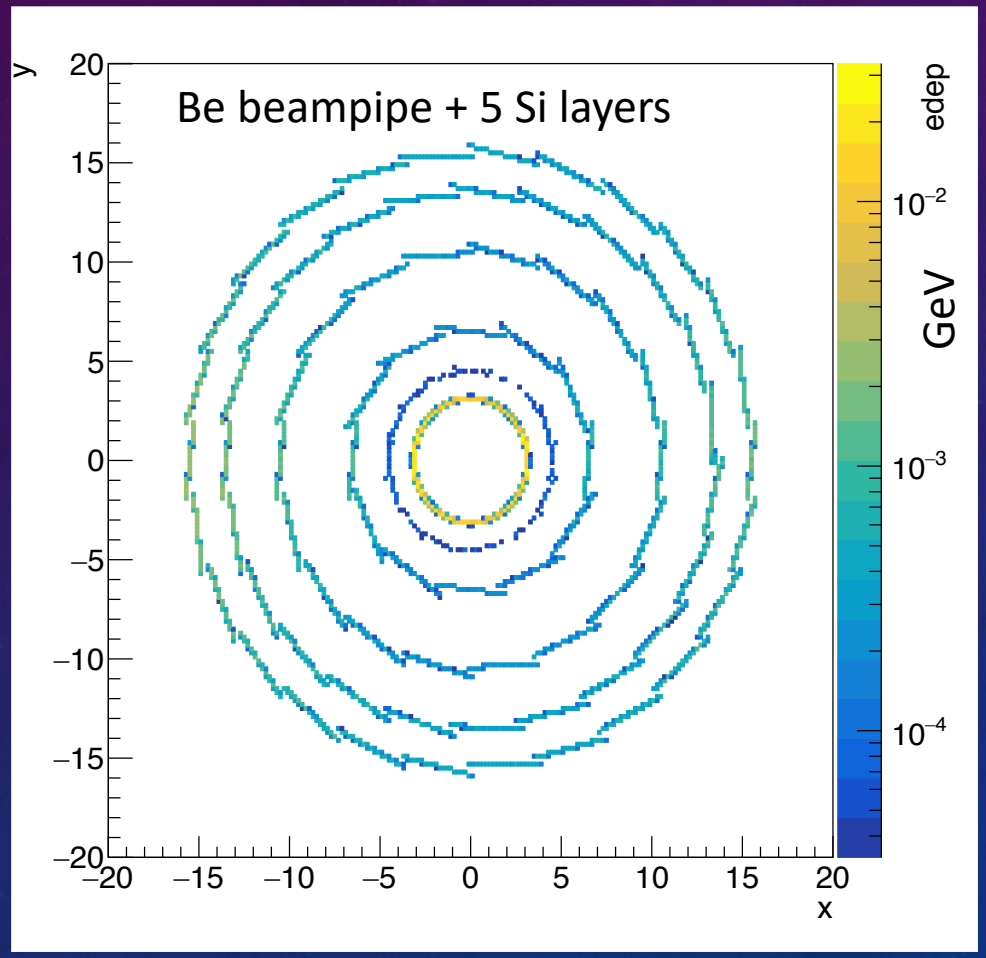
SYNRAD FLUX IN CENTRAL REGION

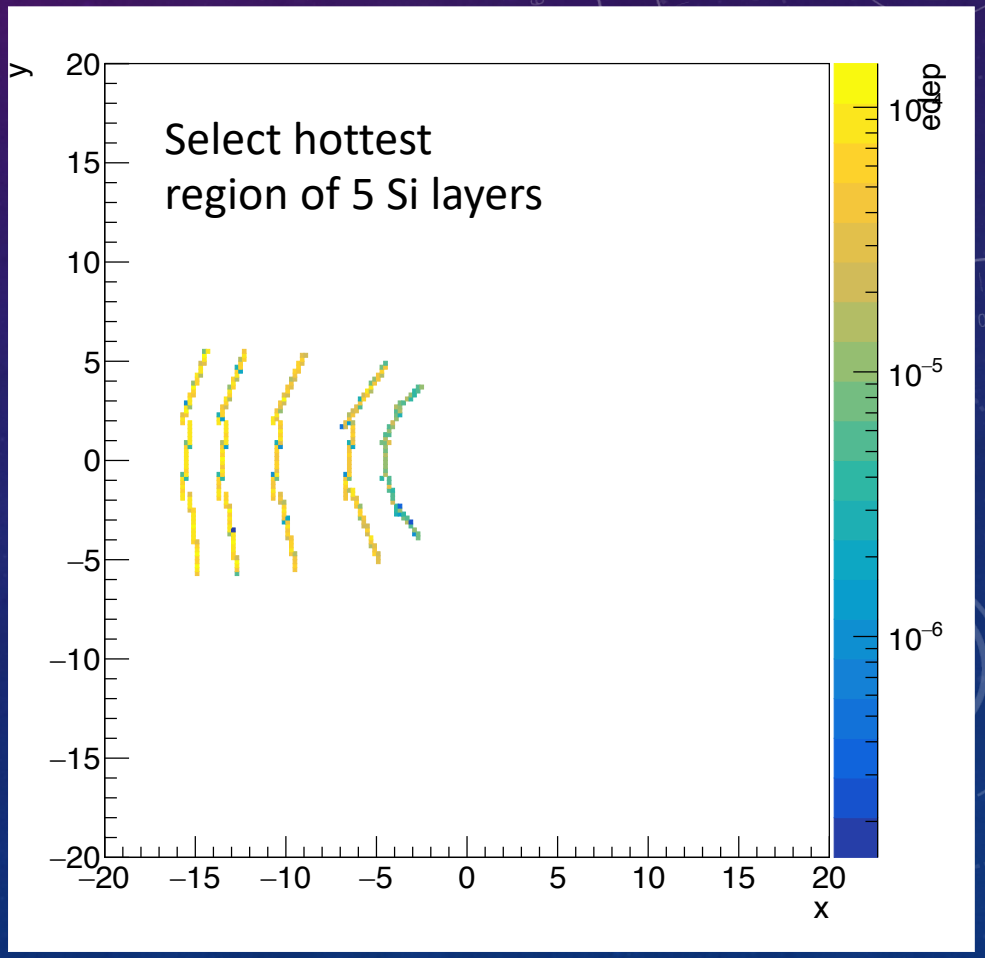
- Hot spots induced by scattering from “photon absorber” at entrance to common pipe.
- Only photon passing through virtual cylinder are passed through to Fun4All or GEANT4 simulation
  - Reduces computation by ~10^{-5}



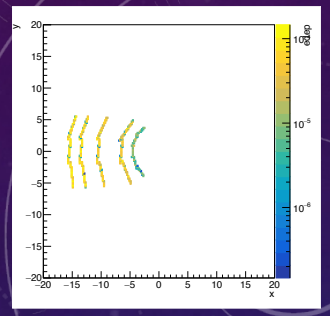
SYNRAD STUDY: 18 GEV ELECTRON BEAM

- 10^9 photons from ~2μs @ 0.26 Amp.





SUMMARY OF HOT-ZONE RESULTS

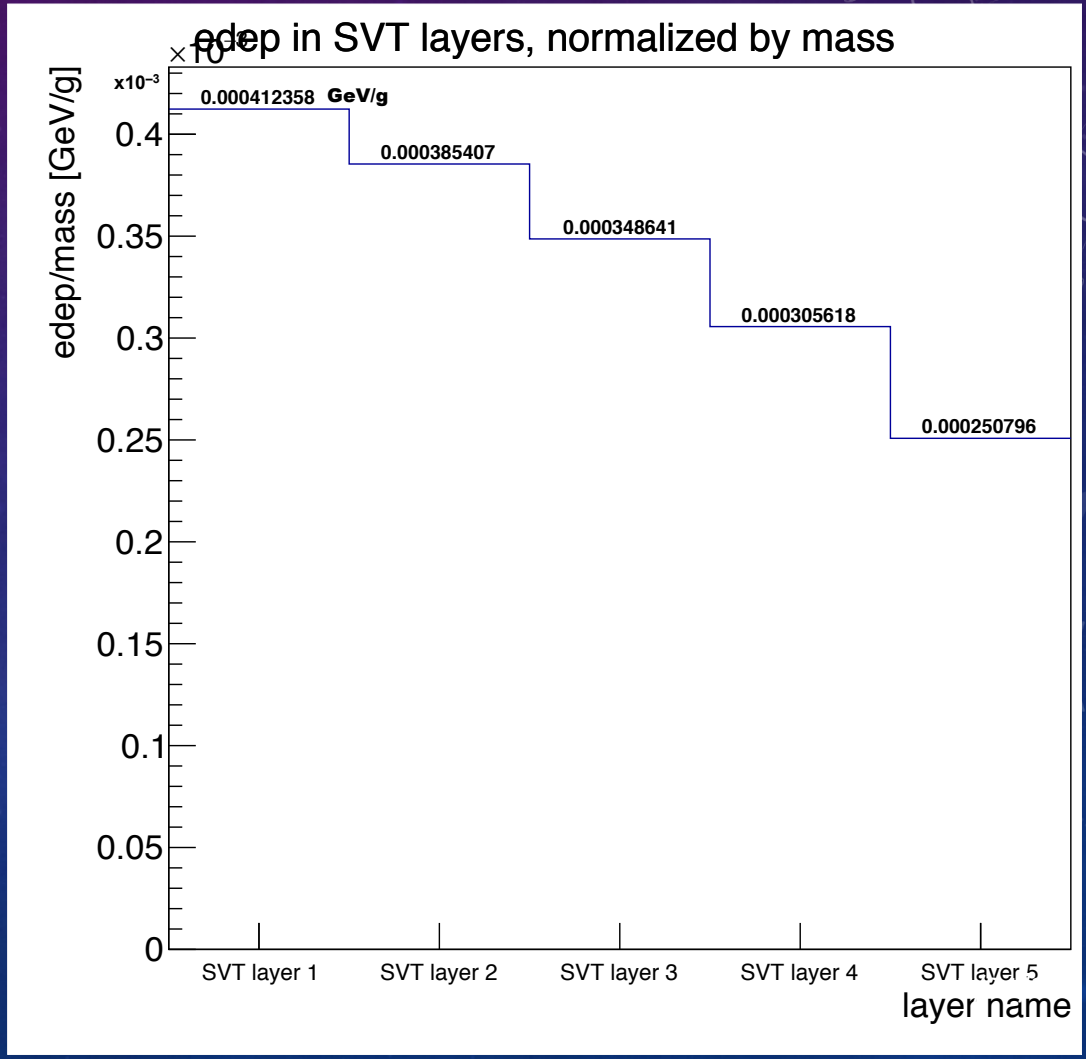


18 GeV electron beam

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

Inner Si Layer

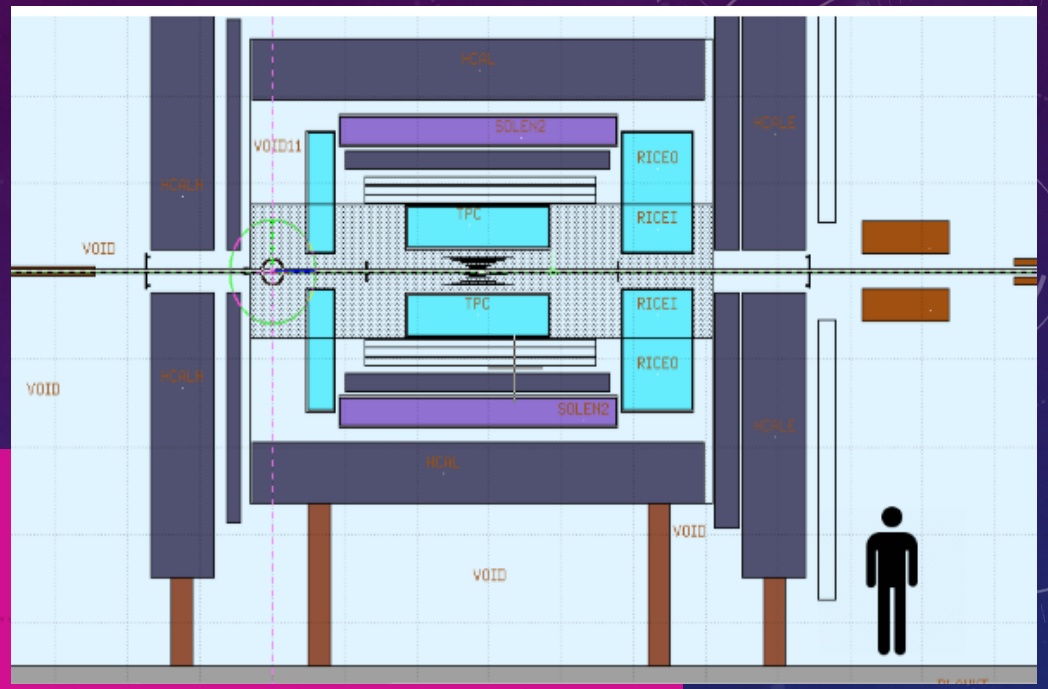
- Dose = $4 \bullet 10^{-4}$ GeV/g/($2\mu s$) = 200 GeV/g/s
- Dose = $3.2 \bullet 10^{-5}$ J/kg/s
- Dose = 320 Gy/Year
  - 1 year = 10^7 sec

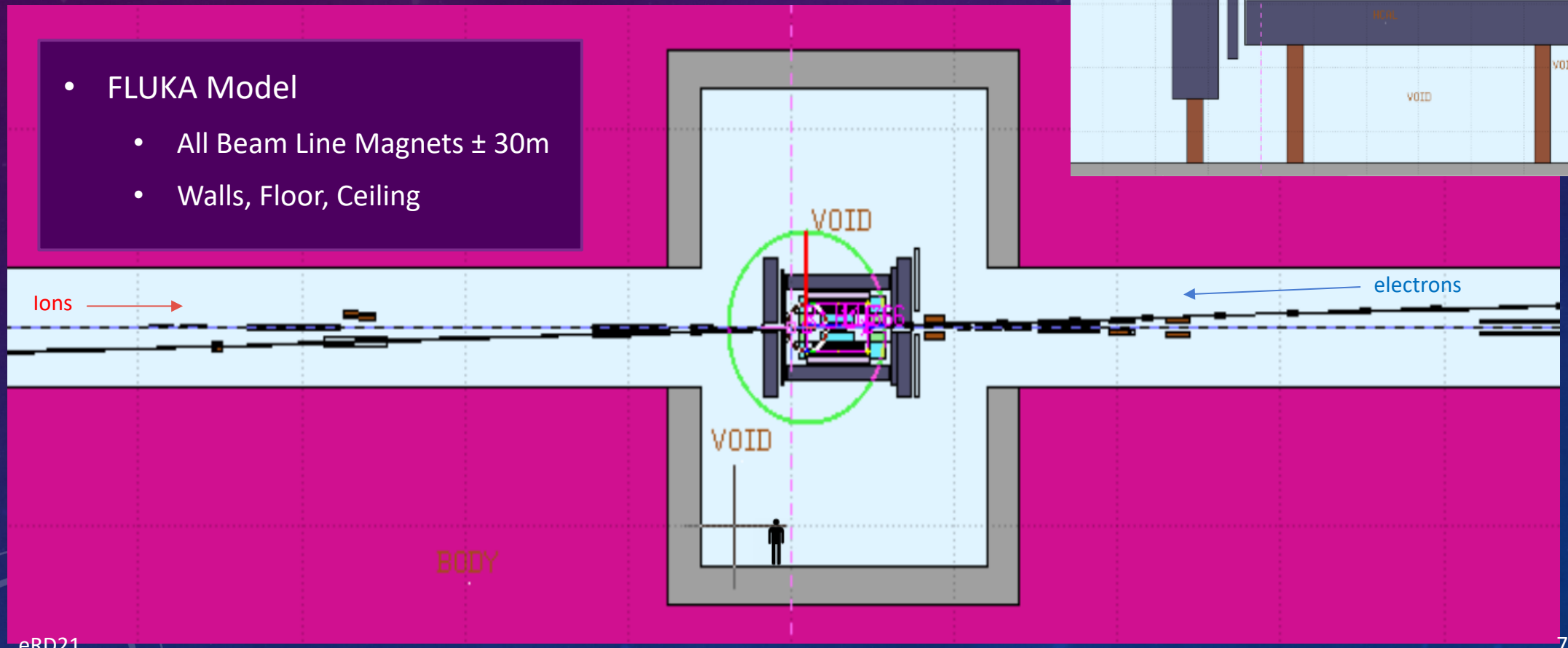


BEAM GAS INTERACTIONS

V. Baturin, et al.

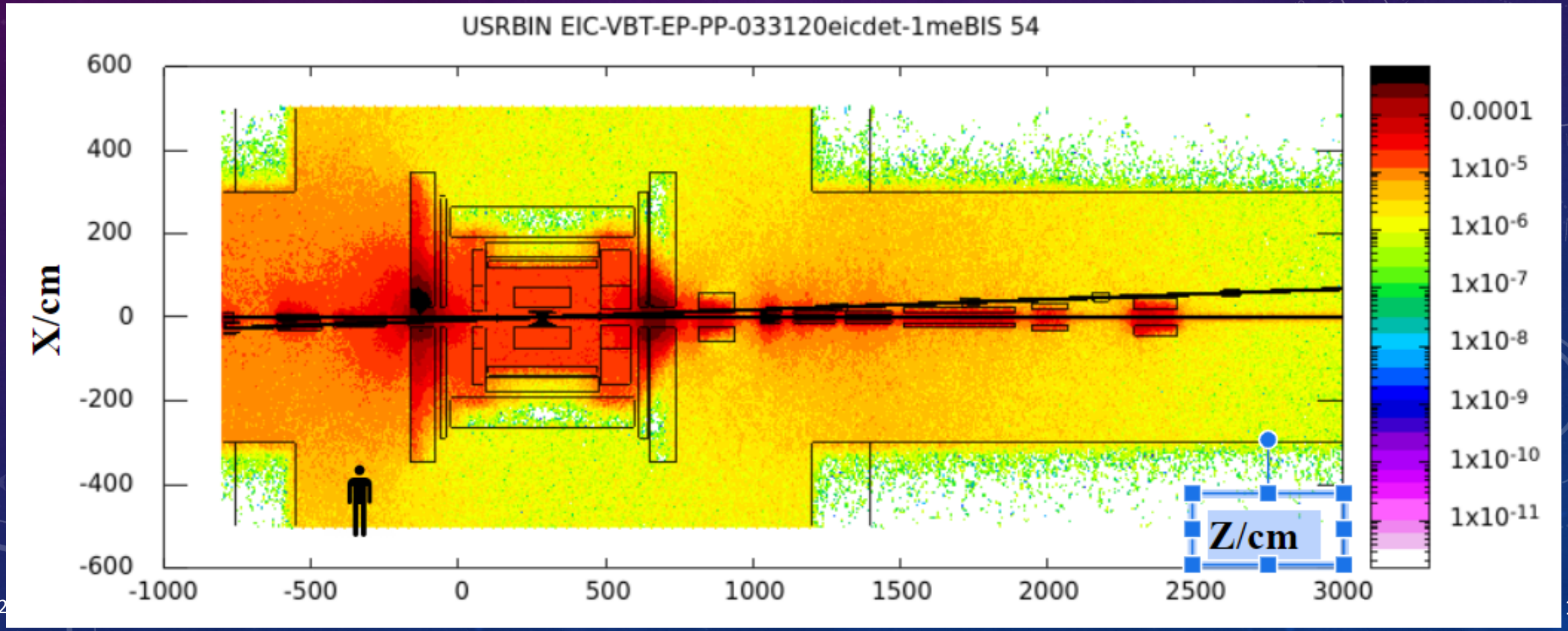
- FLUKA Model
  - All Beam Line Magnets ± 30m
  - Walls, Floor, Ceiling





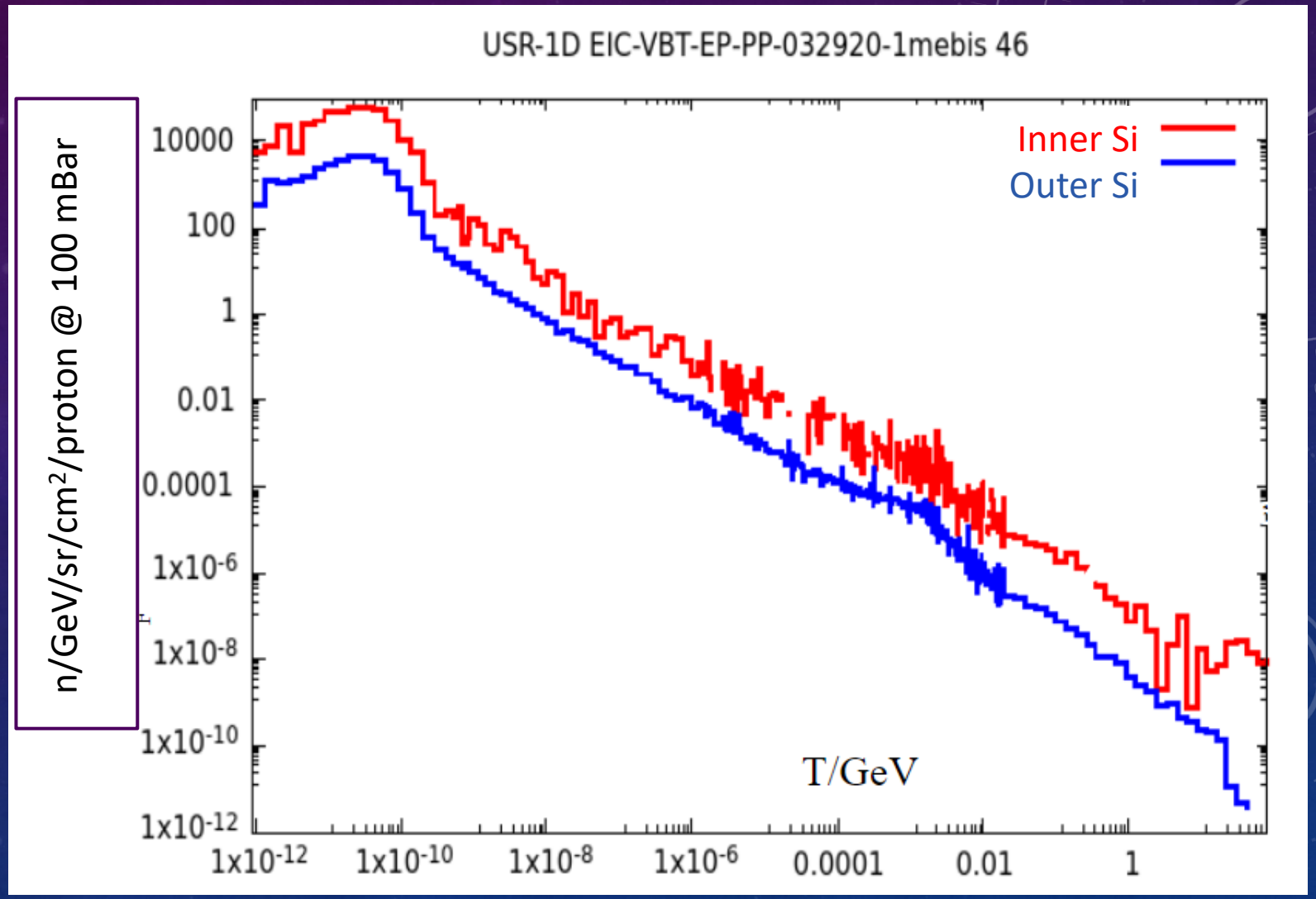
NEUTRON FLUENCE, 275 GEV PROTONS INCIDENT

Color scale is
Neutrons/cm^2/proton @ 100 mBar Air
Scale by 6.25•10^7/sec for
n/cm^2/sec for 1 Amp protons @ 10^{-9} mBar



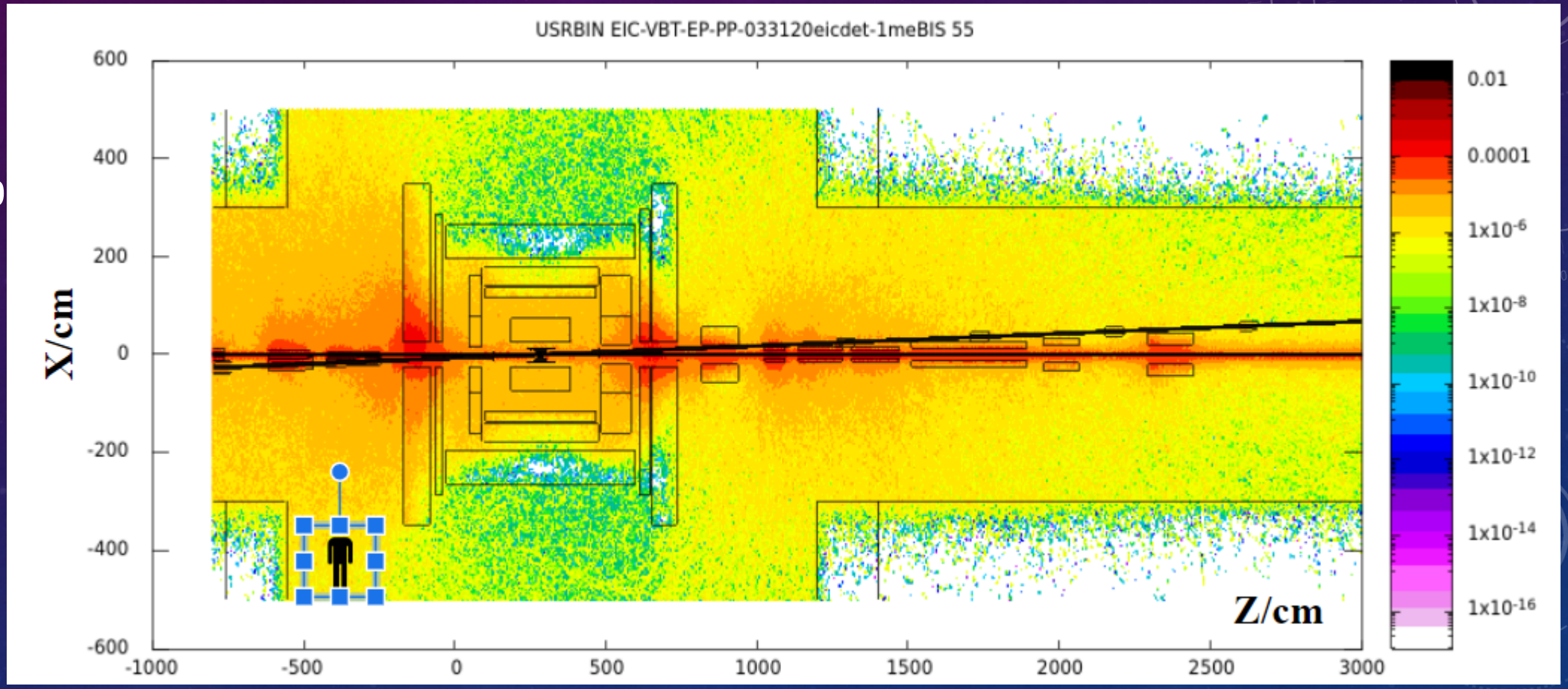
NEUTRON SPECTRA

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



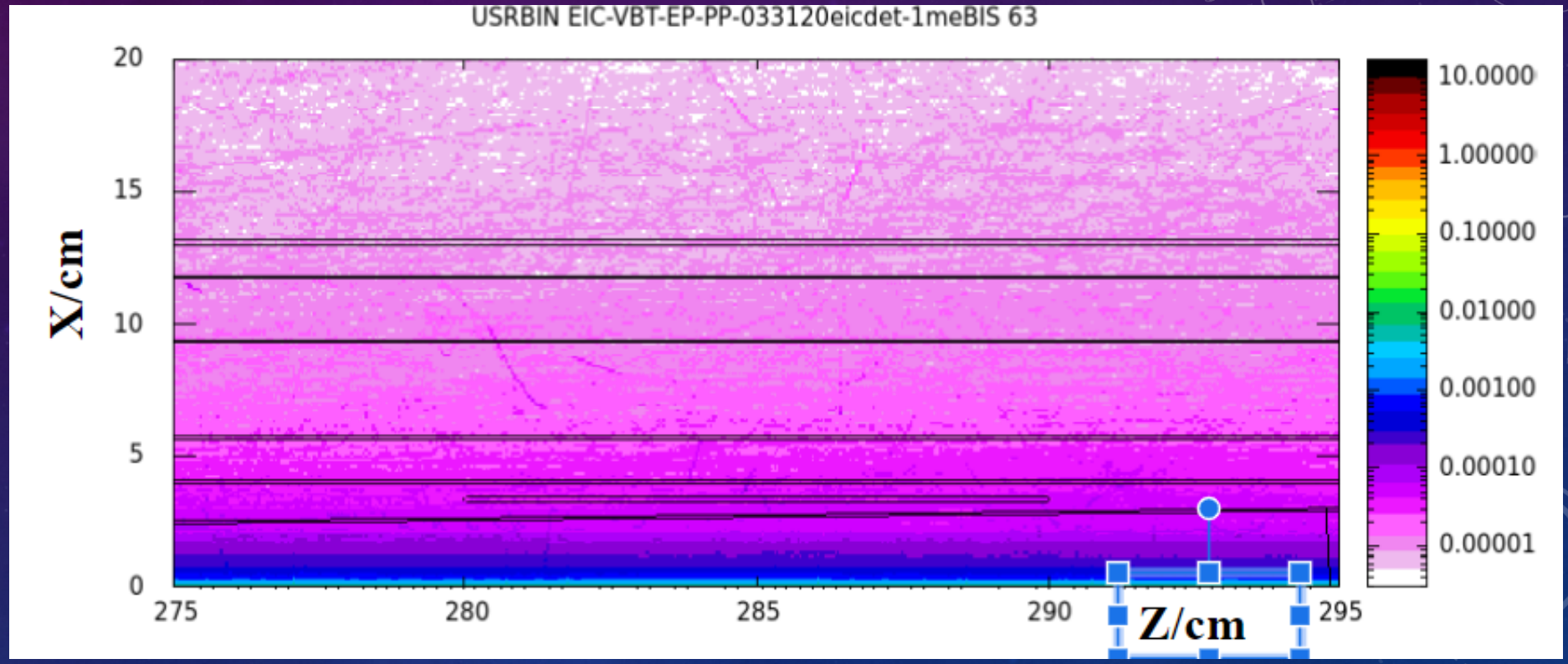
EQUIVALENT 1 MEV NEUTRON FLUENCE

- **Equivalent n/cm² per proton @ 100 mbar Air**
- **Scale by $6.25 \cdot 10^7$/sec for 1 Amp beam and 10^{-9} mBar vacuum**



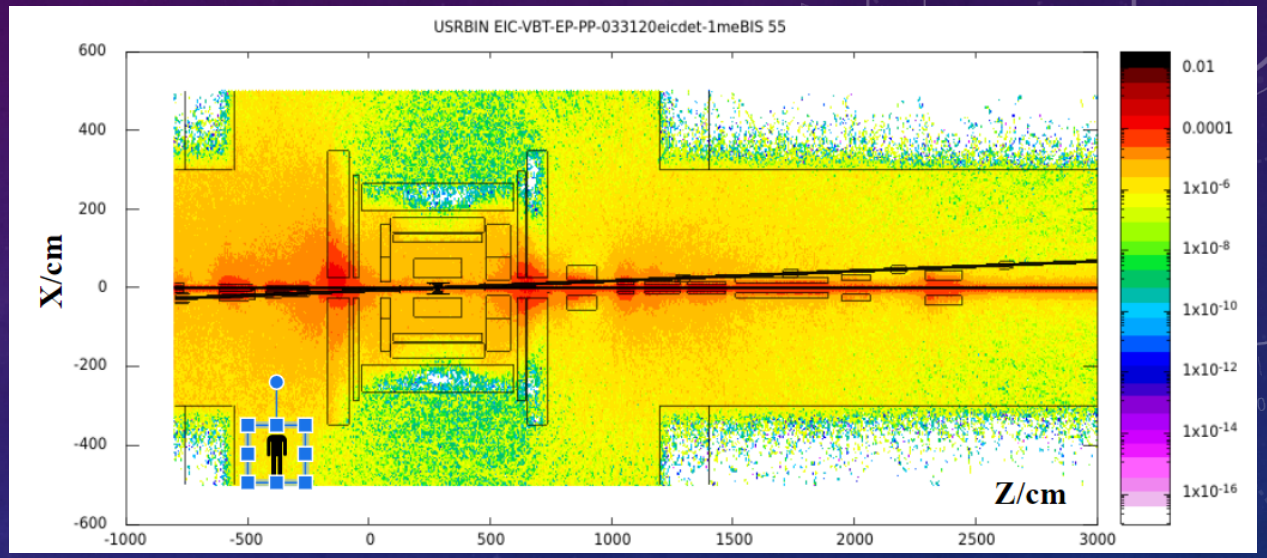
Si VERTEX TRACKER: EQUIVALENT 1MEV NEUTRON FLUENCE

- **Equivalent 1 MeV n/cm^2/proton @ 100 mbar**
- **Scale by $6.25 \cdot 10^7$/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/cm^2/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	$1.6 \cdot 10^{-4}$	10^{11}	$6 \cdot 10^9$
Central Tracker, PID	10^{-5}	$6 \cdot 10^{10}$	
Forward beamline	10^{-4} — 10^{-3}	$6 \cdot 10^{10}$ — $6 \cdot 10^{11}$	

BEAM-GAS STUDIES: NOW UNTIL OCTOBER

- Refine Detector Model
- Tabulate background fluxes of other particle species
  - Protons
  - Pions
- Tabulate background fluxes at additional key detector locations, particularly downstream detectors:
  - B0 tracker (IP + 6m)
  - Off-Energy Tracker (IP + 25 m)
  - Roman Pot Trackers, ZDC (IP + 30 m)

BACKGROUND STUDIES FOR FY2021

- Beam-Gas
  - Ion species beyond protons
  - Realistic vacuum profile
  - Energy spectra
- 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
- Final report submitted for publication (if fully funded).

PROPOSED BUDGET FY 2021

Table II: Requested eRD21 Budget for FY2021. The personnel classifications are A. Kim: Staff Scientist; V. Baturin: Post-Doc; C. Ploen: GRA.

Personnel	Salary (12 month)	Fringe Rate	IDC Rate	FTE %	Budget	Institution
Andrey Kim	$70,000	43%	26%	40%	$50,450	UConn
Vitaly Baturin	$50,000	39%	26%	50%	$43,785	ODU
Christine Ploen	$25,000	4%	26%	—	$32,760	ODU
Other costs						
Tuition (15 credit hours)					$8,265	ODU
Travel	$9,740	—	0%	—	$9,740	BNL
Total					$145,000	

BUDGET SUMMARY

Item	Institution	100%	80%	60%
Post Doc (V. Baturin)	ODU	$43,785	$40,985	$34,100
Grad Student (C.Ploen)	ODU	$41,025	$27,365	$13,700
Staff Scientist (A. Kim)	UConn	$50,450	$47,650	$39,200
Travel	BNL	$9,740	0	0
Total		$145,000	$116,000	$87,000

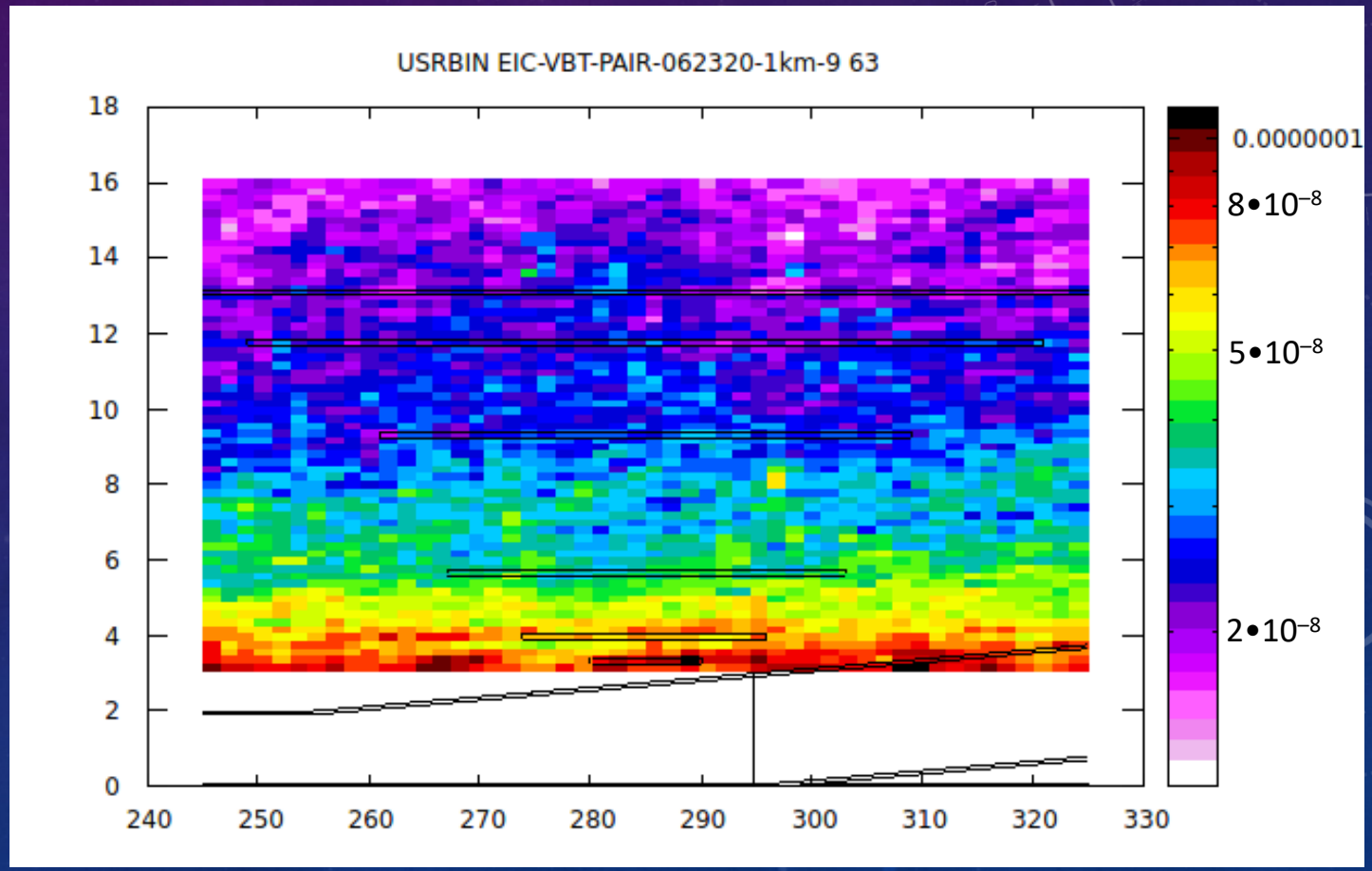
BACKUP SLIDES

BUDGET REDUCTIONS

- 20% reduction = –$29,000
  - Eliminate 1 semester GRA support → $13,700
  - Eliminate Travel → $9,740
  - PostDoc, Scientist reduction of $5,600
  - Reduced productivity on Synchrotron radiation studies.
- 40% reduction = –$58,000
  - Negotiate between ODU and UConn:
    - Additional PostDoc, Scientist reductions

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 = $0.9 \cdot 10^{-7}$ $n/cm^2/proton/mBar$
- 570 n/cm^2 @ 1 Amp & 10^{-9} mBar
- $6 \cdot 10^9$ n/cm^2 /yr



BEAM LOSS ACCIDENT NEAR IP

- 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