Generic Detector R&D for an Electron Ion Collider
Committee Meeting 23-26 March 2021

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

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METHODOLOGY & GOALS

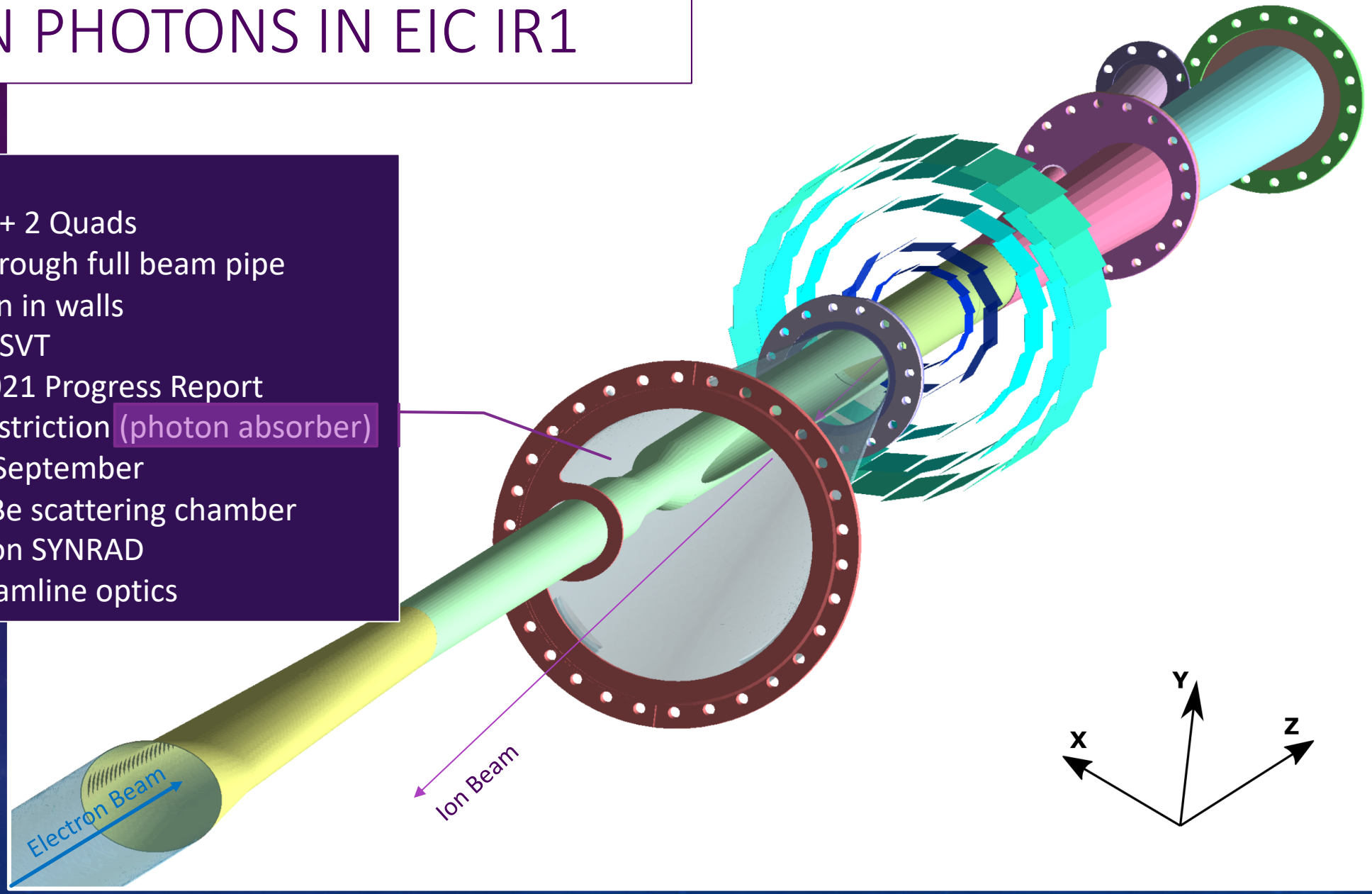
- Synchrotron Radiation impact on central detector (Nov 2020 IR update)
  - X-rays generated and propagated to IP by SYNRAD and detector simulation in Fun4All EIC framework or custom GEANT4 model
  - X-rays generated by SLAC code (Sync_Bgd) and propagated through IP by custom GEANT4
- Ion Beam ⊗ Residual 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.

SYNCHROTRON PHOTONS IN EIC IR1

Synch_Bgd (SLAC+eRD21)
Photons generated in Dipole + 2 Quads

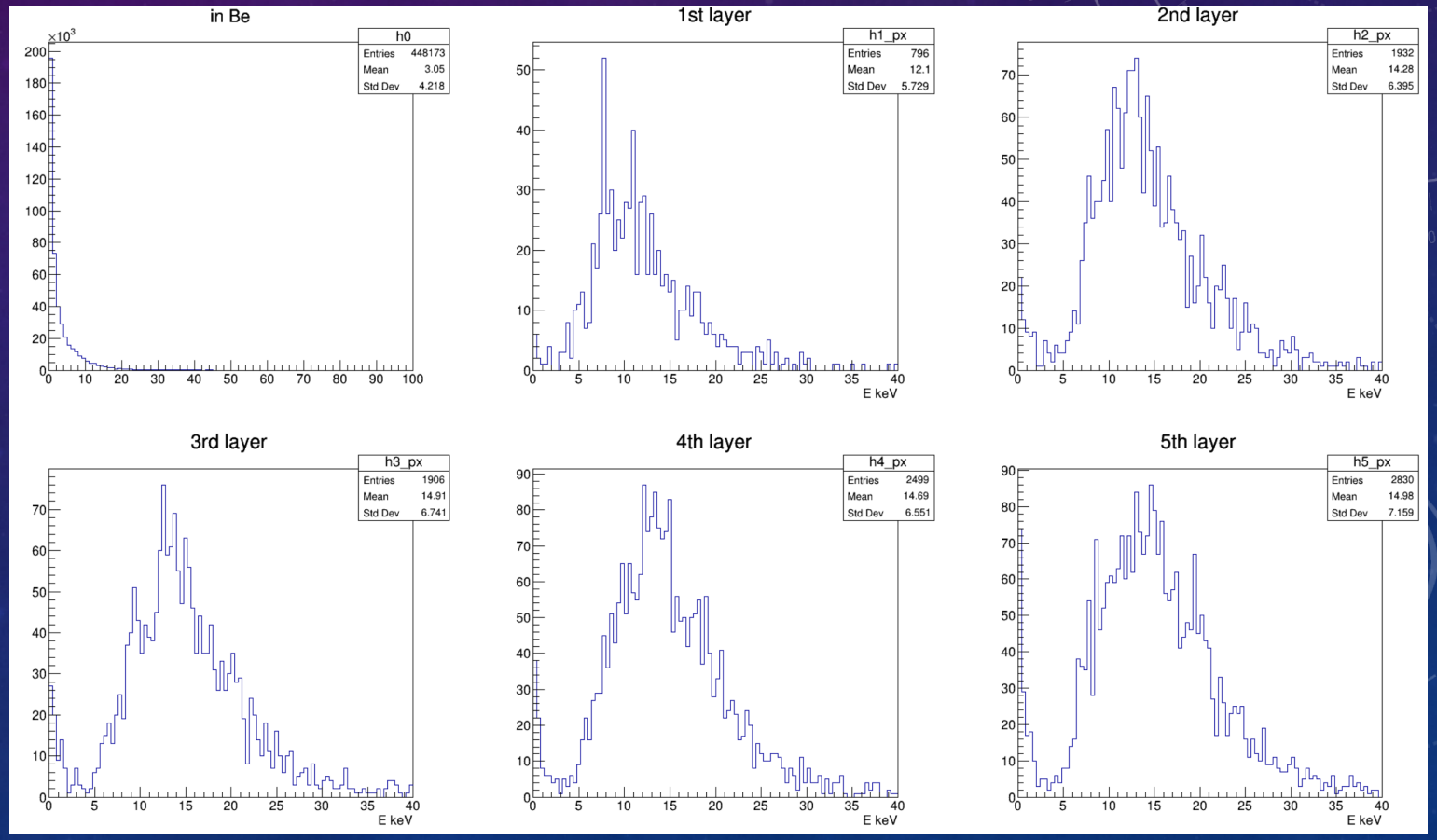
- Propagated by GEANT4 through full beam pipe
  - Scattering/Absorption in walls
  - Energy deposition in SVT
- Update since 05 March 2021 Progress Report
  - 2cm inner radius constriction (photon absorber)
- Elements to be added by September
  - ~2μm Au coating of Be scattering chamber
  - Consistent comparison SYNRAD
  - Updated electron beamline optics

Results for 2.5 Amp, 10 GeV electron beam



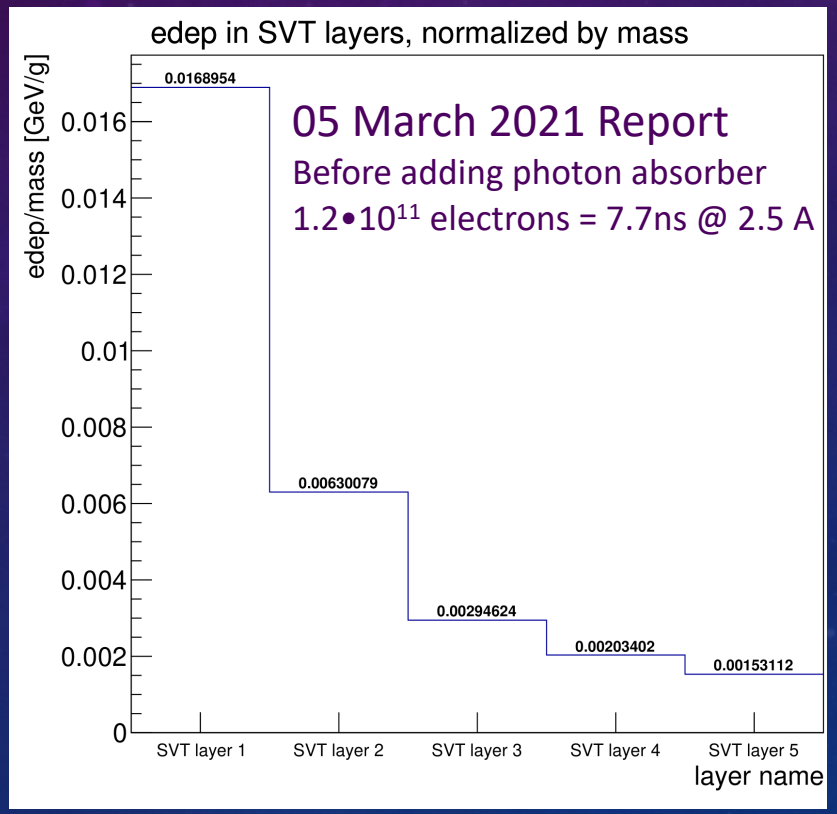
SYNCHROTRON ENERGY DEPOSITION IN SVT LAYERS
(per photon, summed over 10^{10} X-rays from $6 \bullet 10^{10}$ electrons)

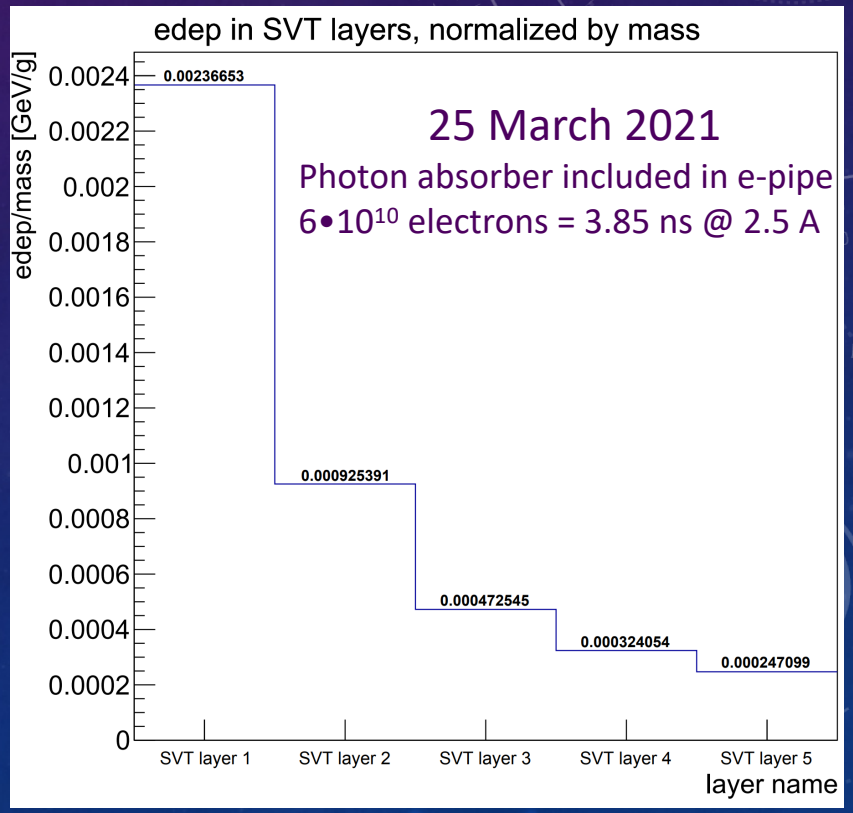
- First layer: 50 μm
  - MIP ≥ 20 KeV, Threshold ≈4KeV
- All other layers 150 μm
- Any synchrotron photon that deposits energy makes a hit.



SYNCHROTRON ENERGY DEPOSITION IN SVT

- Annular photon absorber (far-right) reduces dose by factor of 3.4
  - 2 um gold coating on Be studies underway





SVT DOSE AND OCCUPANCY STATUS:

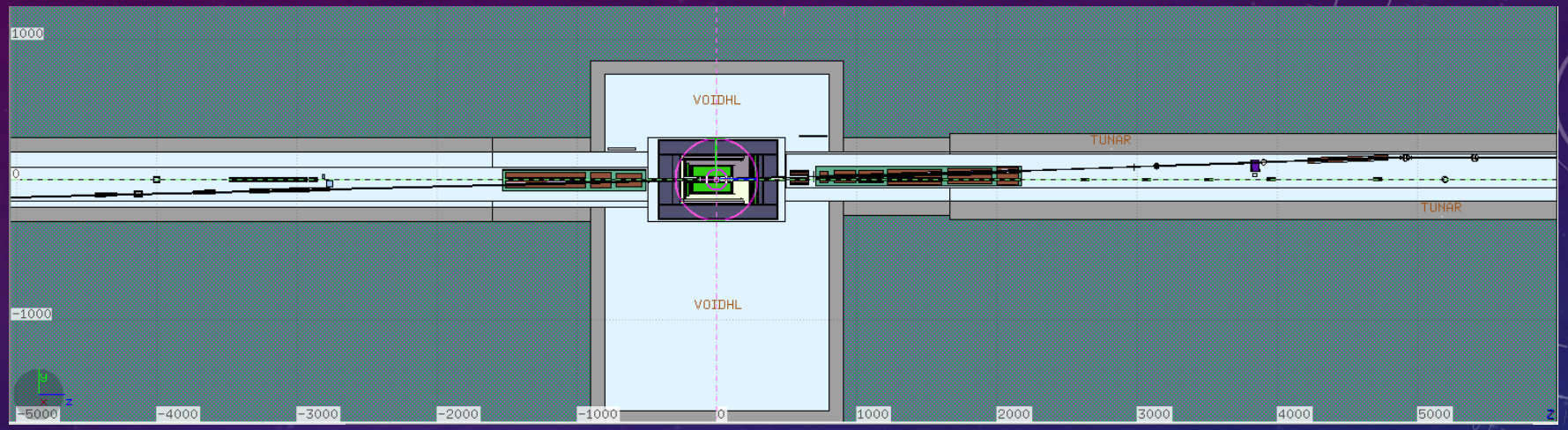
Photon Absorber significantly reduces hits in SVT

SVT Layer	# Staves	Area/layer (cm2)	Mass/layer (g)	Hits /cm^2 /sec	Hits /cm^2/2μs	Occupancy/ (20μm)^2	Dose (Gy/sec)	Dose (MGy/year)
1	16	352	4.10	5.9E+08	1.2E+03	0.47%	0.098	0.98
2	12	864	30.20	5.8E+08	1.2E+03	0.47%	0.038	0.38
3	18	1728	60.39	2.9E+08	5.7E+02	0.23%	0.020	0.20
4	23	3312	115.75	2.0E+08	3.9E+02	0.16%	0.013	0.13
5	26	4992	174.47	1.5E+08	3.0E+02	0.12%	0.010	0.10

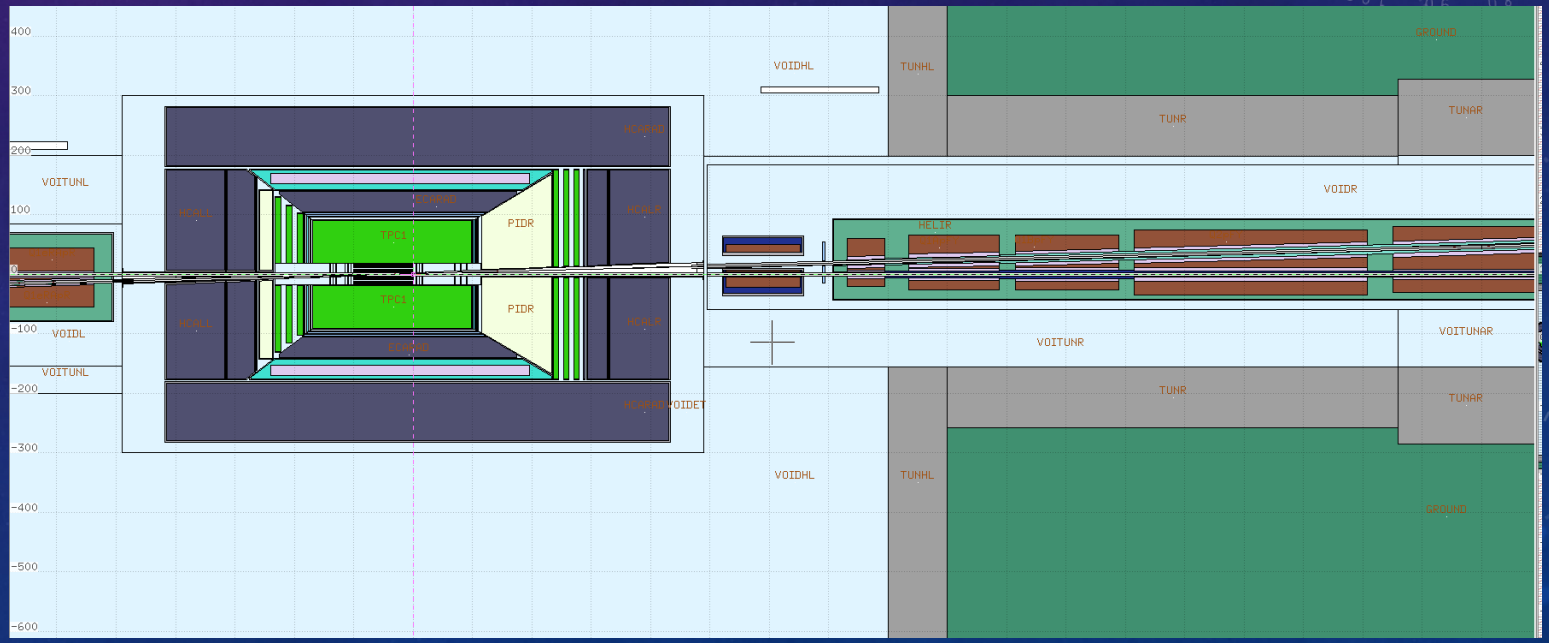
Hits/area and Occupancy values in 05 March 2021 report were overstated by a factor of the number of staves per layer
The Dose rates were correctly calculated in the report

BEAM GAS BACKGROUND STUDIES

- FLUKA



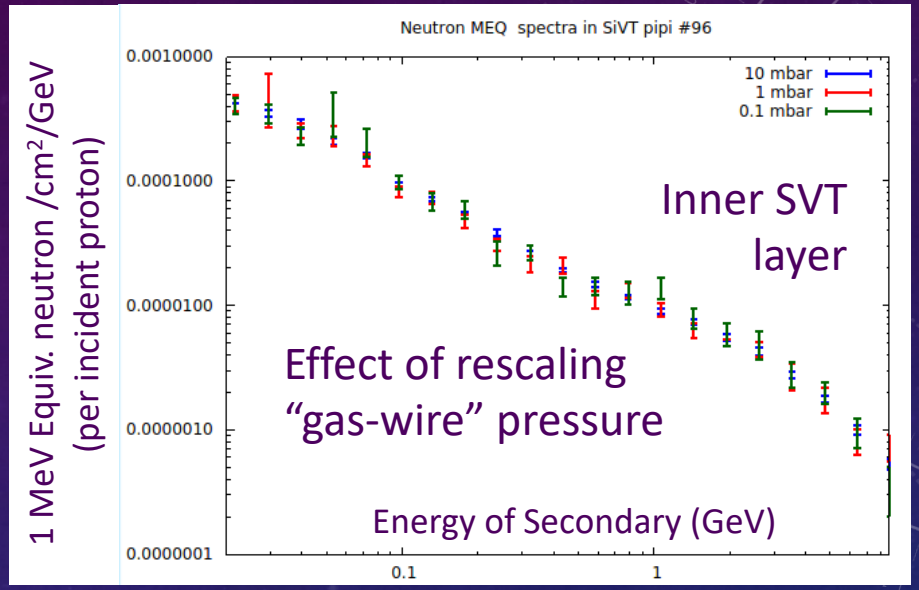
- All beam line elements
  - Magnets w/ iron, cryostat
  - Tunnel and Hall concrete walls, floor, roof
  - Generic Detector:
    HCal, EMCal, SiVT, Tracker, PID

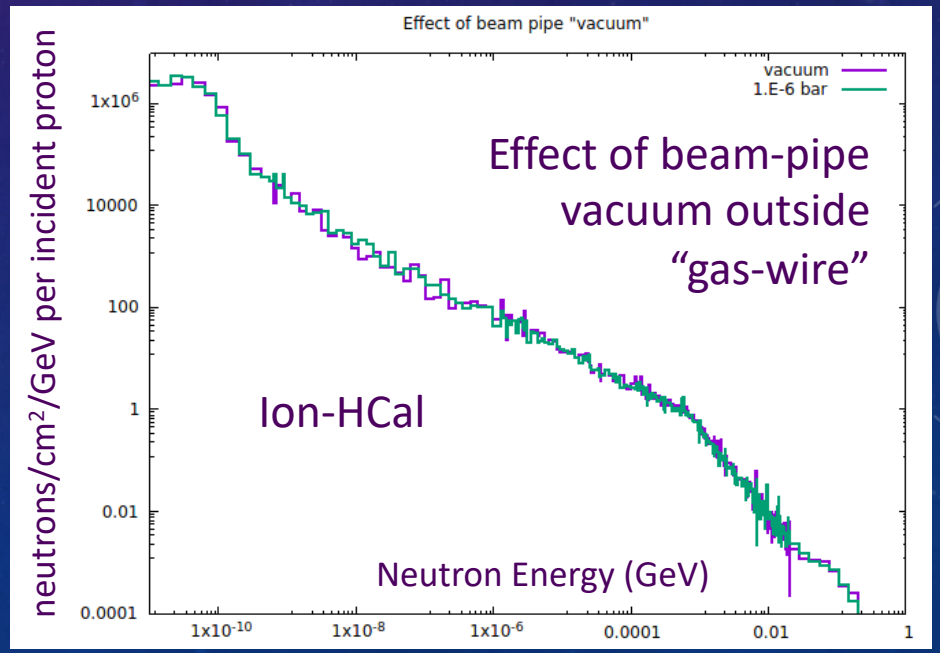


- Artificial 1 mBar “gas-wire” along beam line:
  Rescale to expected 10^{-9} mbar vacuum

RESCALING TO 10^{-9} mBar

- Linear with “gas-wire” pressure
- Independent of vacuum outside beam path





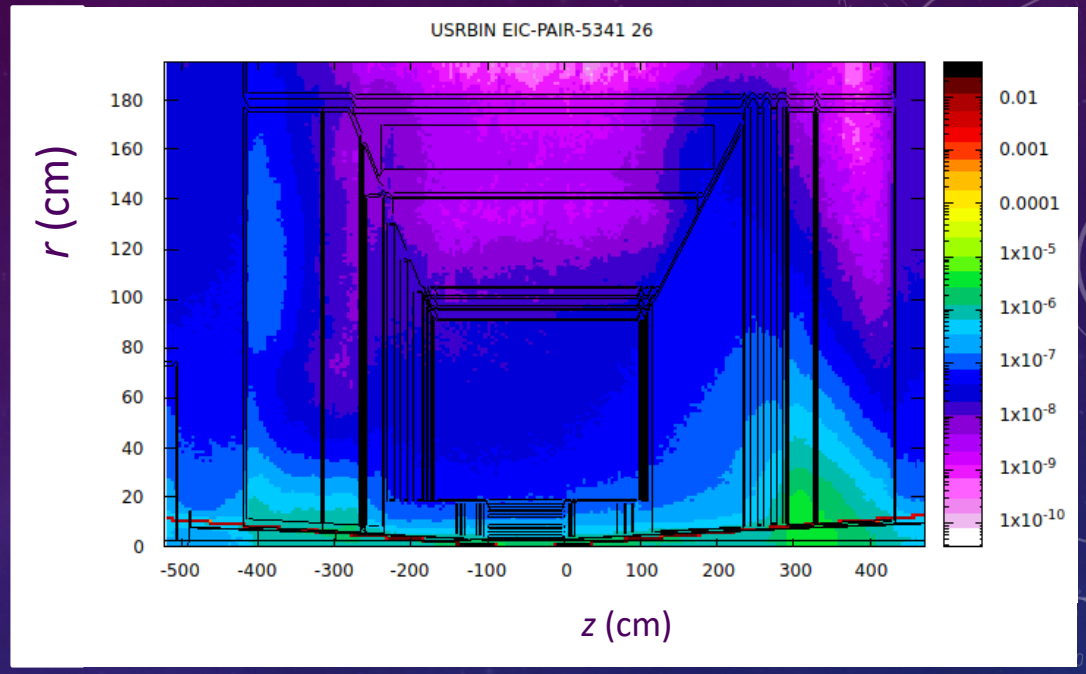
1 MeV Equivalent Neutron flux from Beam-Gas Interactions

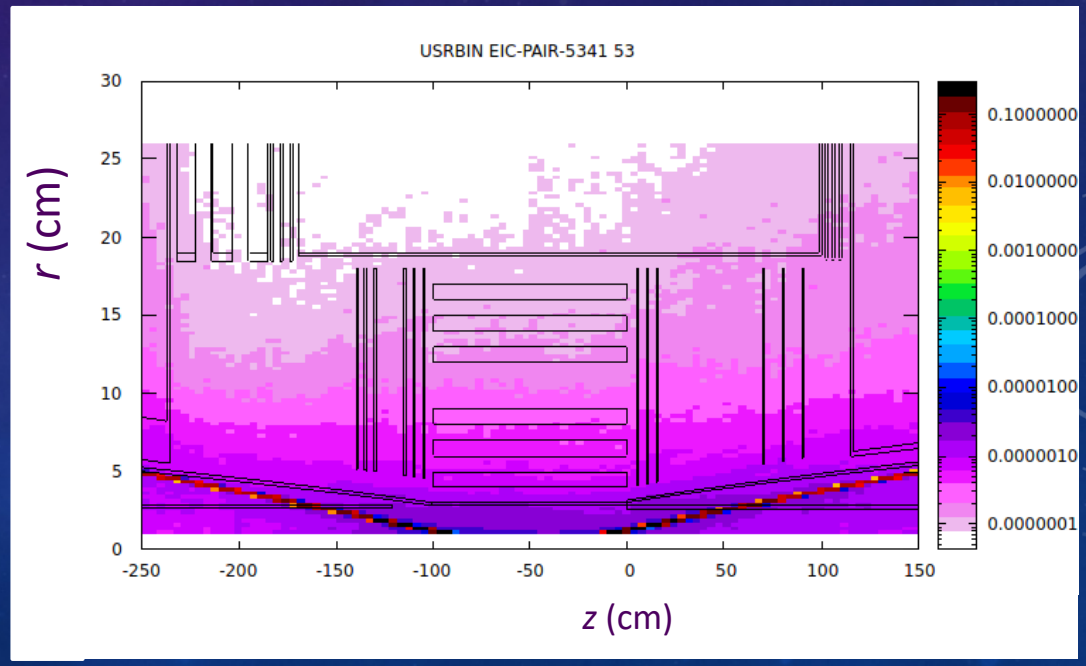
- Raw color values are n/cm²/proton @ P_F = 1 mBar (“gas-wire”)
- Rescale by

$$\frac{P}{P_F}\frac{I_p}{e} = 6.25 \cdot 10^9/s$$ for n/cm²/sec

@ 1 Amp proton current & *P = 10⁻⁹ mBar*

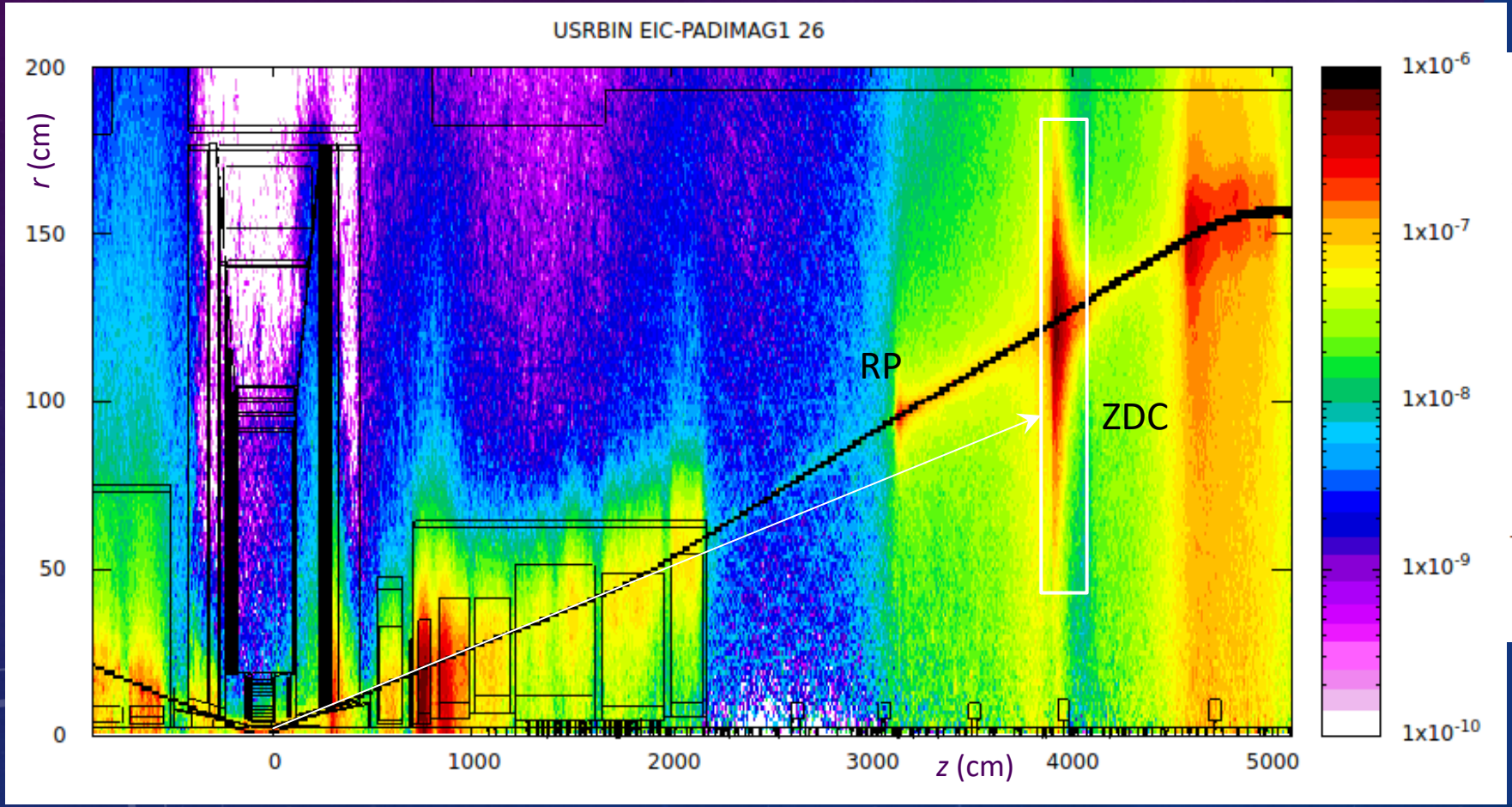
  - e-EMCal (r=10cm)➔6•10³ n/cm²/s
  - h-EMCal (r=10cm)➔30•10³ n/cm²/s
  - SVT (r=4cm) ➔ 5•10³ n/cm²/s
  - BeamPipe (r=3cm) ➔ 9•10³ n/cm²/s
  - Inner focus gas RICH SiPM (r=20cm) ➔ 0.6•10³ n/cm²/s = 6•10⁹ n/cm²/year



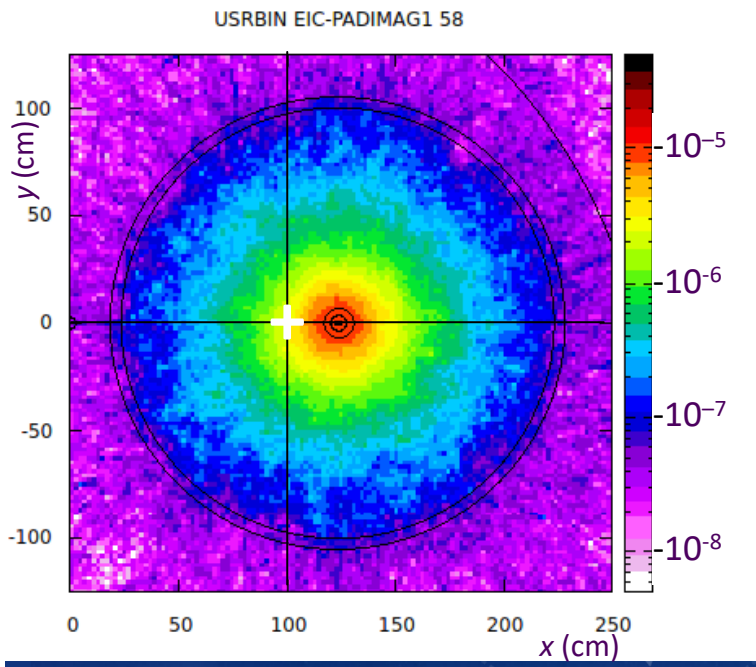


DOWNSTREAM BEAMLINE: ROMAN POTS AND ZDC (FLUKA)

- Image and dose rates averaged over azimuth



- ZDC neutron dose profile *(y vs. x)*
- *Beam gas background centered on beam line, NOT 25 mr* from IP



Rescale raw color values by $6.25 \cdot 10^9/s$ for n/cm²/sec

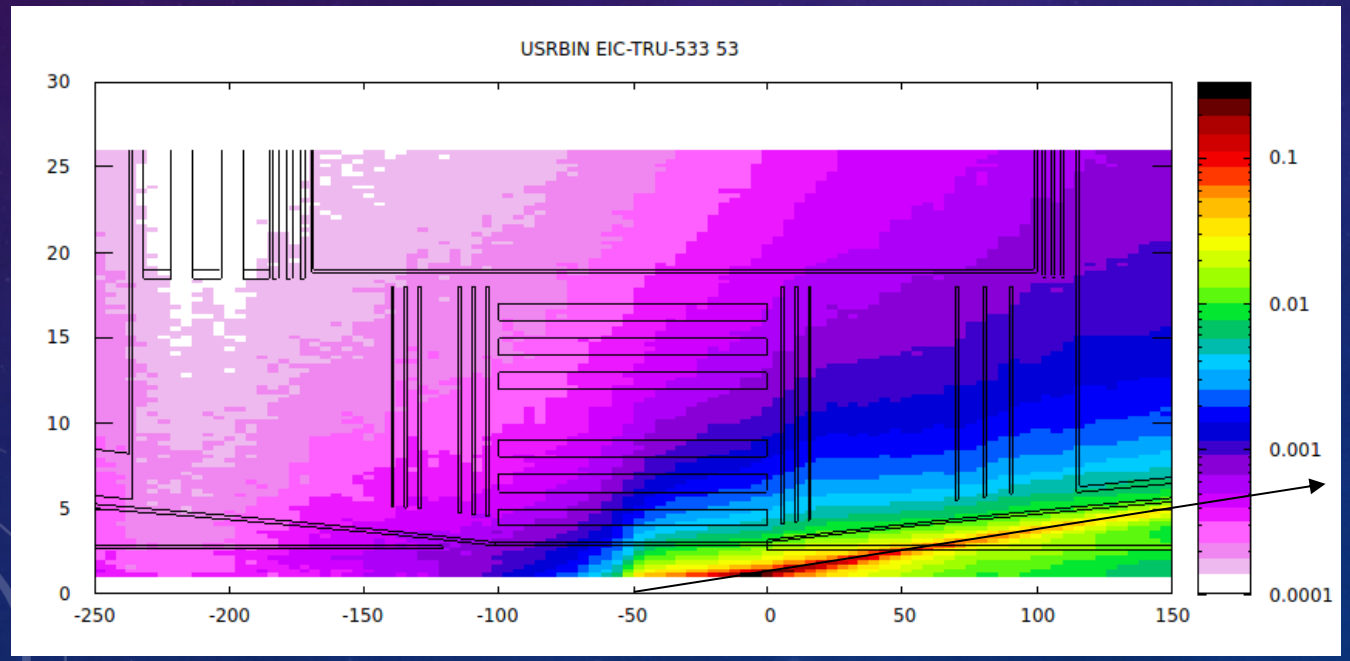
EXAMPLE 1MEV NEUTRON EQUIVALENT DOSE RATES

- SVT doses are well below $10^{14} – 10^{15}$ n/cm^2 lifetime tolerance
- EMCal levels very close to beam ≥ possible SiPM tolerance of 10^{11} n/cm^2

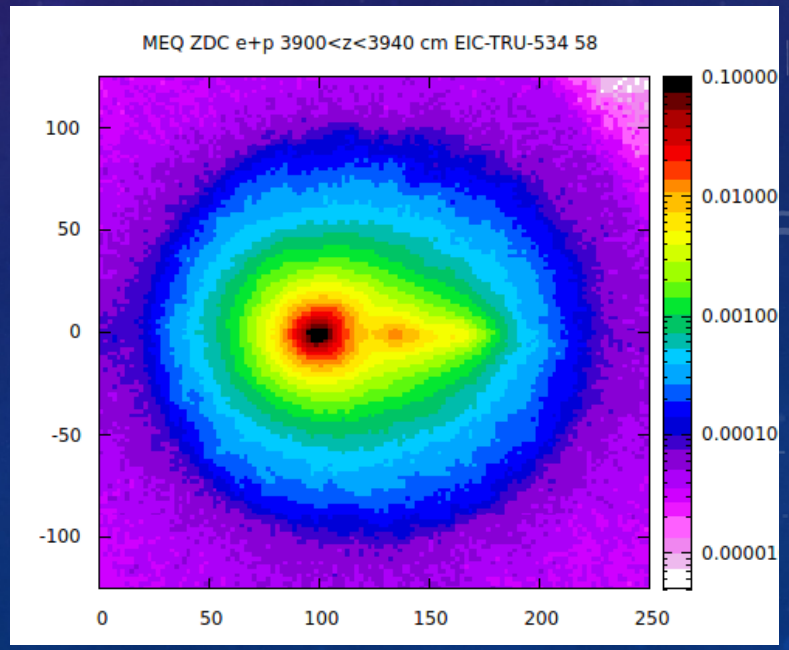
Column	2	3	4	5	6
Detector Region	$z - z_{IP}$ (cm)	r (cm)	Fig. 4 $n/\text{cm}^2/\text{proton}$	Fluence $n/\text{cm}^2/\text{sec}$	Fluence $n/\text{cm}^2/\text{year}$
Beam Pipe	0	3	$1.5 \cdot 10^{-6}$	$9.4 \cdot 10^{3}$	$9.4 \cdot 10^{10}$
SVT	0	4	$8.0 \cdot 10^{-7}$	$5.0 \cdot 10^{3}$	$5.0 \cdot 10^{10}$
	0	6	$5.0 \cdot 10^{-7}$	$3.1 \cdot 10^{3}$	$3.1 \cdot 10^{10}$
	0	8	$3.0 \cdot 10^{-7}$	$1.9 \cdot 10^{3}$	$1.9 \cdot 10^{10}$
	0	12	$2.0 \cdot 10^{-7}$	$1.3 \cdot 10^{3}$	$1.3 \cdot 10^{10}$
	0	14	$1.5 \cdot 10^{-7}$	$9.4 \cdot 10^{2}$	$9.4 \cdot 10^{9}$
	0	16	$1.0 \cdot 10^{-7}$	$6.3 \cdot 10^{2}$	$6.3 \cdot 10^{9}$
e-EMCal	−250	10	$1.0 \cdot 10^{-6}$	$6.3 \cdot 10^{3}$	$6.3 \cdot 10^{10}$
e-EMCal	−250	20	$6.0 \cdot 10^{-7}$	$3.8 \cdot 10^{3}$	$3.8 \cdot 10^{10}$
h-EMCal	350	15	$5.0 \cdot 10^{-6}$	$3.1 \cdot 10^{4}$	$3.1 \cdot 10^{11}$
h-EMCal	350	30	$2.0 \cdot 10^{-6}$	$1.3 \cdot 10^{4}$	$1.3 \cdot 10^{11}$
ZDC	3940	a	$1.0 \cdot 10^{-5}$	$6.3 \cdot 10^{4}$	$6.3 \cdot 10^{11}$
ZDC	3940	b	$3.0 \cdot 10^{-6}$	$1.9 \cdot 10^{4}$	$1.9 \cdot 10^{11}$

BACKGROUND FROM *ep* (Physics) Collisions:

- 18 ⊗275 GeV^2
- Color scale is 1MeV n/cm^2 per inelastic ep collision
- Scale by $L\sigma_{Tot}$ = (10^{33}/cm^2/sec)(45μb) = 45,000/sec
- Peak dose in Si trackers is ~ 2•10^9 n/cm^2/year



- Neutron dose in ZDC from ep collisions centered on line-of-sight from IP.
- ZDC Central dose = 4.5•10^{10} n/cm^2/year



OUTLOOK

- Synch_bgd (SLAC) vs SYNRAD comparison will be completed by September
- Studies of Synchrotron Radiation and Beam-Gas backgrounds need to continue until CD2 and the Project Detector TDR are complete.
  - Require equivalent of 100% FTE Post-Doc each FY beyond 2021, or approximately $135K/year (fully loaded).
- With additional equivalent of 75% FTE Post-Doc funding for balance of calendar year we can implement more detailed detector designs as provided by the Detector Collaborations in preparation of the Dec deadline, including occupancy estimates from beam-gas interactions
  - Funding request for this year was cut by 40% from level required to sustain the effort for the full year.

BACKGROUND FROM *ep* Collisions (Physics):

BEAM-GAS (TOP)
ep (BOTTOM)

- Neutron dose from Beam-Gas interactions centered on beamline
- Neutron dose from ep collisions centered on line-of-sight from IP.