Radiation environment in inner vertex detectors

Sonny Fecanin

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What the project entails

- Radiation in innermost detectors
- Sources of radiation:
  - Electron-proton collisions
  - Proton beam-gas events
  - Electron beam-gas events
- Finding fluence, flux, and dose in vertex detectors
- Creating 2d histograms of flux in SVT region

What hasn’t been done

- Creation of 2d histograms of fluence and dose
  - Fluence: charged particles traverse curved paths
  - Dose: would have to edit GEANT4 to extract necessary info
- Sources of radiation:
  - Synchrotron radiation
  - Low energy neutrons
  - Low energy photons

Running scheme

- EIC runs max 26 weeks/yr at max luminosity
- Values reported on the following slides are for 10 years
- Energies, luminosities, and rates of the various sources of radiation:

Collision type	Rate	Energy	Luminosity
Electron-proton	500 kHz	10x275 GeV	1e34 $\mathrm{cm}^{-2}\mathrm{s}^{-1}$
Proton beam-gas	35kHz	275 GeV	----------
Electron beam-gas	3.2MHz	10 GeV	----------
Synchrotron rad.	10MHz	----------	----------

Fluences

- Charged particle fluences are extracted from path length in detector hits output
- Uncharged particle fluences are determined computationally
- EM fluences include photons and e-/e+
- ep = electron-proton collisions, pbg = proton beam-gas events and ebg = electron beam-gas events

Charged hadron Fluence (/cm^2) Proton Fluence (/cm^2) EM Fluence (/cm^2)

Detector	ep	pbg	ebg	Total	ep	pbg	ebg	Total	ep	pbg	ebg	Total
Inner	4.8e11	3.6e10	0	5.2e11	2.5e10	4.0e9	0	2.9e10	6.5e11	3.0e11	9.3e12	1.0e13
Middle	2.7e11	2.6e9	0	3.0e11	1.3e10	2.7e9	0	1.5e10	3.9e11	2.2e11	6.7e12	7.3e12
Outer	4.5e10	5.1e8	0	5.0e10	2.2e9	6.7e8	0	2.9e9	9.6e10	3.7e10	1.5e12	1.6e12

Neutron fluences

- There are many lower energy neutrons (<1MeV) floating around which aren't simulated properly
- Scaled fluences are >1MeV fluences multiplied by total/>1MeV fluence ratio extracted from wiki
- ep = electron-proton collisions, pbg = proton beam-gas events and ebg = electron beam-gas events

Total neutron (scaled) (/cm^2) Total neutron (unscaled) (/cm^2) >20MeV neutron(/cm^2)

Detector	ep	pbg	ebg	Total	ep	pbg	ebg	Total	ep	pbg	ebg	Total
Inner	6.0e10	1.4e10	6.3e9	8.0e10	3.0e10	4.3e9	1.9e8	3.5e10	2.2e10	3.8e9	0	2.6e10
Middle	5.3e10	1.1e10	5.4e9	6.9e10	1.7e10	2.7e9	1.5e8	2.0e10	1.1e10	2.2e9	0	1.3e10
Outer	2.5e10	4.0e9	4.1e9	3.4e10	5.7e9	8.5e8	1.2e8	6.6e9	2.3e9	5.0e8	0	2.8e9

EIC vs ALICE dimensions

- ALICE assumes a 10 year runtime
- The dimensions of the three innermost detectors in ALICE and EIC are shown below
  - All dimensions are in mm

ALICE inner detector dimensions

Detector	Inner radius	Outer radius	Min z	Max z
SPD1	39	39.71	-165	165
SPD2	76	76.71	-165	165
SDD1	140	140.75	-222	222

EIC inner detector dimensions

Detector	Inner radius	Outer radius	Min z	Max z
Inner vertex	35.98	36.02	-135	135
Middle vertex	47.98	48.02	-135	135
Outer vertex	119.98	120.02	-135	135

A. Morsch and B. Pastircak ALICE Internal Note 2002-28. “Radiation in ALICE detectors and electron racks”

Neutron Fluence comparison to ALICE

- Neutron fluences reported for EIC are scaled values
- Greater proportion of EIC fluence is due to beam-gas compared to ALICE

Total neutrons - data is a combination of our simulation outputs and EIC wiki info

	ALICE Fluence (/cm^2)				EIC Fluence (/cm^2)				EIC/ALICE ratio		
Detector	**IP**	**Beam-gas**	**Halo**	**Total**	**IP**	**pbg**	**ebg**	**Total**	**IP**	**bg + halo**	**Total**
Inner	8.0e11	1.8e10	3.1e10	8.5e11	6.0e10	1.4e10	6.3e9	8.0e10	0.08	0.41	0.09
Middle	5.6e11	1.4e10	2.4e10	6.0e11	5.3e10	1.1e10	5.4e9	6.9e10	0.09	0.43	0.12
Outer	4.5e11	1.4e10	2.2e10	4.9e11	2.5e10	4.0e9	4.1e9	3.4e10	0.06	0.23	0.07

Fluence comparison to ALICE

- Greater proportion of EIC fluence is due to beam-gas compared to ALICE
- EIC fluences are approximately 1/10 that of ALICE fluences

Special fluence - data is solely from our simulation output

	ALICE Fluence (/cm^2)		EIC Fluence (/cm^2)		EIC/ALICE ratio	
Detector	**>20MeV n**	**Charged hadrons**	**>20MeV n**	**Charged hadrons**	**>20MeV n**	**Charged hadrons**
Inner	3.4e11	4.0e12	2.6e10	5.2e11	0.08	0.13
Middle	1.4e11	1.2e12	1.3e10	3.0e11	0.09	0.25
Outer	3.7e11	3.8e11	2.8e9	5.0e10	0.08	0.13

Dose comparison to ALICE

	ALICE dose (Gy)				EIC dose (Gy)				EIC/ALICE ratio		
Detector	**IP**	**Beam-gas**	**Halo**	**Total**	**IP**	**pbg**	**ebg**	**Total**	**IP**	**bg + halo**	**Total**
Inner	2000	250	500	2750	190	46	988	1224	0.10	1.38	0.45
Middle	510	48	120	680	117	34	745	896	0.23	4.64	1.32
Outer	190	12	45	250	25	4.6	64	94	0.13	1.20	0.38

- Total expected dose is similar to that of ALICE
- Dose contributions from beam-gas events are much more significant in EIC than ALICE:
  - 80% of total dose in EIC is from electron beam-gas contributions
  - Only 15% of the dose in EIC is due to IP collisions

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Summary

- Overall radiation in the innermost (vertex) detectors of EIC for a 10 year period can be expected to similar to that predicted for ALICE
- Beam-gas events are a much more significant part of radiation in EIC as compared to ALICE, contributing to 85% of the total dose
- Dose may be a bit higher than what was reported today, because of radiation that wasn’t considered
  - <600MeV photons
  - synchrotron radiation

References

- Radiation Doses information on EIC wiki

https://wiki.bnl.gov/EPIC/index.php?title=Radiation_Doses

- ALICE radiation report: B. Pastircak, A. Morsch, ”Radiation in ALICE Detectors and Electronic Racks”, EDMS 358706, 2005. ALICE Internal Note ALICE-INT-2002-028
- ALICE predicted radiation for runs 3 and 4: RadiationLoadAfterLS2.pdf (cern.ch)