# Radiation environment in inner vertex detectors

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# Progress

- e-p collisions and proton beam gas simulations have been conducted—these are the main contributions to radiation
  - Contributions due to electron beam gas events and synchrotron radiation will also be looked at.
- We still need to conduct ep collision simulations with all proper parameters which
  - Account for lower energy particles
  - Account for 25 mrad beam crossing angle
- Code for analysis of the data is complete

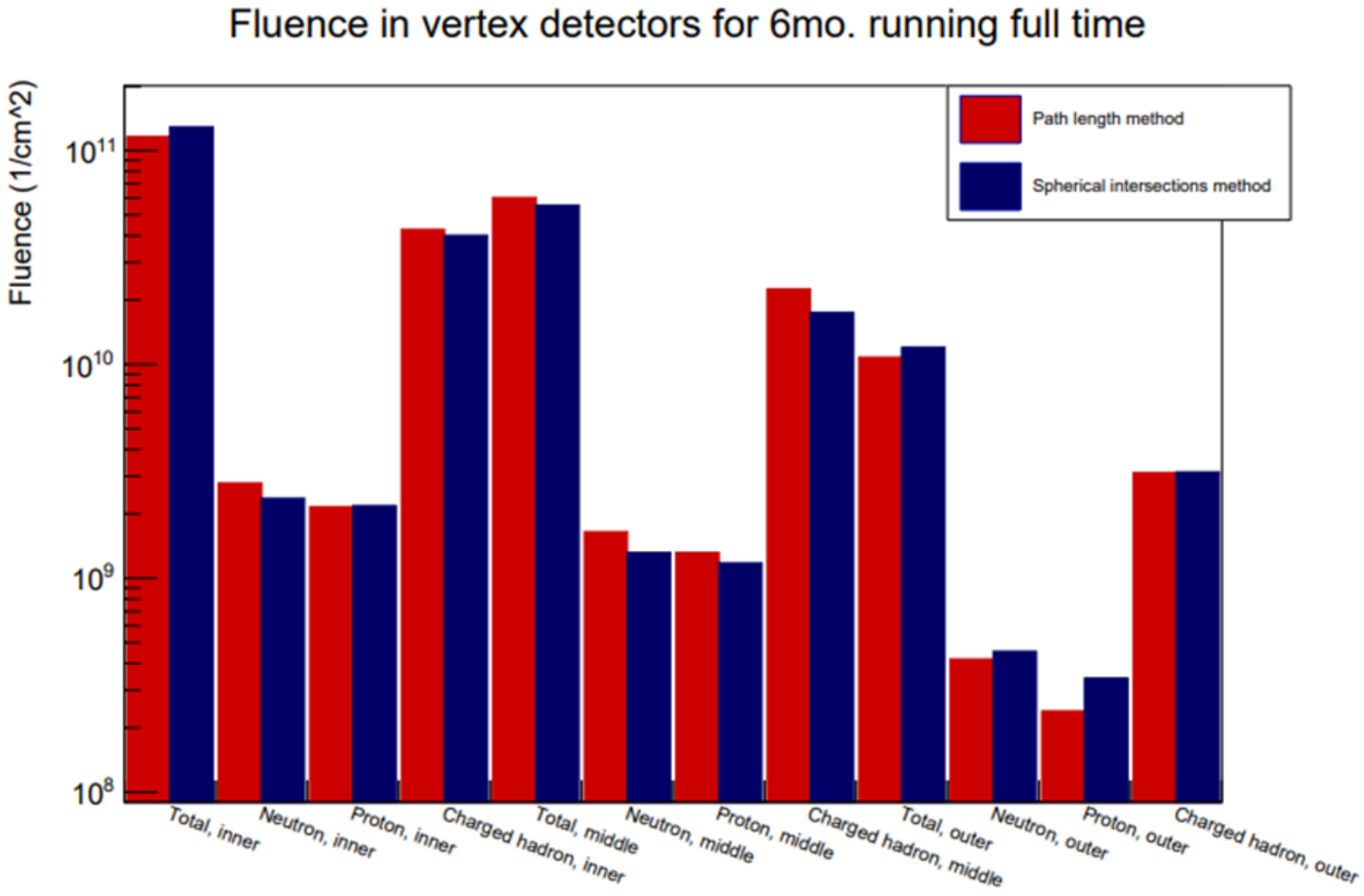
# Running scheme

- EIC runs max 26 weeks/yr at max luminosity
- Values reported on the following slides are for one run period (1 yr)
- 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 | ---------- | ---------- |

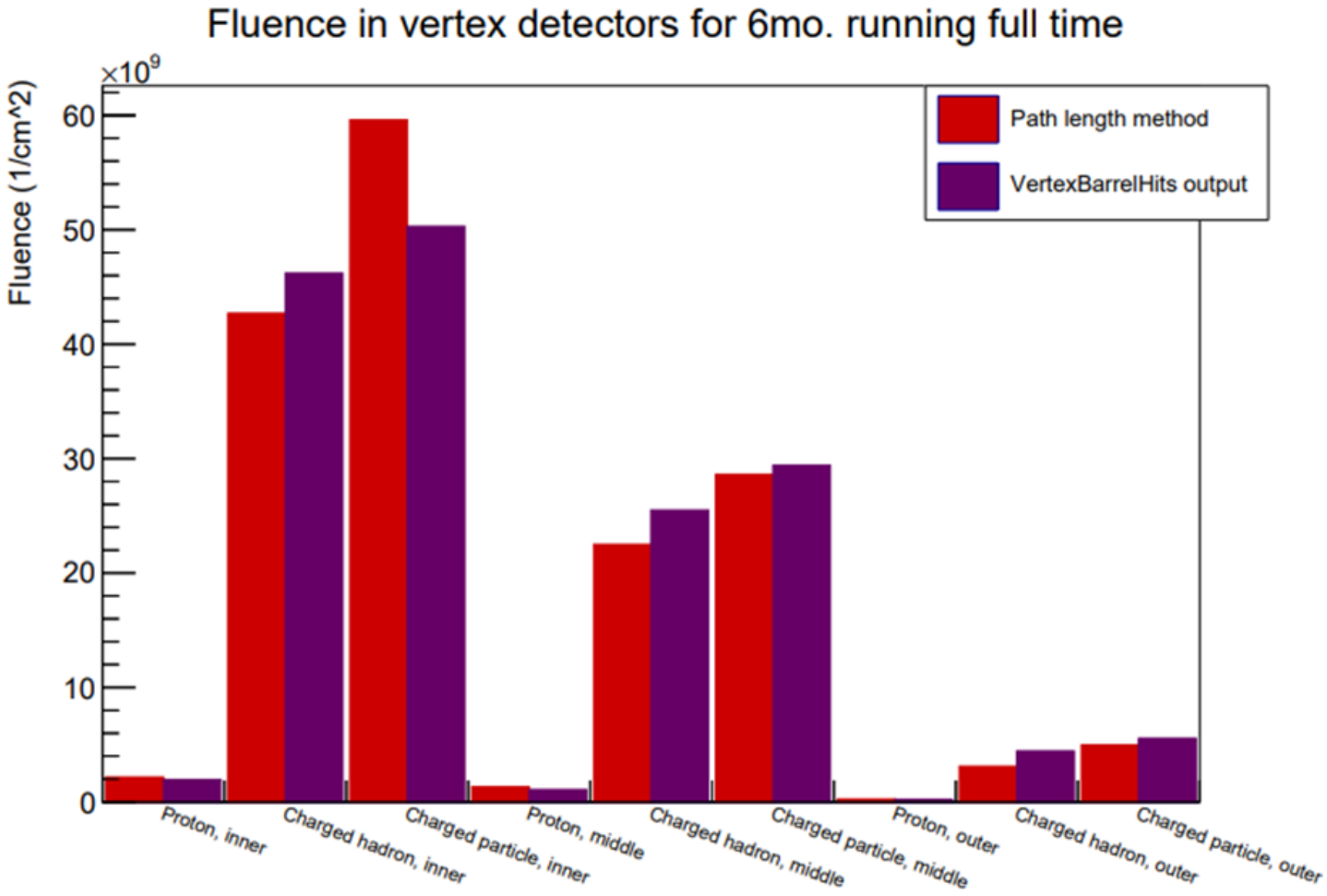
# Calculating Fluence

- Path Length method
  - Assume straight path – only accurate for uncharged
  - Used for neutron fluence
- Spherical method



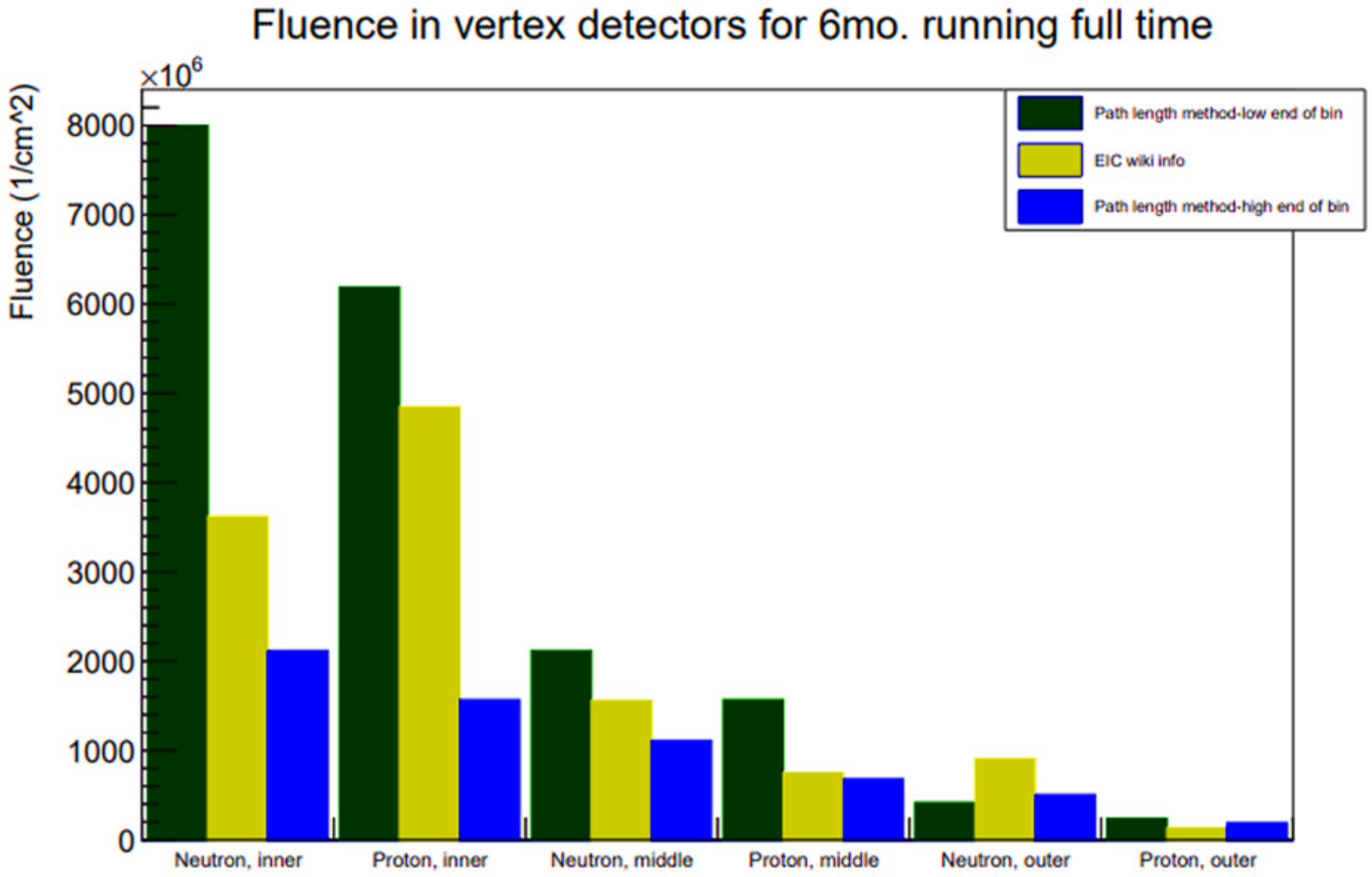
# Calculating Fluence

- Path Length method
  - Assume straight path – only accurate for uncharged
  - Used for neutron fluence
- Spherical method
- Detector hits output
  - Only reports detected particles
  - Used for proton and charged hadron fluence



# Comparison to EIC wiki

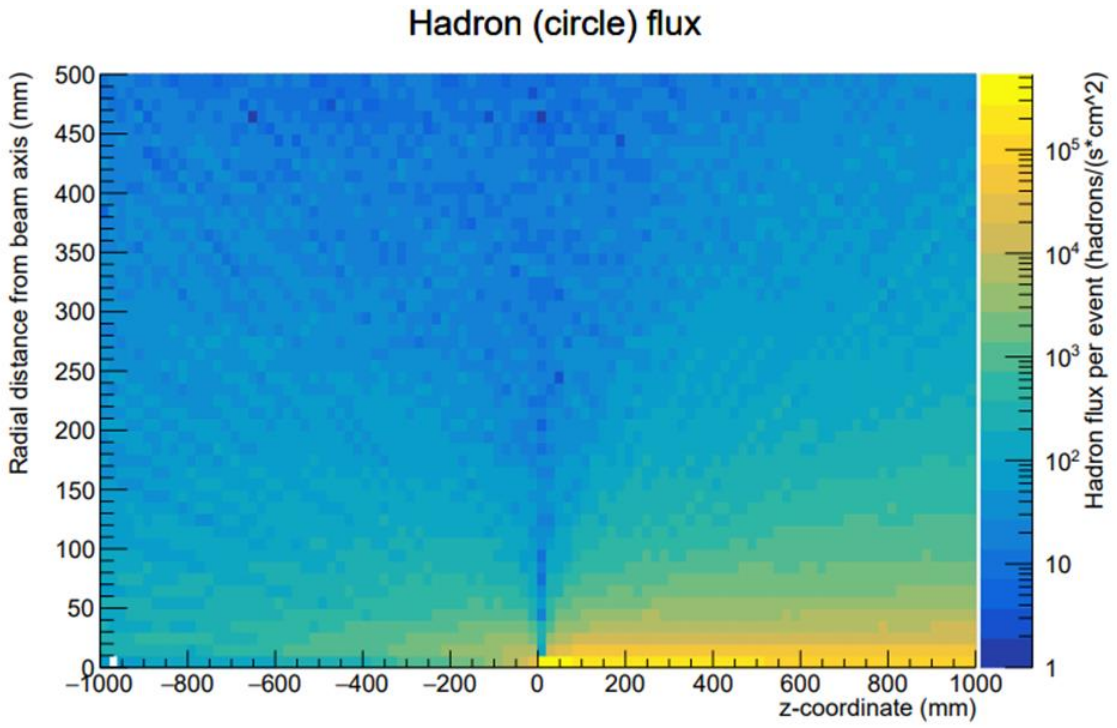
- EIC wiki calculation of fluence
- EIC wiki resolution is poor, but using the path length method to find fluence at the top and bottom of the bins does in fact bind the values reported by the wiki



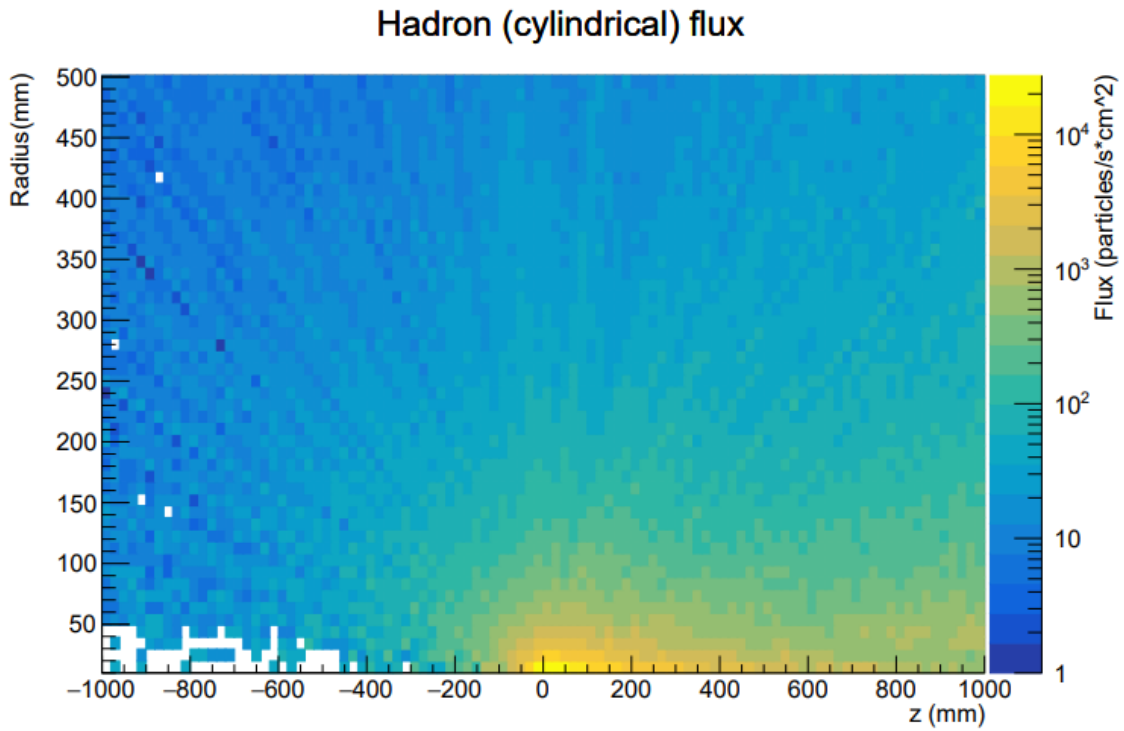

Radiation info on EIC wiki: [Radiation Doses - Electron-Proton/Ion Collider Experiment (bnl.gov)]

# Calculating flux using MCParticles output

## Circular flux




## Cylindrical flux



# Flux using VertexBarrelHits output and EIC wiki

- EIC wiki uses the same method as fluence to find flux; therefore our results aren't comparable to theirs.
- Flux through detectors using VBH:
  - dependent on particle hits, so particles may be counted multiple times

**Flux due to ep collisions in $Hz/cm^2$**

| '///////, | Charged particle flux | | Charged hadron flux | | Proton flux | |
|---|---|---|---|---|---|---|
| Detector | VBH | Cylind | VBH | Cylind | VBH | Cylind |
| Inner | 1724 | 1349 | 1588 | 1322 | 67.95 | 63.86 |
| Middle | 1164 | 845.5 | 1019 | 825.2 | 45.4 | 42.98 |
| Outer | 277.3 | 166.0 | 237.5 | 160.1 | 11.30 | 11.30 |

**VBH** = particle counts in VertexBarrelHits output

**Cylind** = MC particles count using cylindrical method to find flux

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- Flux through detectors using VBH:
  - dependent on particle hits, so particles may be counted multiple times

**Flux due to proton beam gas interactions in $Hz/cm^2$**

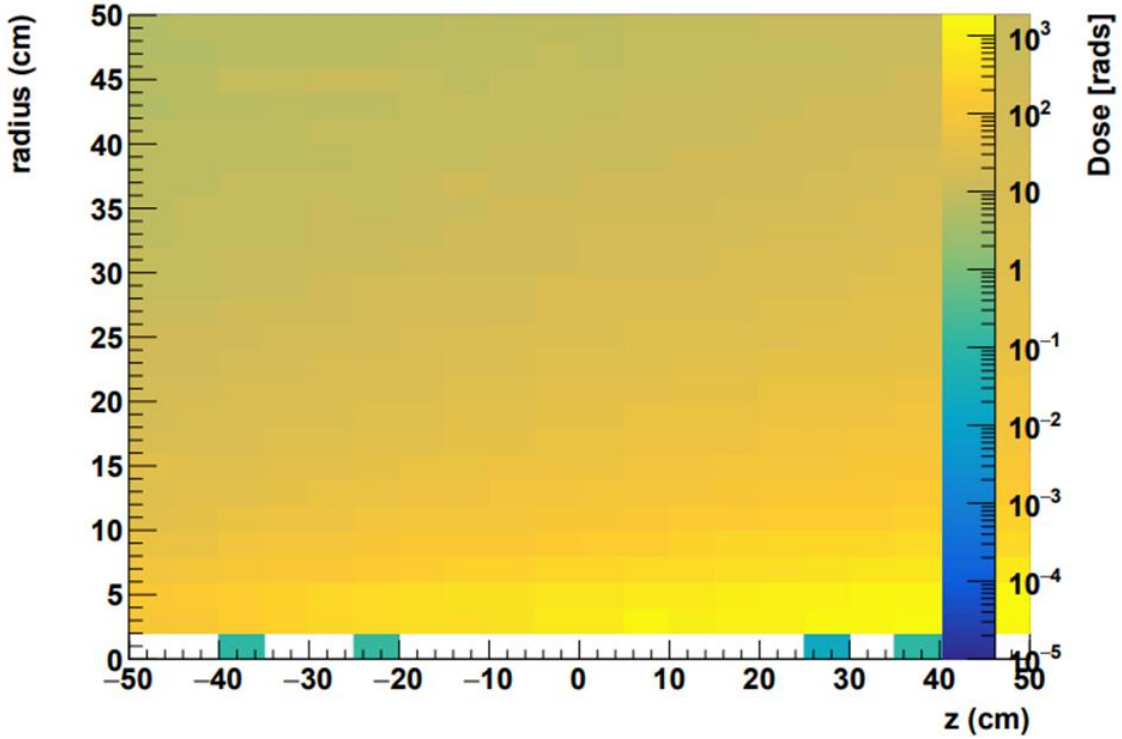
| '///////, | Charged particle flux | | Charged hadron flux | | Proton flux | |
|---|---|---|---|---|---|---|
| Detector | VBH | Cylind | VBH | Cylind | VBH | Cylind |
| Inner | 218.2 | 26.25 | 20.46 | 15.47 | 2.464 | 2.292 |
| Middle | 175.5 | 18.27 | 17.11 | 11.86 | 4.212 | 2.149 |
| Outer | 34.18 | 5.639 | 5.622 | 4.333 | 1.032 | 0.774 |

**VBH** = particle counts in VertexBarrelHits output

**Cylind** = MC particles count using cylindrical method to find flux

# Dose Calculations

- Detector hits simulation output
- EIC wiki dose: charged hadron dose for ep collisions (in rad)




**Comparison between VertexBarrelHits output and charged hadron dose reported on EIC wiki**

| ‘///////, | e-p collisions | | Beam-gas events | |
|---|---|---|---|---|
| Detector | VBH | wiki | VBH | wiki |
| Inner | 1498 | 788 | 102.6 | 22.5 |
| Middle | 808.4 | 661 | 77.9 | 32.0 |
| Outer | 172.7 | 84.6 | 16.6 | 9.16 |

All doses are reported in rad

Radiation info on EIC wiki: [Radiation Doses - Electron-Proton/Ion Collider Experiment (bnl.gov)]

# 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”

# Fluence comparison to ALICE

- There are many lower energy neutrons floating around -- our simulation discards those with Ekin<10MeV
- 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) | | | ALICE/EIC ratio | | |
|---|---|---|---|---|---|---|---|---|---|
| **Detector** | **IP collisions** | **Beam-gas** | **Total** | **IP collisions** | **Beam-gas** | **Total** | **IP collisions** | **Beam-gas** | **Total** |
| Inner | 8e11 | 1.8e10 | 8.5e11 | 6.84e10 | 1.41e10 | 8.25e10 | 11.7 | 1.28 | 10.3 |
| Middle | 5.6e11 | 1.4e10 | 6.0e11 | 5.32e10 | 1.36e10 | 6.60e10 | 10.7 | 1.03 | 9.1 |
| Outer | 4.5e11 | 1.4e10 | 4.9e11 | 4.39e10 | 1.22e10 | 5.61e10 | 10.3 | 1.15 | 8.7 |

# Fluence comparison to ALICE

- There are many lower energy neutrons floating around -- our simulation discards those with Ekin<10MeV
- Greater proportion of EIC fluence is due to beam-gas compared to ALICE
- Overall, fluence seems to be 10% that of ALICE

## Special fluence - data is solely from our simulation output

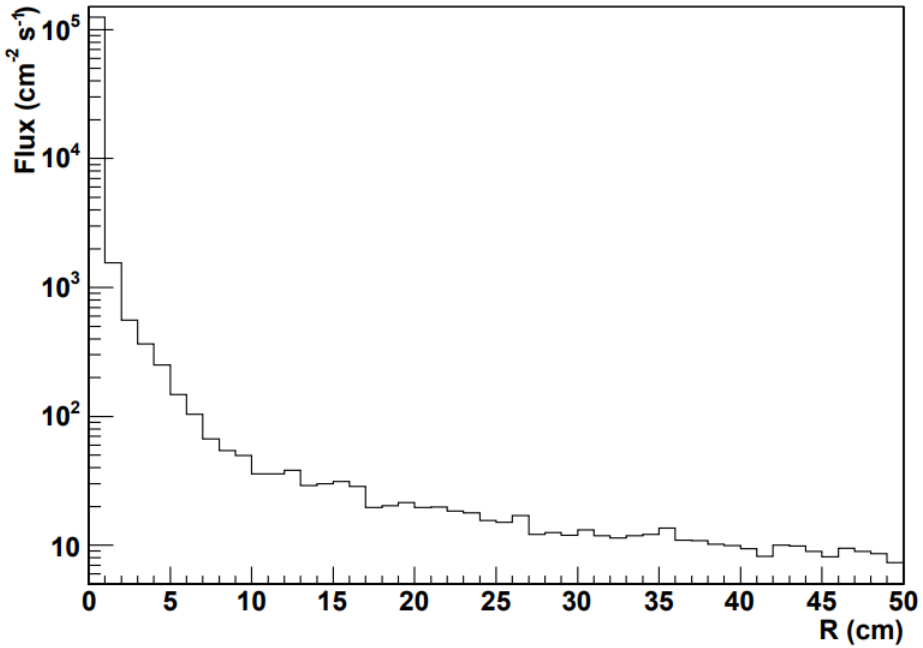
| | ALICE Fluence (/cm^2) | | EIC Fluence (/cm^2) | | ALICE/EIC ratio | |
|---|---|---|---|---|---|---|
| **Detector** | **>20MeV n** | **Charged hadrons** | **>20MeV n** | **Charged hadrons** | **>20MeV n** | **Charged hadrons** |
| Inner | 3.4e11 | 4.0e12 | 2.33e10 | 5.00e11 | 14.59 | 8.00 |
| Middle | 1.4e11 | 1.2e12 | 1.33e10 | 2.82e11 | 9.52 | 4.26 |
| Outer | 3.7e11 | 3.8e11 | 2.02e9 | 4.97e10 | 18.32 | 7.65 |

# Flux comparison to ALICE

- ALICE report doesn't include much about fluxes, other than a histogram of the circle-method flux at the tunnel entrance.
  - The highest flux at the tunnel entrance was reported to be $10^5$ Hz/cm$^2$
  - The most significant contribution to hadron flux was from charged hadrons.

**Hadron flux at the tunnel entrance as a function of distance from the beam axis**

(figure 4 in ALICE radiation report)



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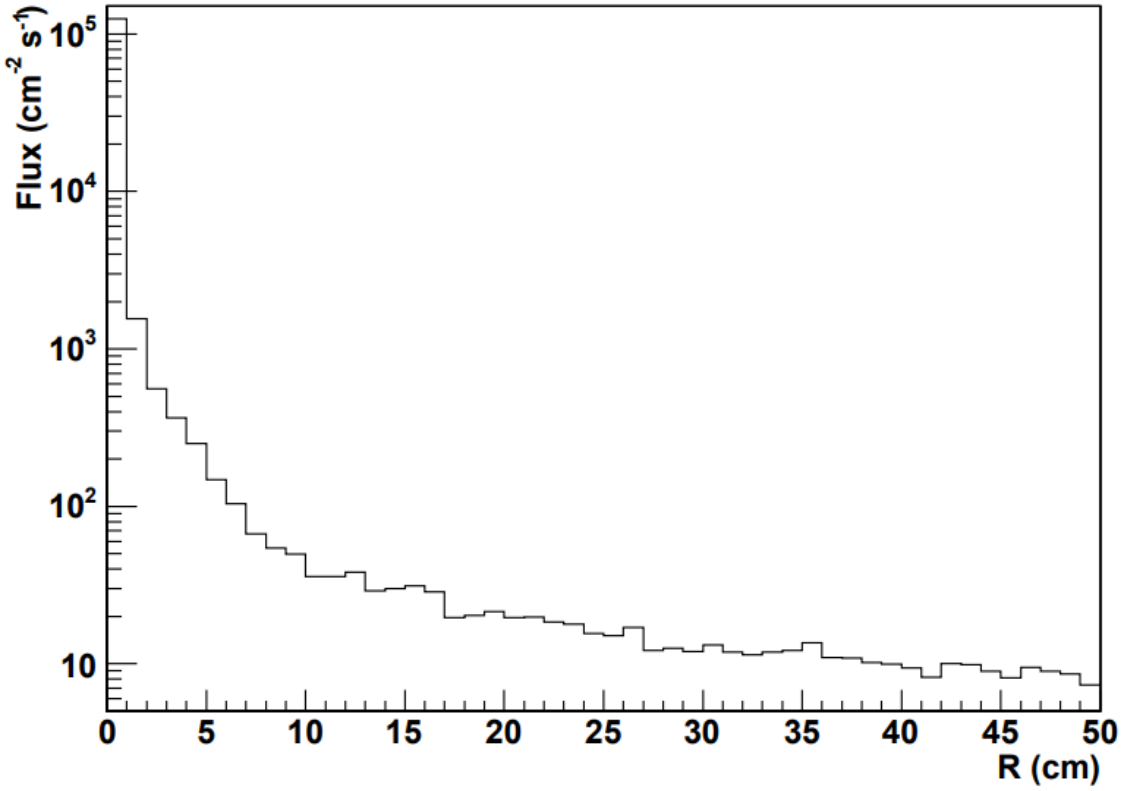
  - The highest flux at the tunnel entrance was reported to be $10^5$ Hz/$\mathrm{cm}^2$
  - The most significant contribution to hadron flux was from charged hadrons.
- High flux may be significant in detector occupancies

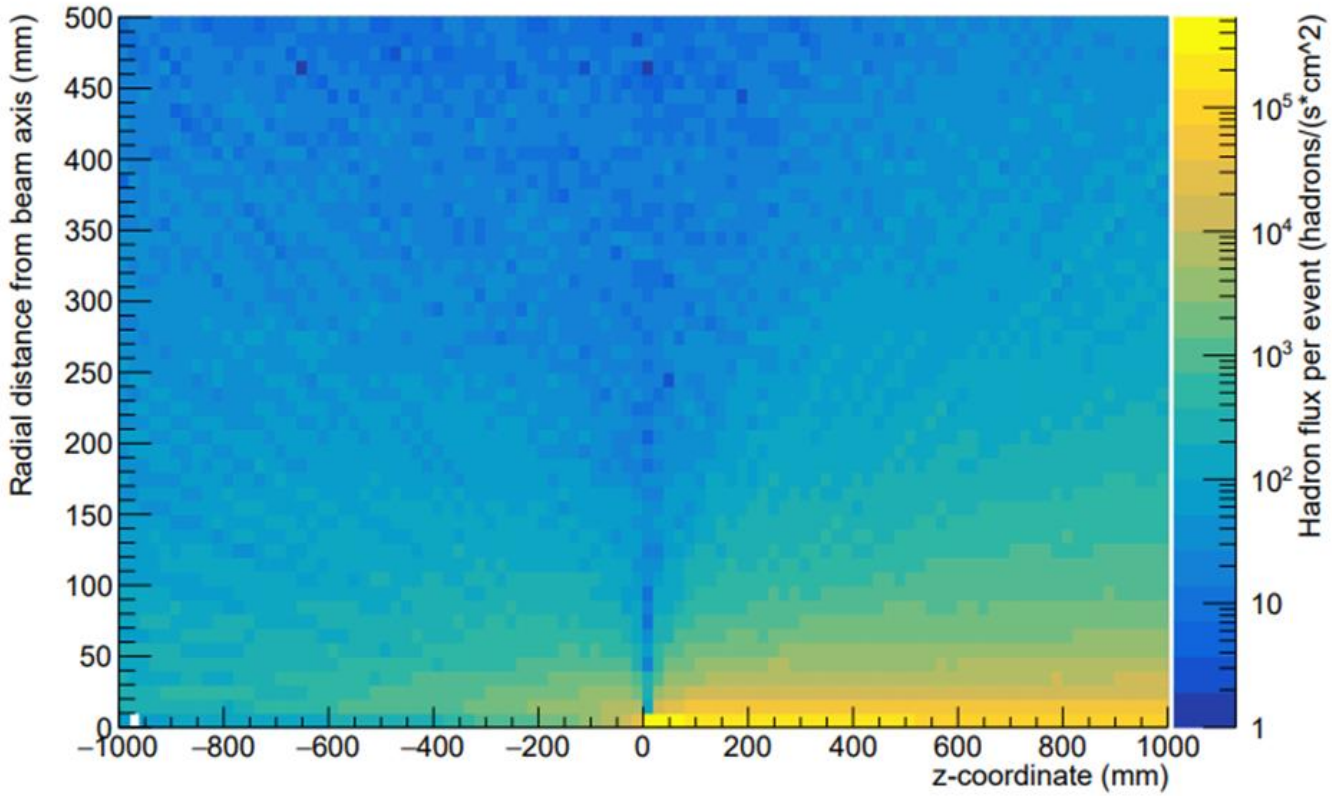
# Flux comparison to ALICE

- EIC max flux seems to be the same order of magnitude as ALICE

**ALICE hadron flux at some z value**




**EIC simulation hadron flux**



# Dose comparison to ALICE

| | ALICE dose (Gy) | | | EIC dose (Gy) | | | ALICE/EIC ratio | | |
|---|---|---|---|---|---|---|---|---|---|
| **Detector** | **IP collisions** | **Beam-gas** | **Total** | **IP collisions** | **Beam-gas** | **Total** | **IP collisions** | **Beam-gas** | **Total** |
| Inner | 2000 | 250 | 2750 | 205.2 | 47.8 | 253.0 | 9.75 | 5.23 | 10.9 |
| Middle | 510 | 48 | 680 | 124.2 | 34.8 | 159.0 | 4.11 | 1.38 | 4.28 |
| Outer | 190 | 12 | 250 | 27.4 | 5.5 | 32.8 | 6.93 | 2.18 | 7.62 |

- Dose is approx. 15% that of ALICE
- Dose contributions from beam-gas events are more significant in EIC than ALICE
  - 20% of total dose in EIC is from beam-gas contributions
  - This data does not account for electron beam-gas events in EIC

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

# Summary of tentative results

- Overall radiation in the innermost (vertex) detectors of EIC for a 10 year period can be expected to only be 10% - 15% that of the innermost detectors of ALICE
- Beam-gas events are a more significant part of radiation in EIC as compared to ALICE, but still only ~20-25% of the total radiation
- Simulations are still being run, and eventually electron beam-gas events and synchrotron radiation will also be accounted for in the EIC radiation results.

# References


- Radiation Doses information on EIC wiki

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

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