# Radiation environment in inner vertex detectors

Sonny Fecanin

8/8/2023

# What the project entails

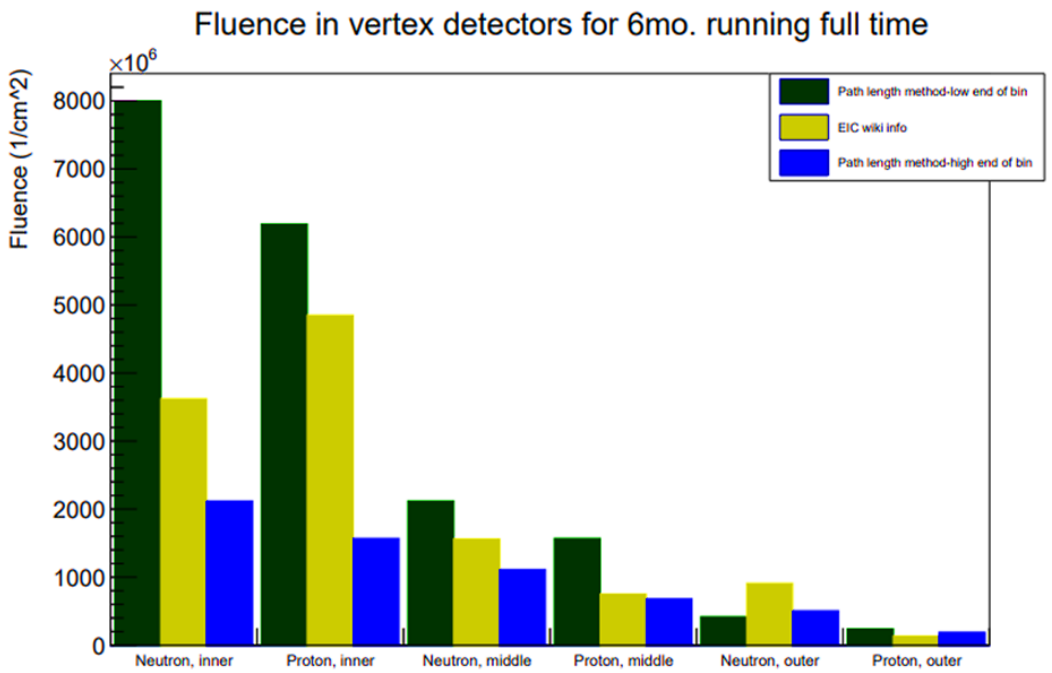
- Radiation environment around collision point and innermost radii
- Sources of radiation:
  - Electron-proton collisions
  - Proton beam-gas events
  - Electron beam-gas events
  - Synchrotron radiation
- Finding fluence and dose in vertex detectors
- Creating 2d histograms of fluence, flux and dose in the inner 300mm region.

# Fluence Methods

- VertexBarrelHits branch: gives fluence of charged particles within vertex detectors
- MCParticles branch: output can be used to find fluence of uncharged particles
  - Use knowledge of vertex and endpoint to sum up paths within cylindrical shell

# Fluence Results

- Comparison to wiki:
  - This is for proton beam-gas->
- Expected fluences in 6 months running worst case scenario
  - 26 weeks/year at max luminosity




## Neutron Fluences (all neutrons)

| Detector | IP collisions | Beam-gas | Total |
|---|---|---|---|
| Inner | 6.84e9 | 1.41e9 | 8.25e9 |
| Middle | 5.23e9 | 1.36e9 | 6.60e9 |
| Vertex | 4.39e9 | 1.22e9 | 5.61e9 |

## Special Fluences – all contributions

| Detector | >20MeV n | Charged hadrons |
|---|---|---|
| Inner | 2.33e9 | 5.00e10 |
| Middle | 1.33e9 | 2.82e10 |
| Vertex | 2.02e8 | 4.97e9 |

# Dose Calculations

- Detector hits simulation output (charged hadrons only in table below)
- EIC wiki dose: charged hadron dose
  - Averaged over the bins from -15 to 15cm within which the vertex detectors are located

**Comparison between VBH output and EIC wiki: charged hadron dose,**

| ‘///////, | e-p collisions | | Beam-gas events | |
|---|---|---|---|---|
| Detector | VertexBarrelHits | EIC wiki | VertexBarrelHits | EIC 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

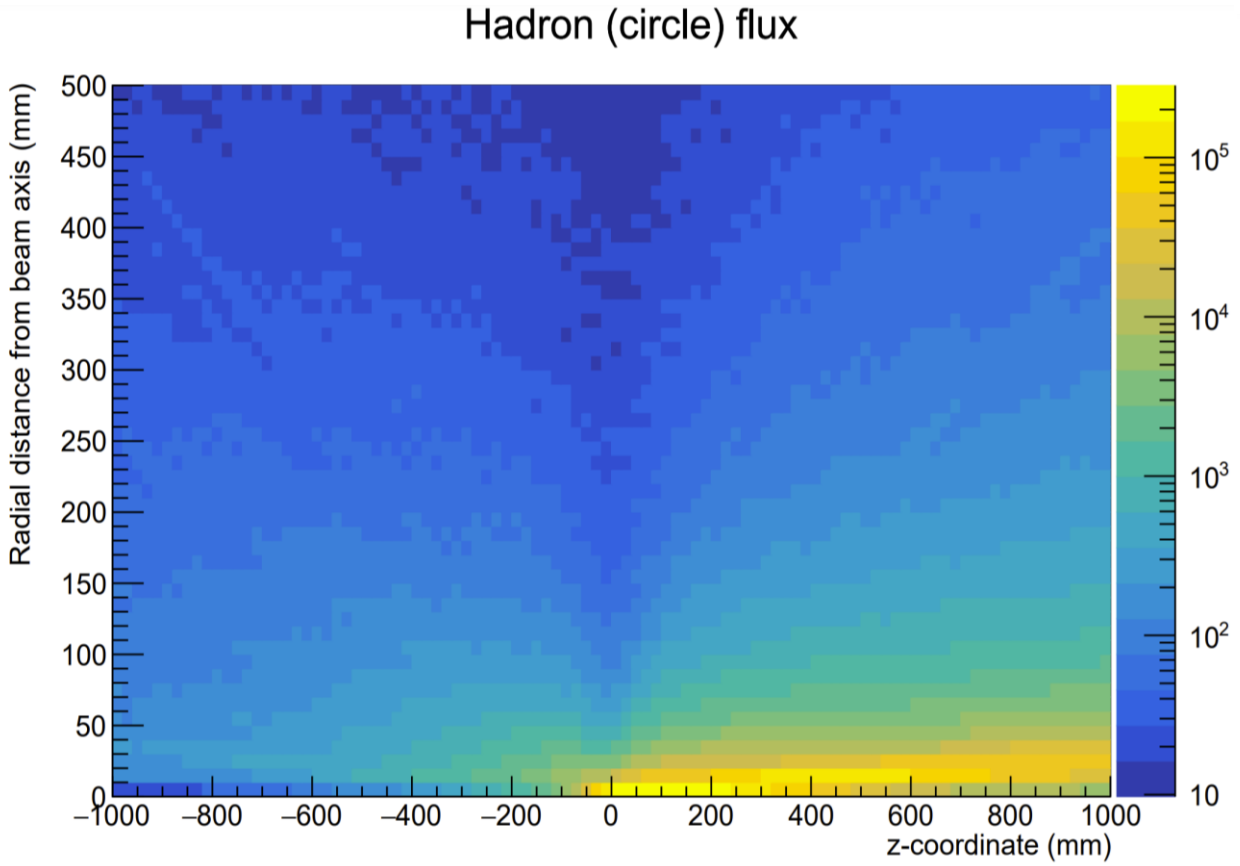
Radiation info on EIC wiki: Radiation Doses - Electron-Proton/Ion Collider Experiment (bnl.gov)

# Flux Methods

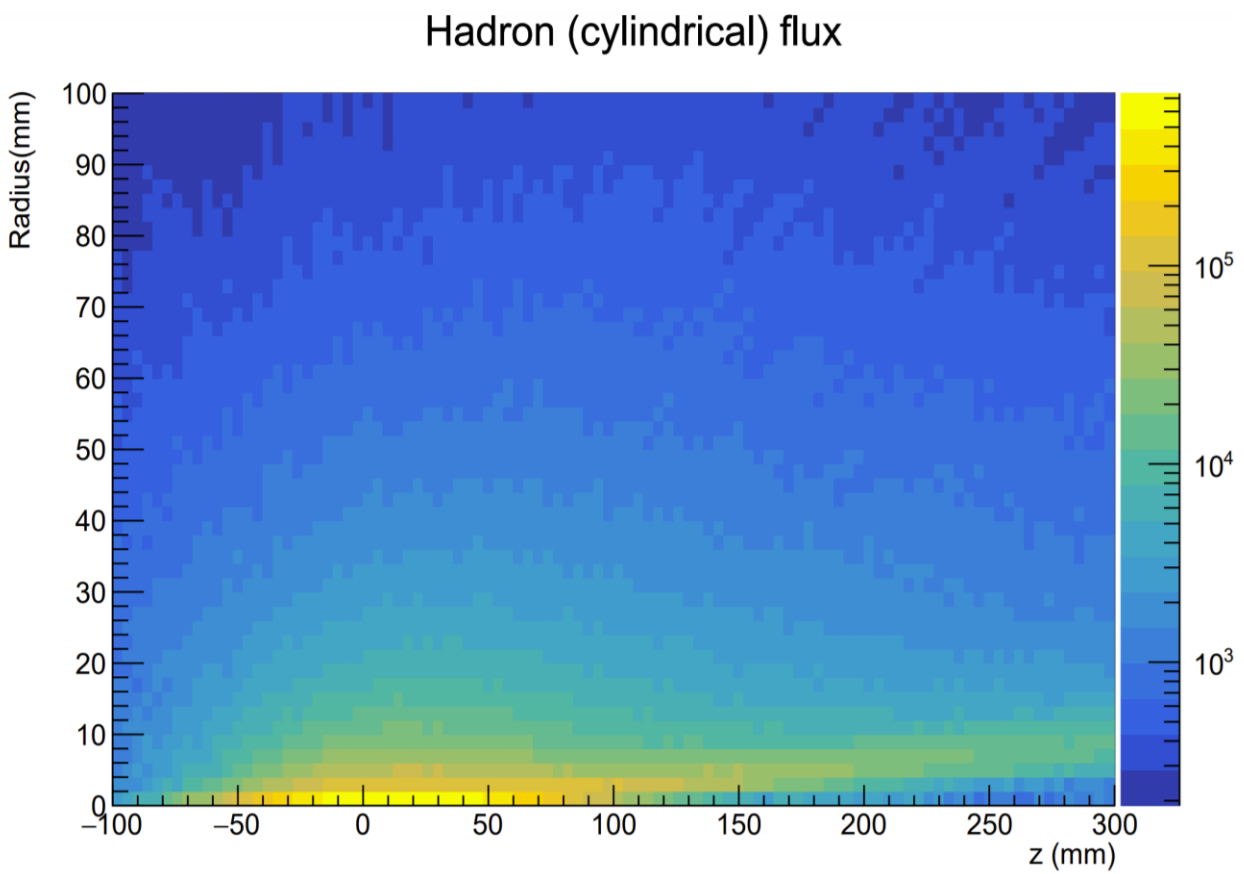
- Method used: counting number of particles intersecting with surface, scaling by rate at which events occur and 1/surface area
- Instantaneous flux is not as important to radiation, but may be significant in detector occupancies

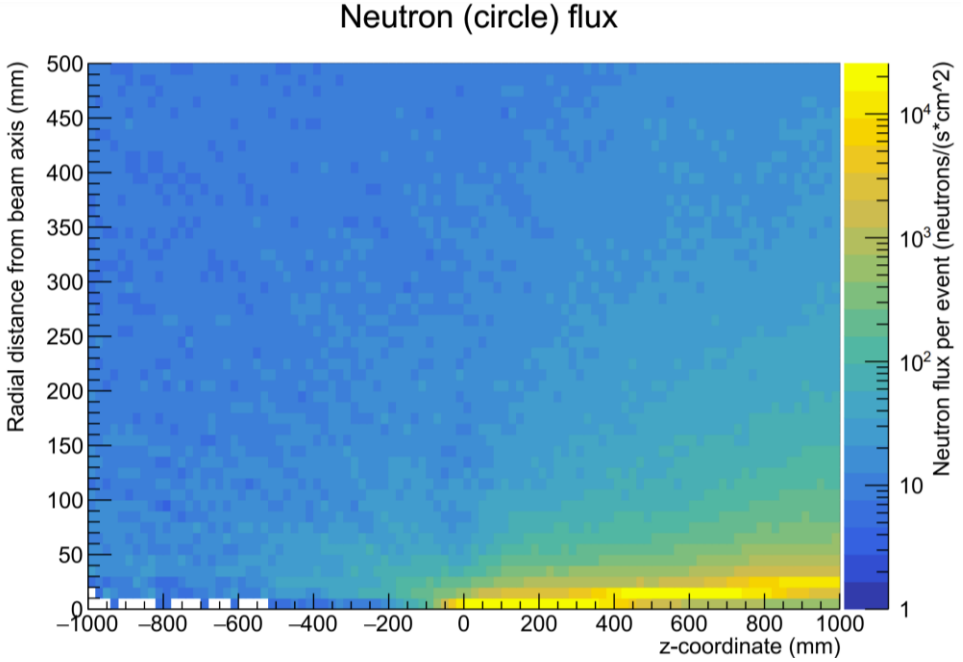
# Flux Plots

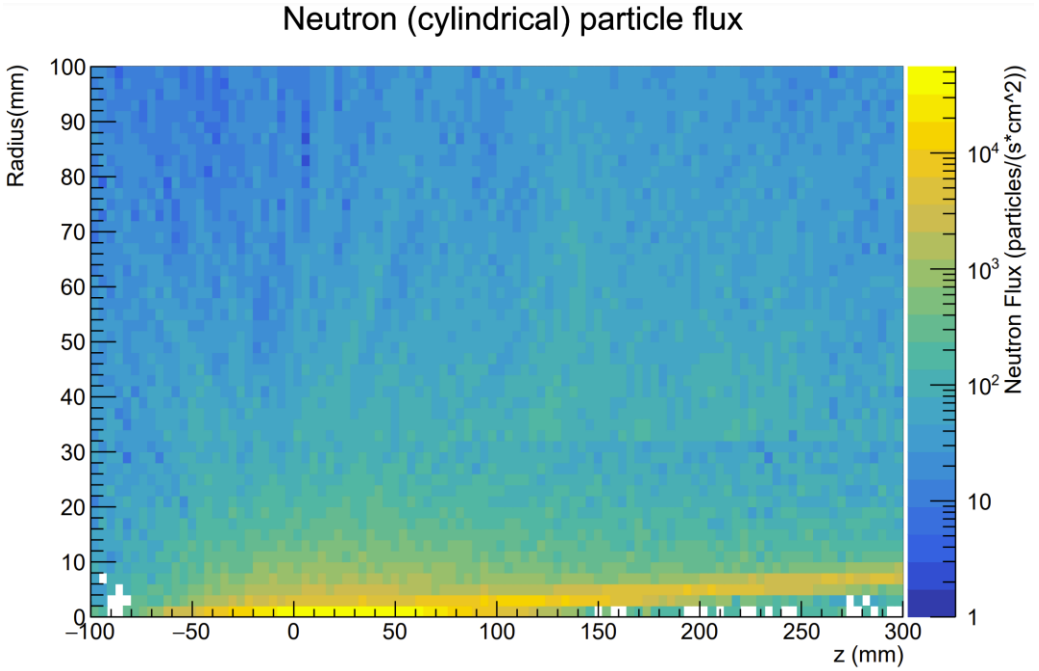
## Circular flux

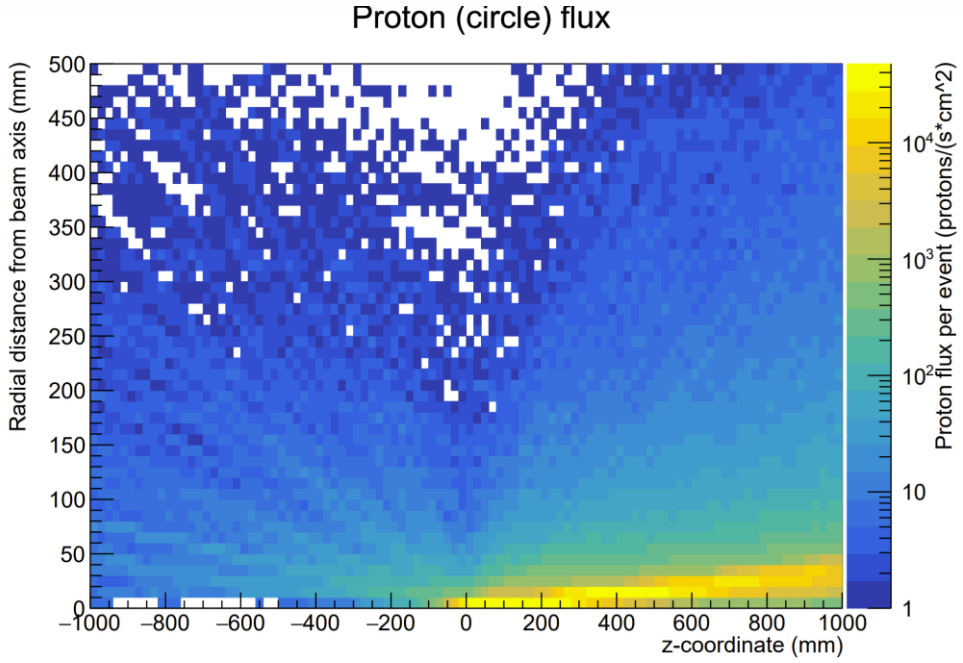


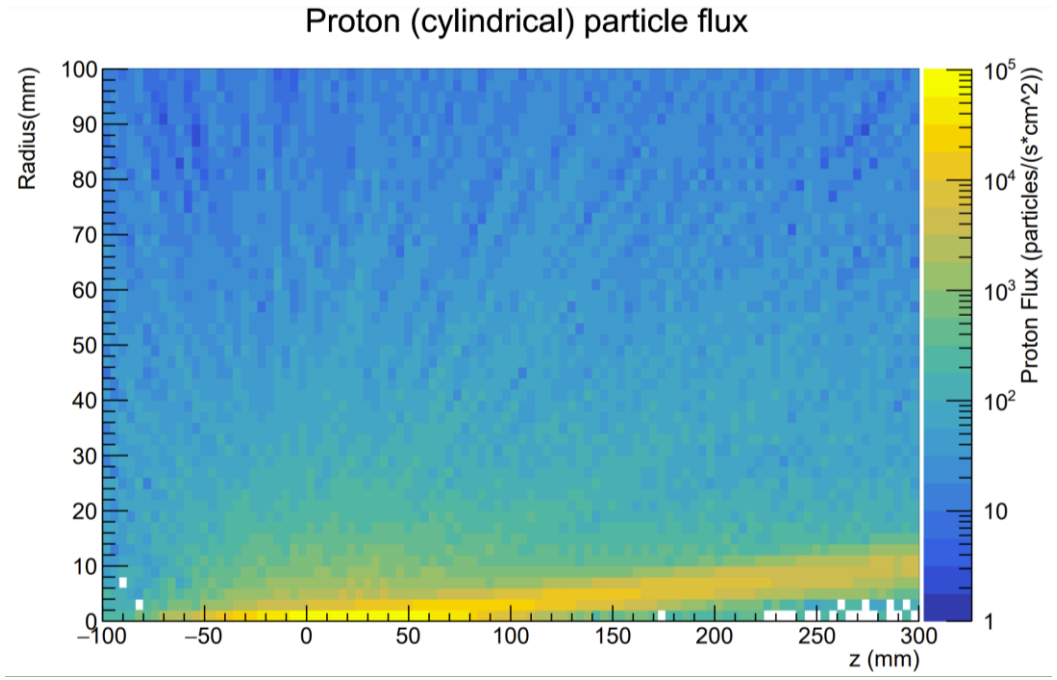

## Cylindrical flux




Neutron (circle) flux
Radial distance from beam axis (mm)
z-coordinate (mm)
Neutron flux per event (neutrons/(s*cm^2)


Neutron (cylindrical) particle flux
Radius(mm)
z (mm)
Neutron Flux (particles/(s*cm^2))


Proton (circle) flux
Radial distance from beam axis (mm)
z-coordinate (mm)
Proton flux per event (protons/(s*cm^2)


Proton (cylindrical) particle flux
Radius(mm)
z (mm)
Proton Flux (particles/(s*cm^2))

# 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

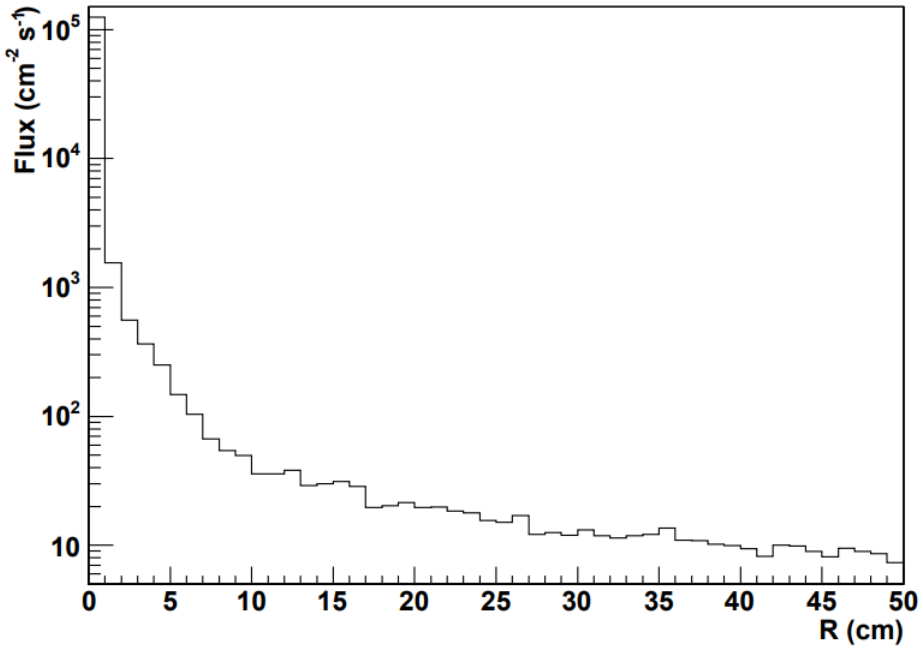
| | ALICE Fluence (/cm^2) | | EIC Fluence (/cm^2) | | ALICE/EIC ratio | |
|---|---|---|---|---|---|---|
| **Detector** | **>20MeV n** | **Charged hadrons** | **>20MeV n** | **Charged hadrons** | **>20MeV n** | **Charged hadrons** |
| Inner | 3.4e11 | 4.0e12 | 2.33e10 | 5.00e11 | 14.59 | 8.00 |
| Middle | 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**

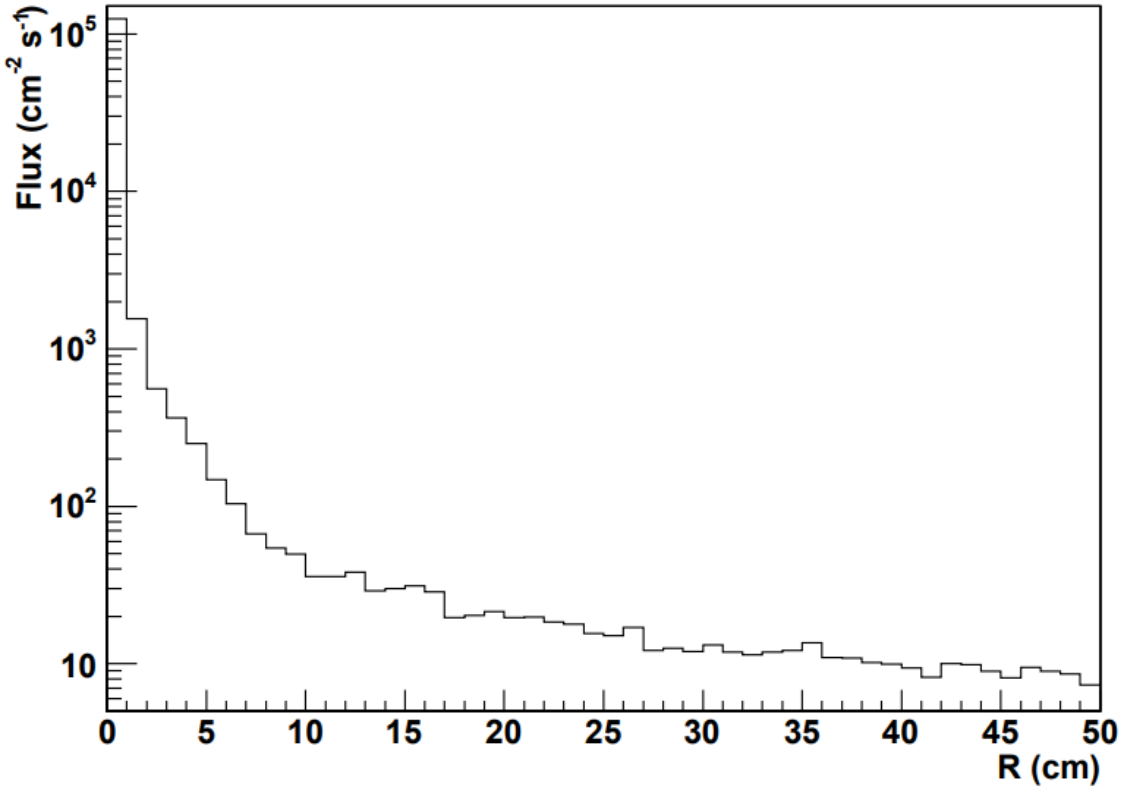
(figure 4 in ALICE radiation report)



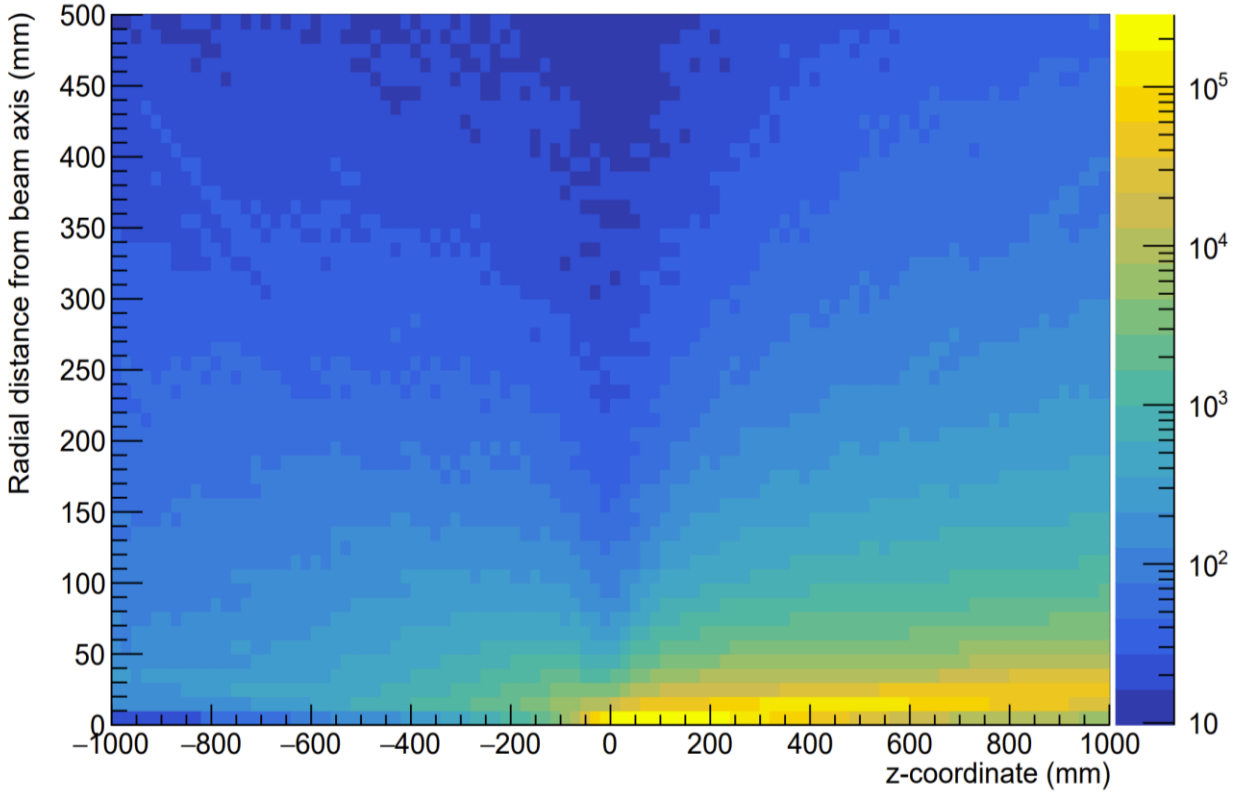
# Flux comparison to ALICE

- 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

- Using my code and simulations I ran, I will be able to determine the fluence, flux, and dose through the vertex detectors. I am also able to create maps of the flux.
- I am not able to create (charged particle) fluence and dose maps with the output I have
- 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

# Acknowledgments


- Dr. Alexander Jentsch
- Mr. Stephen Maple
- Dr. Todd Huffman
- Dr. Sam Henry


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”