



# hpDIRC Background Hit Rates



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CUA



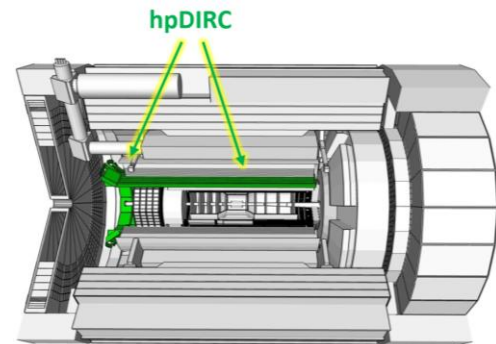
Jefferson Lab



University of Glasgow



# Introduction



- ❖ Estimate hpDIRC background hit rates for the **18×275 configuration**.

In the last update background hit occupancy results were shown ([link](#)).

- ❖ Compare the background contributions with reconstructed SIDIS signals
- ❖ Calculate the hit-rate density, fluence per  $\text{fb}^{-1}$  and HRPPD integrated anode charge (IAC)
- ❖ **The two known limitations** that affect the results is present as the datasets used were generated before the fix in the simulation framework
  - Fully pixelated detector plane, no gaps or dead areas
  - Current results contain artificial, rare high-multiplicity event anomalies
  - Expect the results **scale down by ~50%** for realistic HRPPD layout and photon detection efficiency

# Hit Rate Estimation (BKG)

❖ Total hit rate:  $r = \sum_i R h_i / N$

$R \rightarrow$  Event rate

❖ For instantaneous luminosity ( $L$ ) of  $5.0 \times 10^{33}$ ,  $1 \text{ fb}^{-1}$  is equivalent to  $2 \times 10^5 \text{ sec}$

$h_i \rightarrow$  # hits in  $i^{\text{th}}$  - cell

$N \rightarrow$  # sim events

| Background   | Event Rate (kHz) | Total Hit Rate (kHz) | Total Hits / $\text{fb}^{-1}$            | Total Hits / $\text{fb}^{-1}$ per module |
|--------------|------------------|----------------------|------------------------------------------|------------------------------------------|
| e- Coulomb   | 0.86             | 2096.24              | $4.19 \times 10^{11}$                    | $3.49 \times 10^{10}$                    |
| e- Touschek  | 0.55             | 1068.78              | $2.14 \times 10^{11}$                    | $1.78 \times 10^{10}$                    |
| e- Brem      | 316.94           | 30167.22             | $60.33 \times 10^{11}$                   | $50.28 \times 10^{10}$                   |
| p+ BeamGas   | 22.5             | 15583.63             | $31.17 \times 10^{11}$                   | $25.98 \times 10^{10}$                   |
| Synrad       | 3324000          | 0                    | 0                                        | 0                                        |
| <b>Total</b> | -                | <b>48915.87</b>      | <b><math>97.83 \times 10^{11}</math></b> | <b><math>81.53 \times 10^{10}</math></b> |

The hit rate is overestimated because the simulation does not account for photon detection efficiency (PDE) and the inactive regions between the HRPPDs. Accounting for these effects will reduce the actual hit rate by approximately 50%.

# Hit Rate Estimation (SIG)

❖ Total hit rate:  $r = \sum_i R h_i / N$

$R \rightarrow$  Event rate

❖ For instantaneous luminosity ( $L$ ) of  $5.0 \times 10^{33}$ ,  $1 \text{ fb}^{-1}$  is equivalent to  $2 \times 10^5 \text{ sec}$

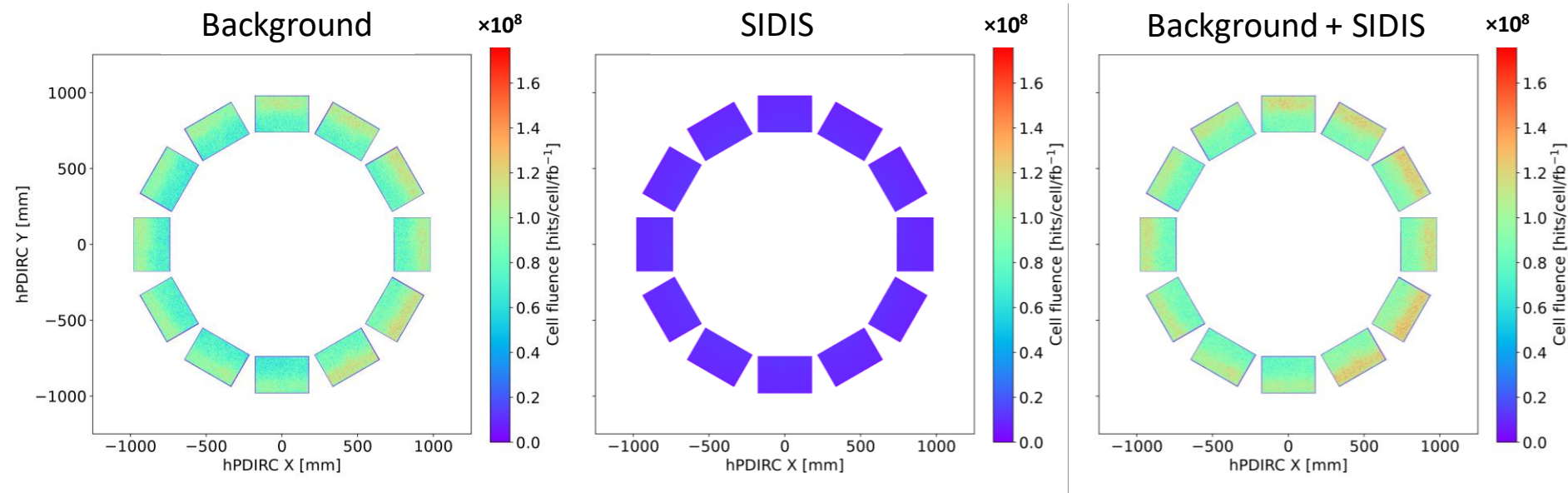
$h_i \rightarrow$  # hits in  $i^{\text{th}}$  - cell

$N \rightarrow$  # sim events

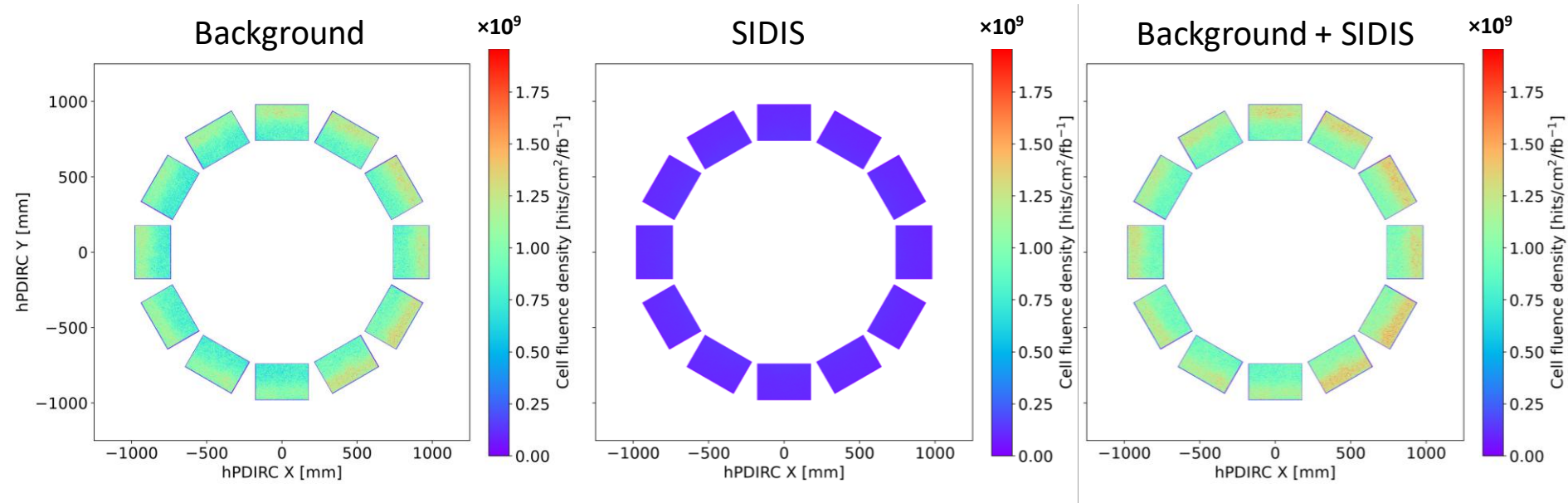
| Signal                                | Event Rate (kHz) | Total Hit Rate (kHz) | Total Hits / $\text{fb}^{-1}$            | Total Hits / $\text{fb}^{-1}$ per module |
|---------------------------------------|------------------|----------------------|------------------------------------------|------------------------------------------|
| SIDIS ep 18x275 $Q^2 = 1 - 10$        | 3.8543           | 4916.98              | $9.83 \times 10^{11}$                    | $8.19 \times 10^{10}$                    |
| SIDIS ep 18x275 $Q^2 = 10 - 100$      | 0.3270           | 695.54               | $1.39 \times 10^{11}$                    | $1.16 \times 10^{10}$                    |
| SIDIS ep 18x275 $Q^2 = 100 - 1000$    | 0.0131           | 18.14                | $3.63 \times 10^9$                       | $3.02 \times 10^8$                       |
| SIDIS ep 18x275 $Q^2 = 1000 - 100000$ | 0.0002           | 0.35                 | $7.0 \times 10^7$                        | $5.83 \times 10^6$                       |
| <b>Total</b>                          | -                | <b>5631.01</b>       | <b><math>11.26 \times 10^{11}</math></b> | <b><math>9.38 \times 10^{10}</math></b>  |
| <b>Total (background)</b>             | -                | <b>48915.87</b>      | <b><math>97.83 \times 10^{11}</math></b> | <b><math>81.53 \times 10^{10}</math></b> |

Looking into  $Q^2 < 1$  as well; results will be included in a future update

The hit rate is overestimated because the simulation does not account for photon detection efficiency (PDE) and the inactive regions between the HRPPDs. Accounting for these effects will reduce the actual hit rate by approximately 50%.

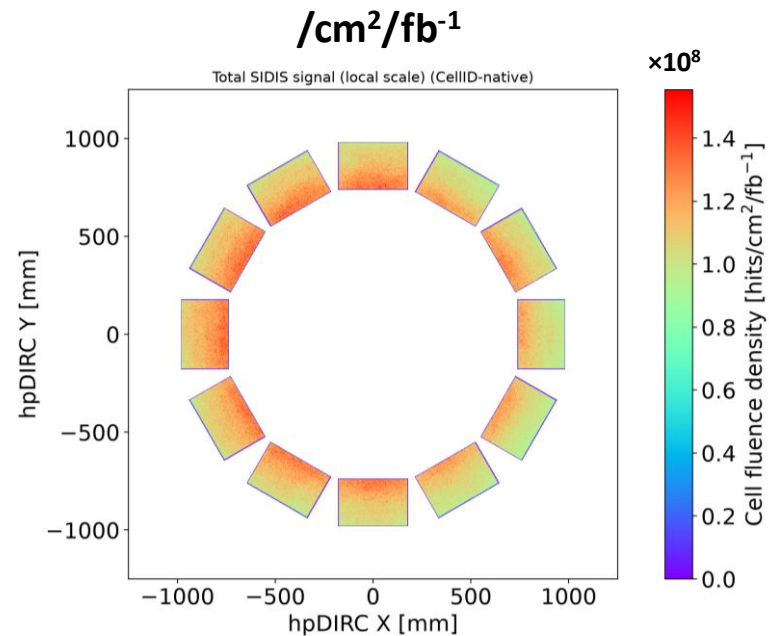
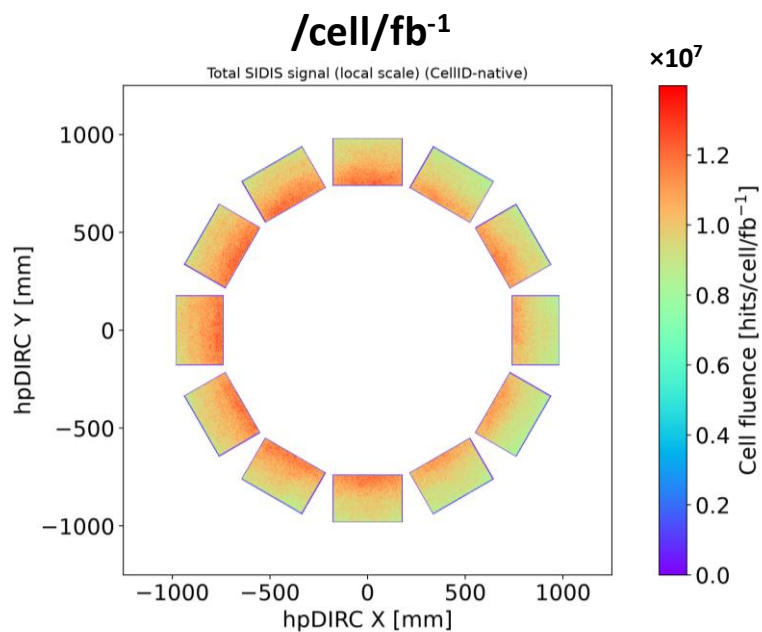


All maps use the same Z-linear scale



All maps use the same Z-linear scale

## #Hits (SIG)



# Hit Rate Density (BKG)

$R \rightarrow$  Event rate

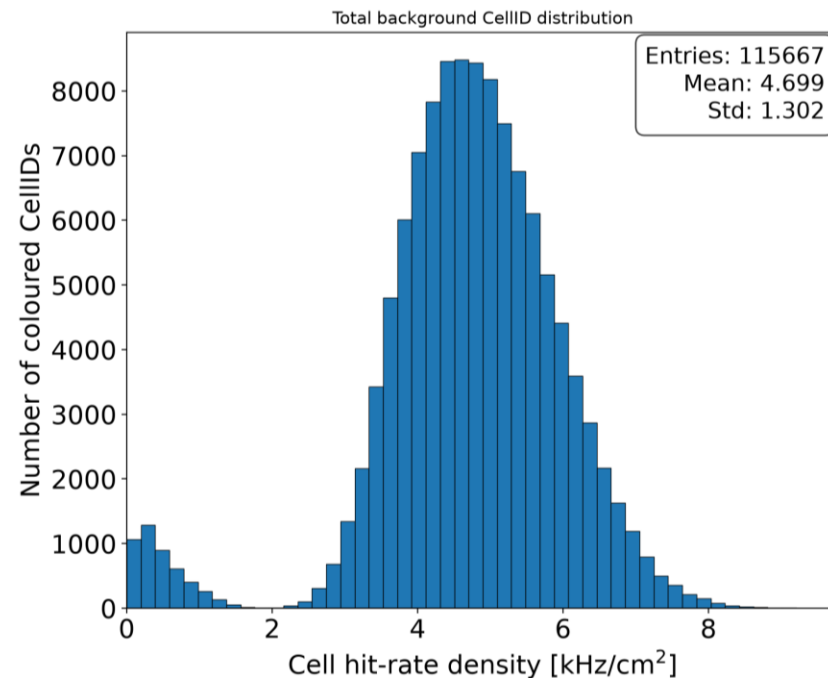
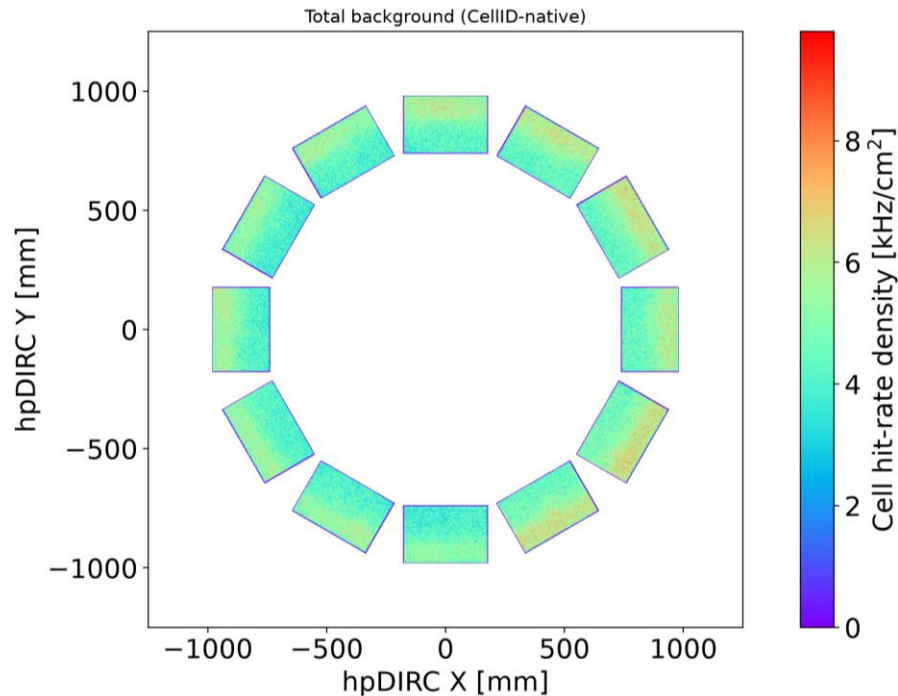
$h_i \rightarrow$  # hits in  $i^{\text{th}}$  - cell

$N \rightarrow$  # sim events

❖ Hit rate:  $r_i = R h_i / N$

Hit Rate density:  $\rho_i = r_i / 0.09 \text{ kHz/cm}^2$   
(for  $3 \times 3 \text{ mm}^2$  cells)

**kHz/cm<sup>2</sup>**



# Integrated Anode Charge (BKG)

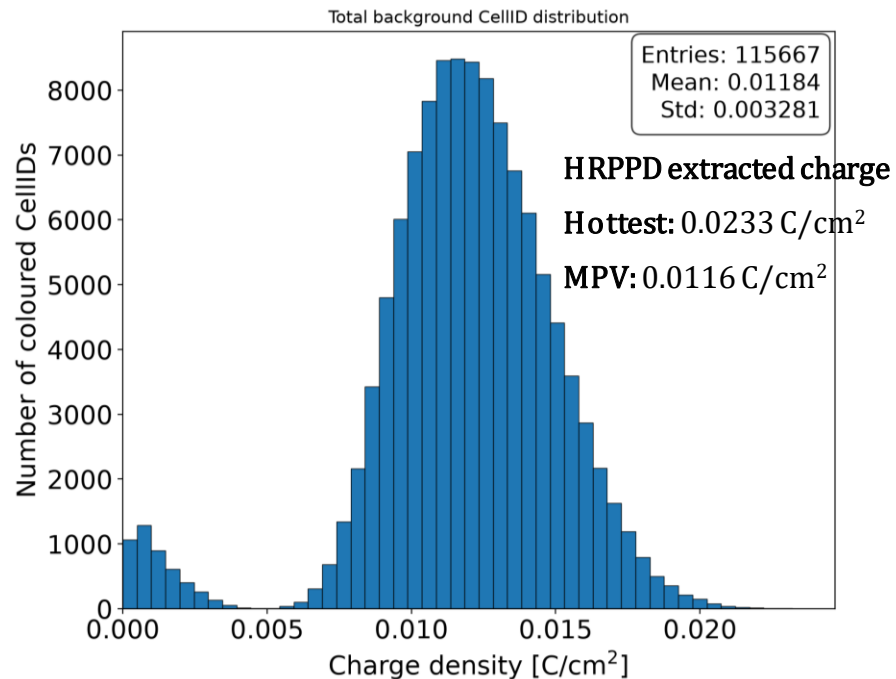
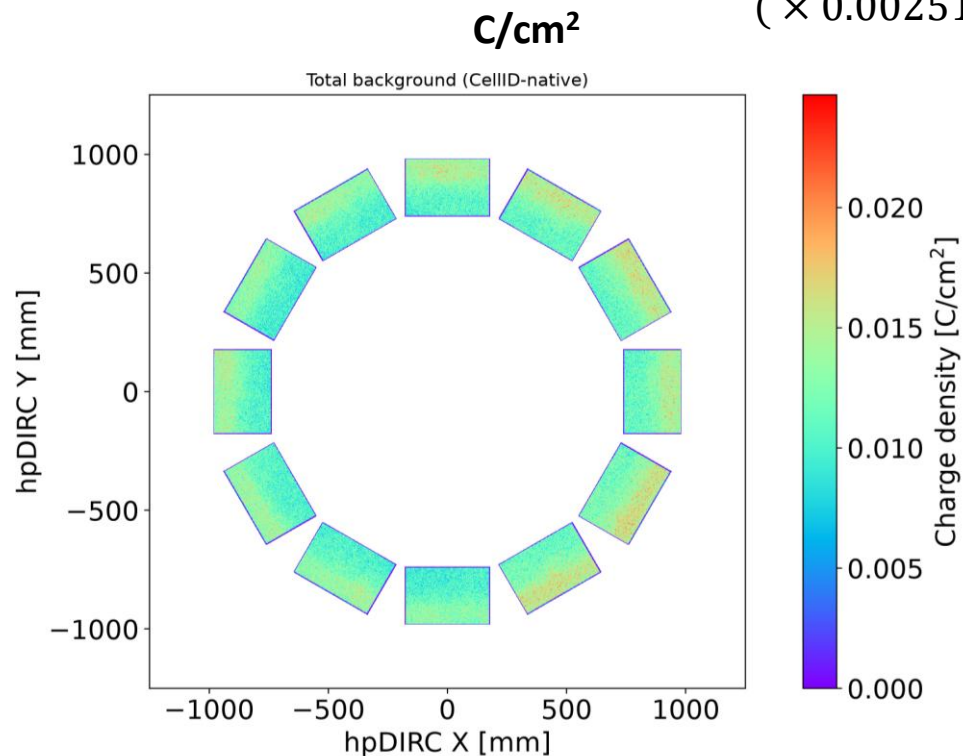
❖ IAC:  $Q/A = \rho_i (\text{kHz/cm}^2) \times 1000 \times t \times G \times e$   
 $(\times 0.0025191)$

$r_i^0 \rightarrow$  hit rate density of  $i^{\text{th}}$  - cell

$t \rightarrow$  time (26 weeks  $\times$  24 h)

$G \rightarrow$  Gain ( $10^6$ )

$e \rightarrow$  electronic charge



# Hit Rate Density (SIG)

$R \rightarrow$  Event rate

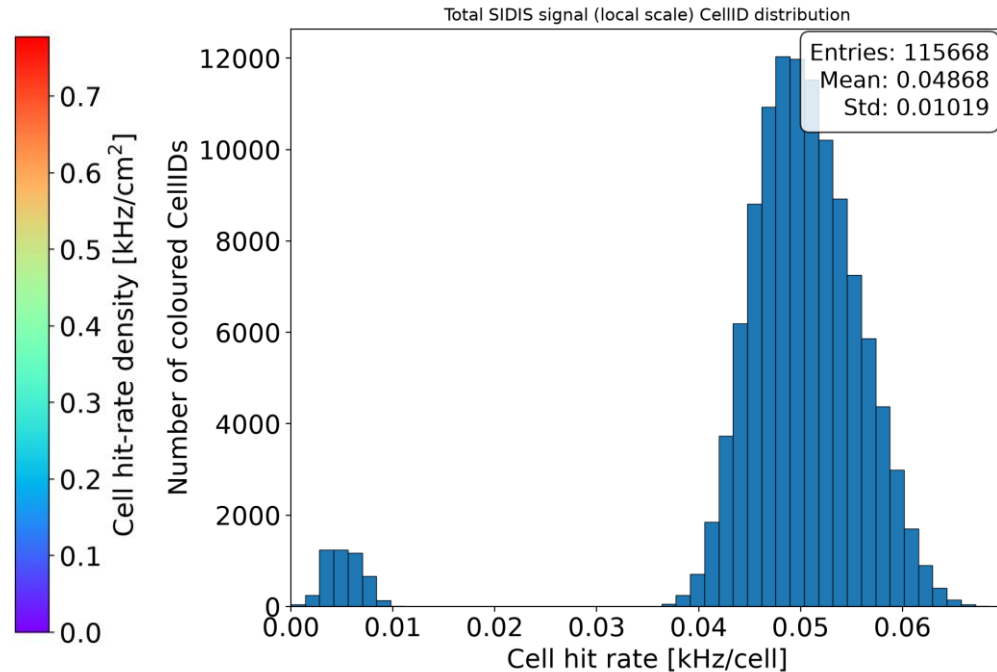
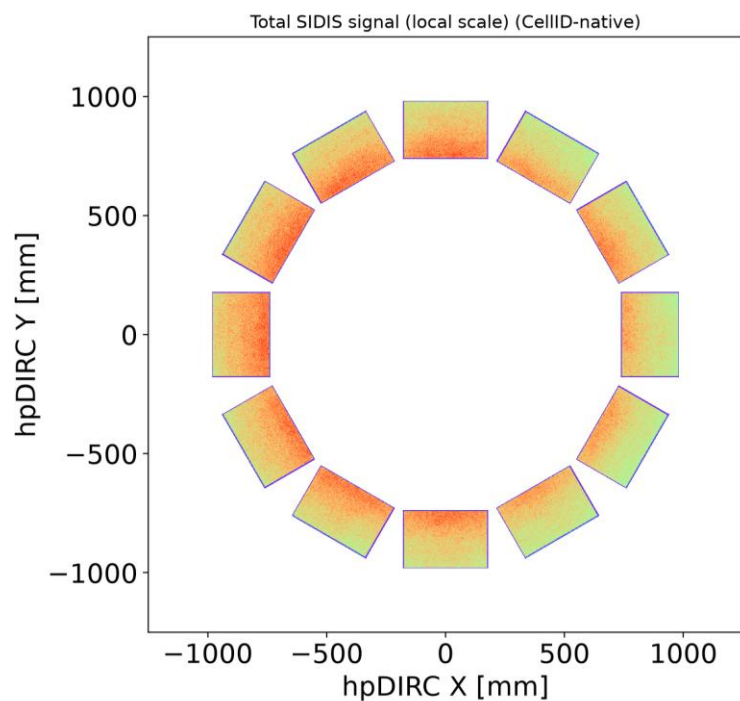
$h_i \rightarrow$  # hits in  $i^{\text{th}}$  - cell

$N \rightarrow$  # sim events

❖ Hit rate:  $r_i = R h_i / N$

Hit Rate density:  $\rho_i = r_i / 0.09 \text{ kHz/cm}^2$   
(for  $3 \times 3 \text{ mm}^2$  cells)

**kHz/cm<sup>2</sup>**



# Integrate Anode Charge (SIG)

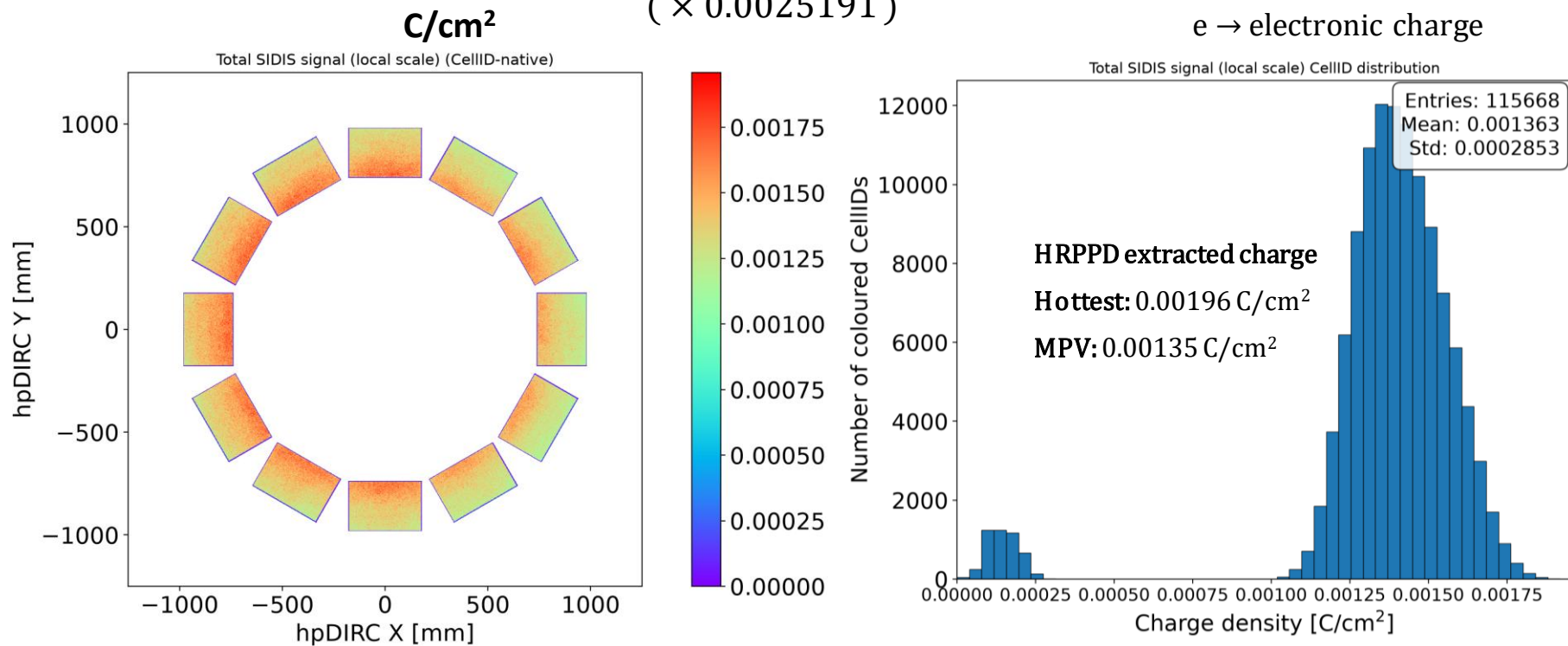
❖ IAC:  $Q/A = \rho_i (\text{kHz/cm}^2) \times 1000 \times t \times G \times e$   
 $(\times 0.0025191)$

$r_i^0 \rightarrow$  hit rate density of  $i^{\text{th}}$  - cell

$t \rightarrow$  time (26 weeks  $\times$  24 h)

$G \rightarrow$  Gain ( $10^6$ )

$e \rightarrow$  electronic charge



# Hit Rate Density (BKG+SIG)

$R \rightarrow$  Event rate

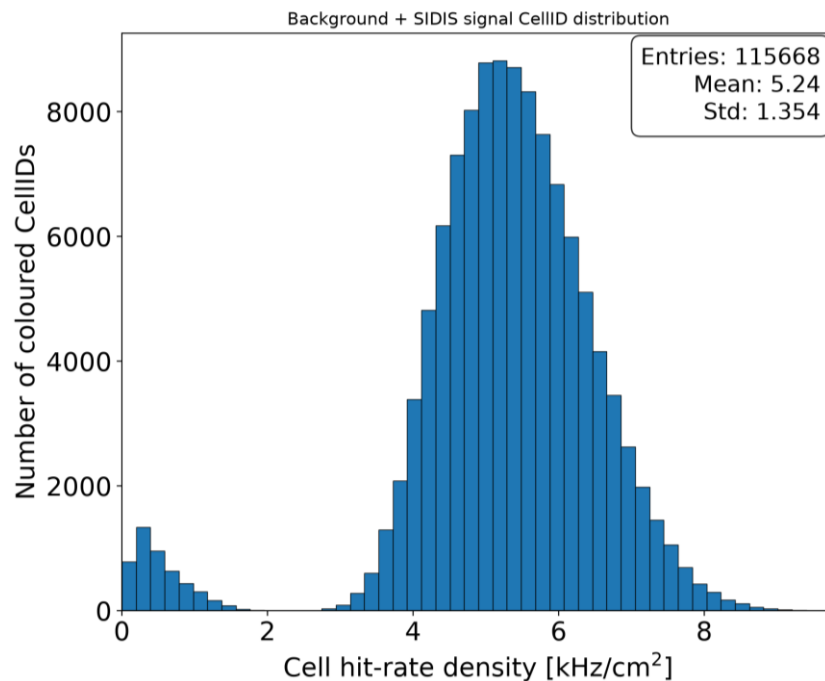
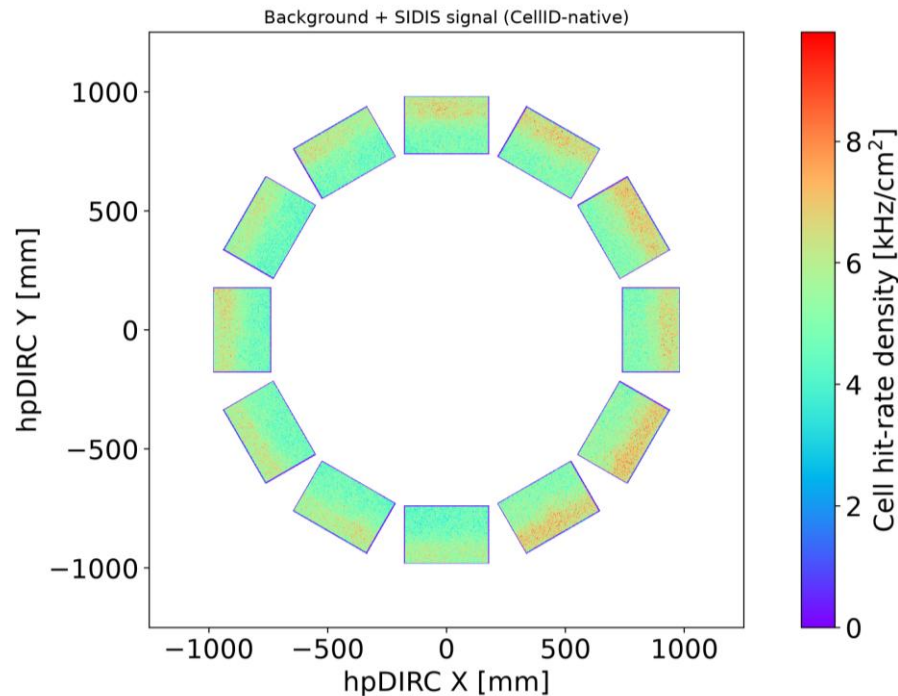
$h_i \rightarrow$  # hits in  $i^{\text{th}}$  - cell

$N \rightarrow$  # sim events

❖ Hit rate:  $r_i = R h_i / N$

Hit Rate density:  $\rho_i = r_i / 0.09 \text{ kHz/cm}^2$   
(for  $3 \times 3 \text{ mm}^2$  cells)

**kHz/cm<sup>2</sup>**



# Integrated Anode Charge (BKG+SIG)

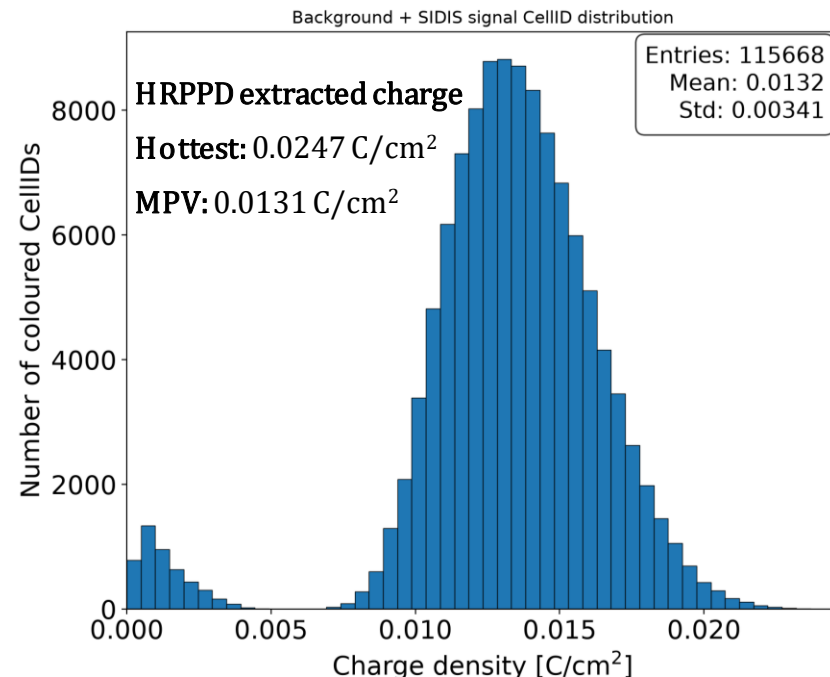
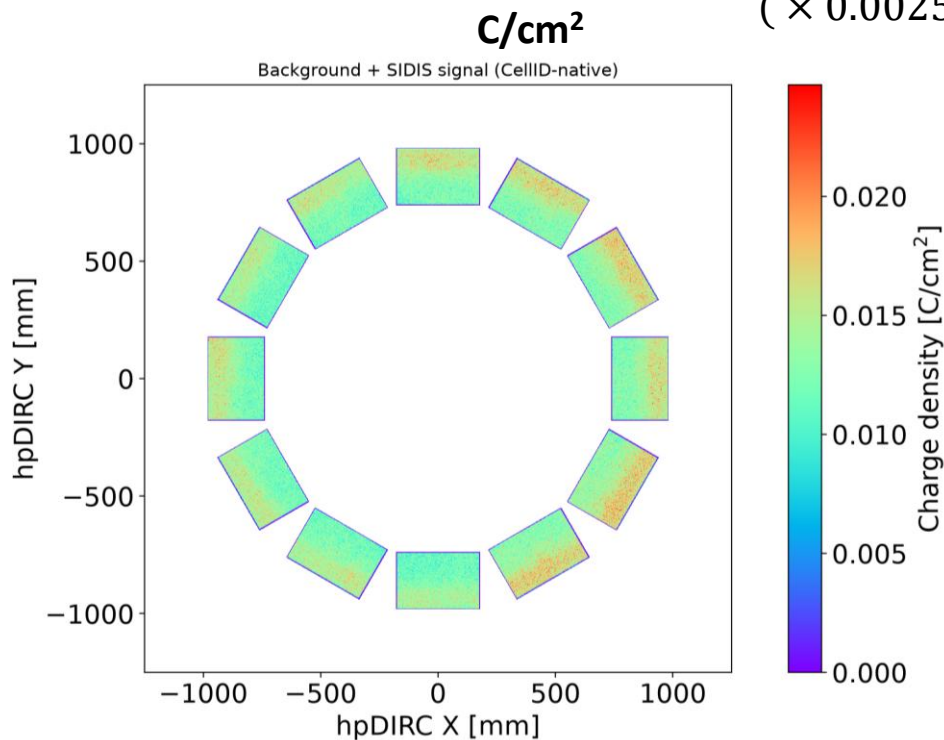
❖ IAC:  $Q/A = \rho_i (\text{kHz/cm}^2) \times 1000 \times t \times G \times e$   
 $(\times 0.0025191)$

$r_i^0 \rightarrow$  hit rate density of  $i^{\text{th}}$  - cell

$t \rightarrow$  time (26 weeks  $\times$  24 h)

$G \rightarrow$  Gain ( $10^6$ )

$e \rightarrow$  electronic charge



# Summary

- ❖ Background and SIDIS hit rates estimated for **18×275 GeV** configuration, assuming instantaneous **luminosity of  $5.0 \times 10^{33}$ ,  $1 \text{ fb}^{-1}$**  is equivalent to  **$2 \times 10^5 \text{ sec}$**
- ❖ The total background and SIDIS hit rates are approximately **48.9 and 5.63 MHz**, respectively. Note that for SIDIS,  $Q^2 = 0-1$  bin has not been included in the calculation
- ❖ The expected fluence is  **$1.09 \times 10^{13}$**  for combined background and SIDIS hits **per  $\text{fb}^{-1}$**
- ❖ The hottest-region **IAC is  $0.0247 \text{ C/cm}^2$**  with **MPV  $0.0131 \text{ C/cm}^2$**  for combined background and SIDIS, assuming a 26 weeks  $\times$  24 hr run and HRPPD gain of  $10^6$
- ❖ Including realistic photon efficiencies and the HRPPD layout is expected to reduce these estimates by about 50%
- ❖ Presently, working on the estimates for the  $10 \times 275 \text{ GeV}$  configuration

# BACKUP

# RECO Datasets

## ❖ Background datasets include:

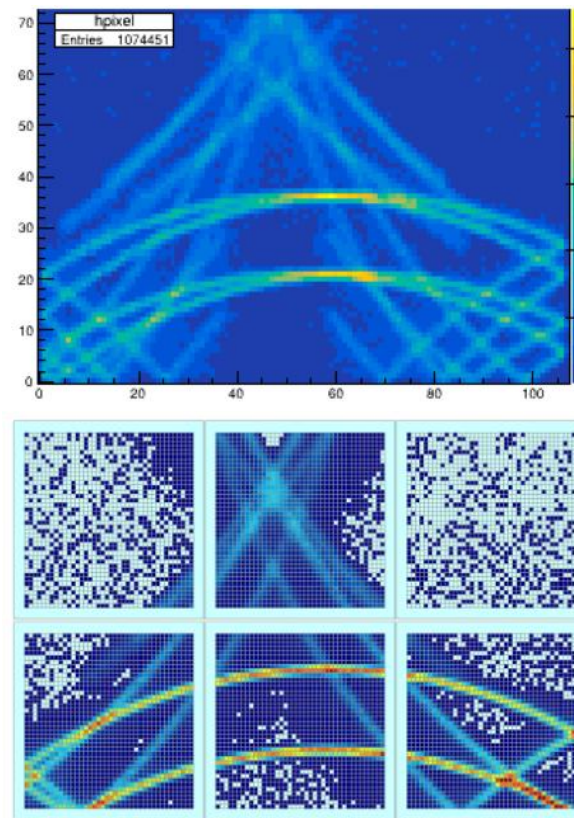
- `/RECO/26.03.0/epic_craterlake/BACKGROUNDS/SYNRAD/dataproduct_rel_1.0.0/18x275` Synrad
- `/RECO/26.03.0/epic_craterlake/BACKGROUNDS/BEAMGAS/electron/coulomb/EIC_ESR_Xsuite/dataproduct_rel_1.0.1/18x275/10000Ahr/MachineRuntime50s` Electron coulomb
- `/RECO/26.03.0/epic_craterlake/BACKGROUNDS/BEAMGAS/electron/touschek/EIC_ESR_Xsuite/dataproduct_rel_1.0.1/18x275/10000Ahr/MachineRuntime50s` Electron touschek
- `/RECO/26.03.0/epic_craterlake/BACKGROUNDS/BEAMGAS/electron/GETaLM1.0.0-1.1/18GeV` Electron Brem
- `/RECO/26.03.0/epic_craterlake/BACKGROUNDS/BEAMGAS/proton/pythia8.306-1.0/275GeV` Proton BeamGas

## ❖ Physics signal datasets:

- `/RECO/26.04.1/epic_craterlake/SIDIS/pythia6-eic/1.2.0/ep_noradcor/18x275/q2_1to10`
- `/RECO/26.04.1/epic_craterlake/SIDIS/pythia6-eic/1.2.0/ep_noradcor/18x275/q2_10to100`
- `/RECO/26.04.1/epic_craterlake/SIDIS/pythia6-eic/1.2.0/ep_noradcor/18x275/q2_100to1000`
- `/RECO/26.04.1/epic_craterlake/SIDIS/pythia6-eic/1.2.0/ep_noradcor/18x275/q2_1000to100000`

# Limitations

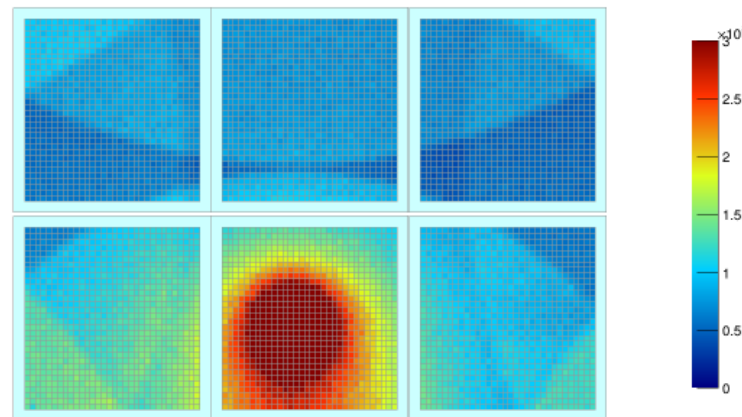
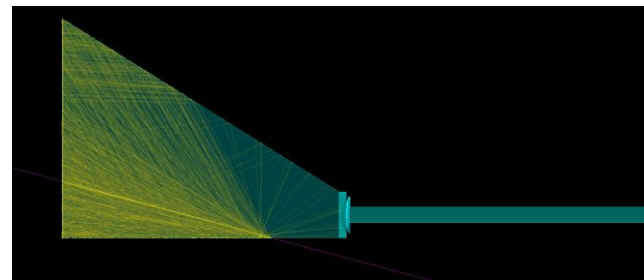
- ❖ Fully pixelated detector plane, no gaps or dead areas
  - Expect occupancy to scale down by  $\sim 50\%$  for realistic HRPPD layout and photon detection efficiency
- ❖ Results were produced before the recent software correction for the treatment of photons generated in the prism
  - Current results contain artificial, rare high-multiplicity event anomalies



Results from **standalone simulation**

# Limitations

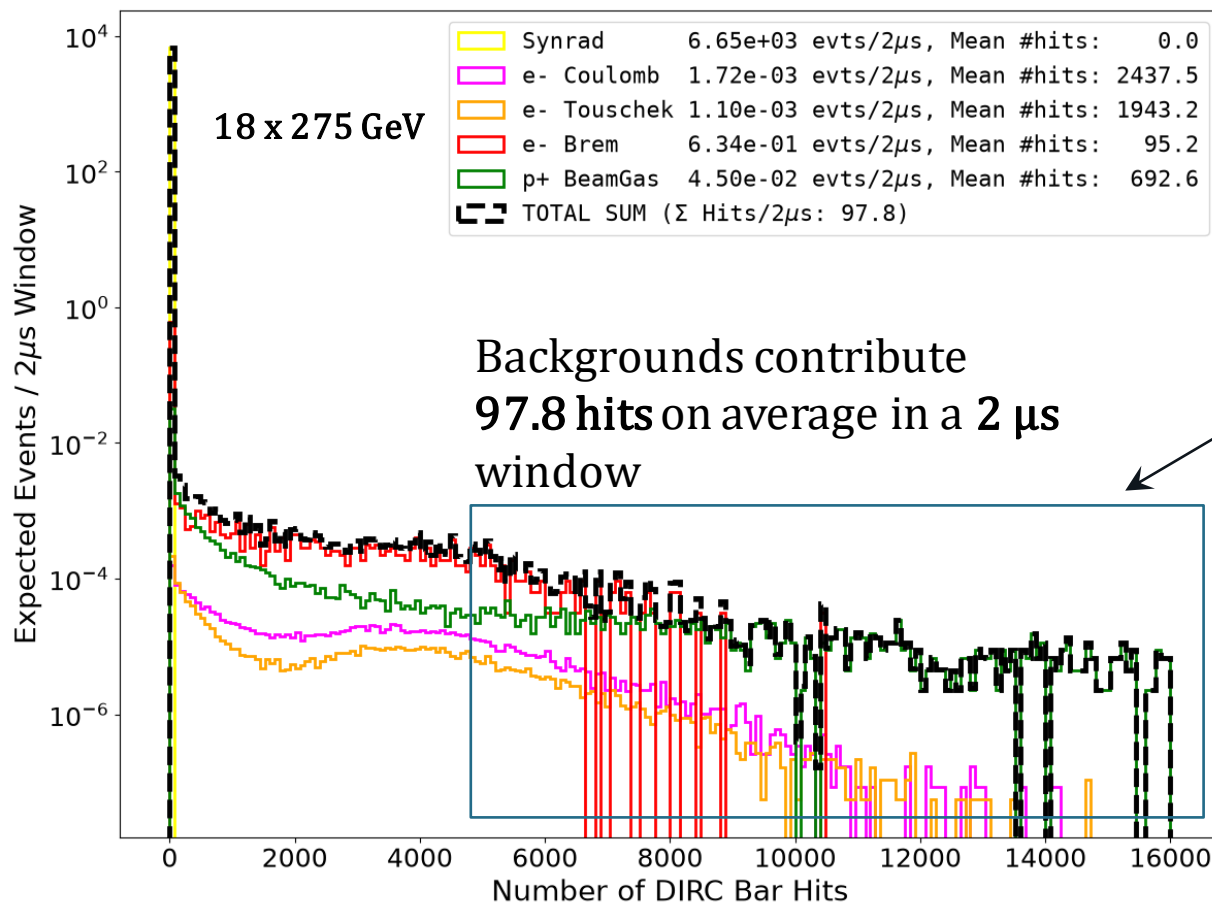
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Results from **standalone simulation**

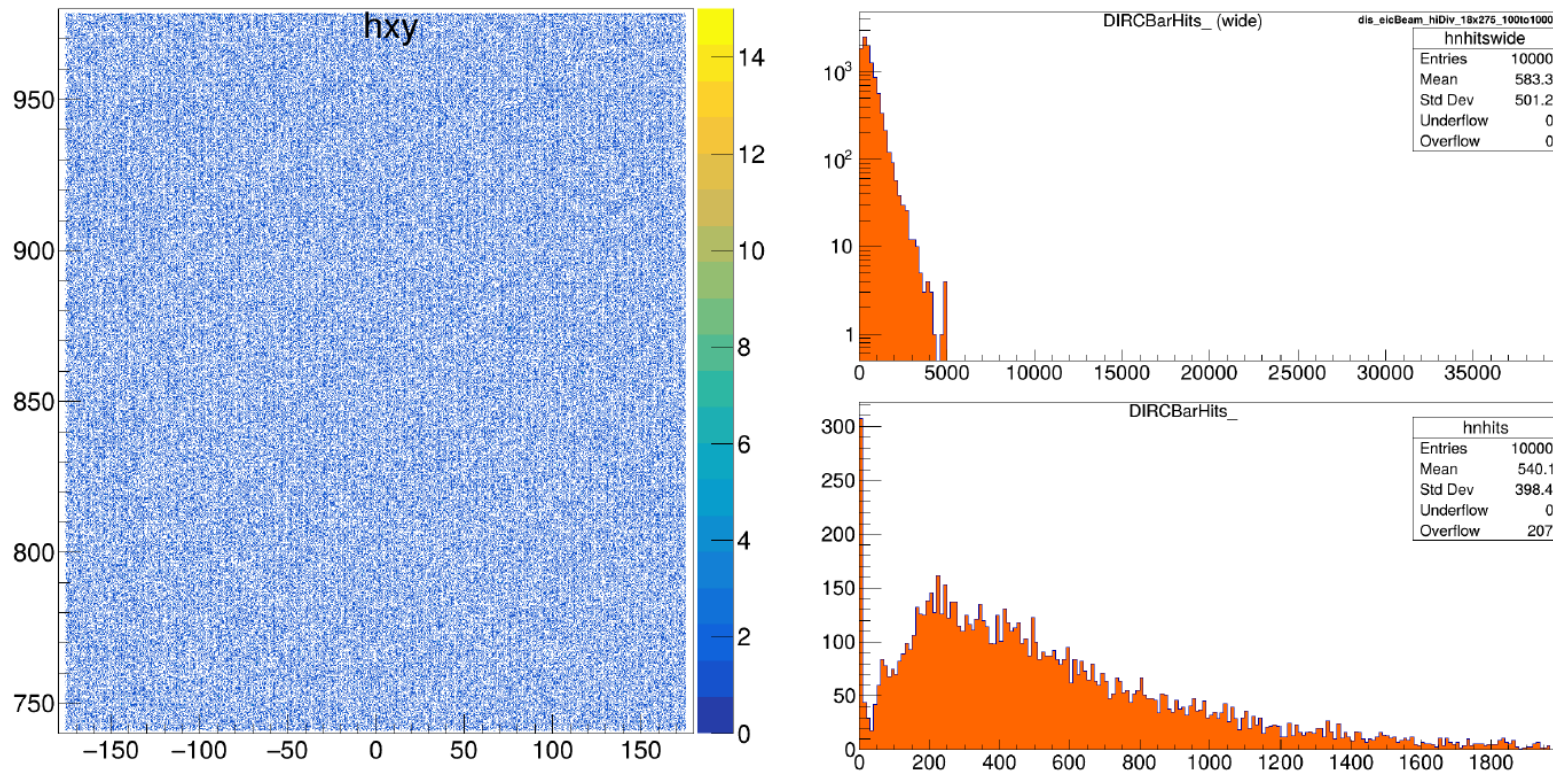
# Background Rate

Norm = Rate  $\times$  2  $\mu$ s / # sim events



# Realistic Hit Distribution

pythia8 DIS, epic,  $100 < Q^2 < 1000$



Plots obtained by running npsim over DIS 18x275 hepmc3 datasets produced using pythia8

# Signal Rates

- ❖ The rate is calculated for an instantaneous luminosity ( $L$ ) of  $5.0 \times 10^{33}$  as:

$$\text{Rate} = L \times \sigma$$

$\sigma$  is the **integrated cross-section** of the signal obtained from the EVGEN/hepmc3 files

| Signal                                | Cross-section (pb)    | Rate (kHz) |
|---------------------------------------|-----------------------|------------|
| SIDIS ep 18x275 $Q^2 = 1 - 10$        | $7.70862 \times 10^5$ | 3.8543     |
| SIDIS ep 18x275 $Q^2 = 10 - 100$      | $6.54077 \times 10^4$ | 0.3270     |
| SIDIS ep 18x275 $Q^2 = 100 - 1000$    | $2.61440 \times 10^3$ | 0.0131     |
| SIDIS ep 18x275 $Q^2 = 1000 - 100000$ | $4.04528 \times 10^1$ | 0.0002     |

# Cell ID Position

- ❖ Cell positions are not available from the EPICstack directly; encoded in the cell ID
- ❖ Cell IDs and corresponding (x,y) positions attainable from the standalone setup
- ❖ Used the standalone setup to create a mapping from the Cell ID to their positions for the EPICstack datasets
- ❖ Each pixel in the plots shown today are  $3 \times 3 \text{ mm}^2$  rotated cells, whose position and orientation is obtained from the mapping

# Fitting and Transformation Map

$$P(i_x, i_y) = O + i_x e_x + i_y e_y$$

$$\theta_m = 30^\circ \times m$$

$$e_x = 3(\cos \theta_m, \sin \theta_m)$$

$$e_y = 3(-\sin \theta_m, \cos \theta_m)$$

$$O = \bar{P} - \bar{i}_x e_x - \bar{i}_y e_y$$

Residual being minimized

$$r_k(O) = P_k - O - i_{x,k} e_x - i_{y,k} e_y$$

$$\chi^2(O) = \sum_{k=1}^N \| r_k(O) \|^2$$

$(i_x, i_y)$

signed local CellID indices, unitless

$(e_x, e_y)$

fixed global basis vectors, mm per index

$P_k = (X_k, Y_k)$

GEANT4 mean position, mm

$O = (O_x, O_y)$

fitted module origin, mm

$$M = [e_x \ e_y] = \begin{bmatrix} e_{x,x} & e_{y,x} \\ e_{x,y} & e_{y,y} \end{bmatrix}$$

# Comparison with pfRICH

```
hpDIRC (18x275, combined) versus pfRICH (10x275, reference) (1.57248e+07 s, gain 1e+06):
```

| Quantity                                    | hpDIRC      | pfRICH    |
|---------------------------------------------|-------------|-----------|
| Total background hit rate [hits/s]          | 4.89159e+07 | 8e+07     |
| Total signal hit rate [hits/s]              | 5.63106e+06 | 1e+07     |
| Total combined hit rate [hits/s]            | 5.45469e+07 | 9e+07     |
| Peak rate density [hits/cm <sup>2</sup> /s] | 9795.08     | 200000    |
| MPV rate density [hits/cm <sup>2</sup> /s]  | 5191.39     | 6000      |
| Peak extracted charge [C/cm <sup>2</sup> ]  | 0.0246776   | 0.503878  |
| MPV extracted charge [C/cm <sup>2</sup> ]   | 0.0130791   | 0.0151163 |