Status of TPC Calibrations

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on behalf of the subcommittee

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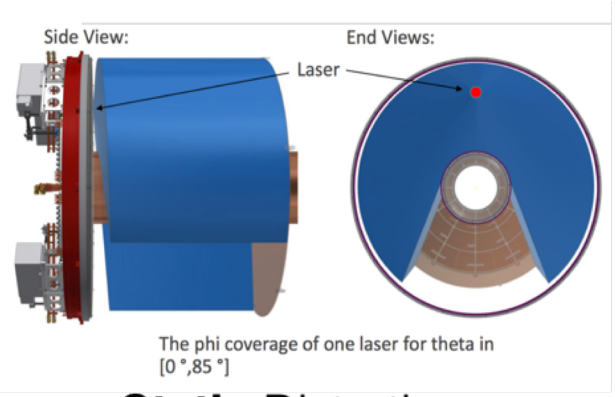
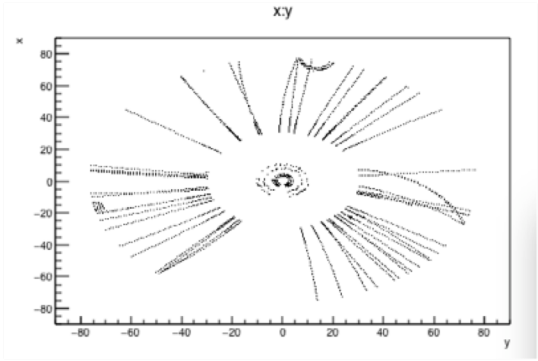
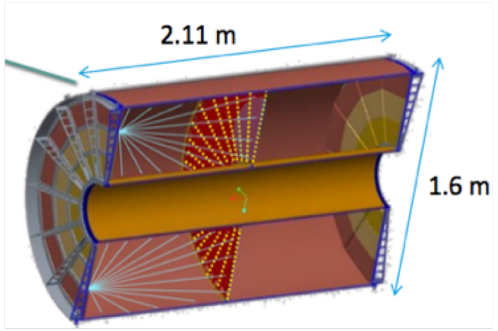
Distortion Monitors



Static Distortions mapped by **line laser**.
O(Hz) rep rate, not used during data-taking
Monitors full 3D volume

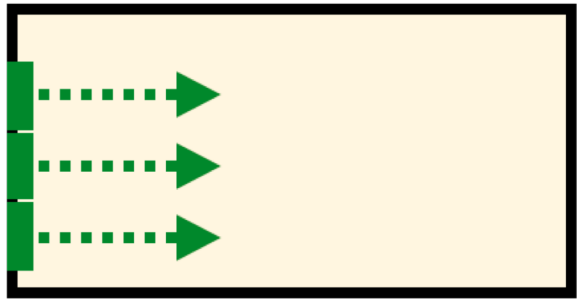


Average distortions monitored by **tracks**
O(10min) to accumulate statistics
Monitors full 3D volume

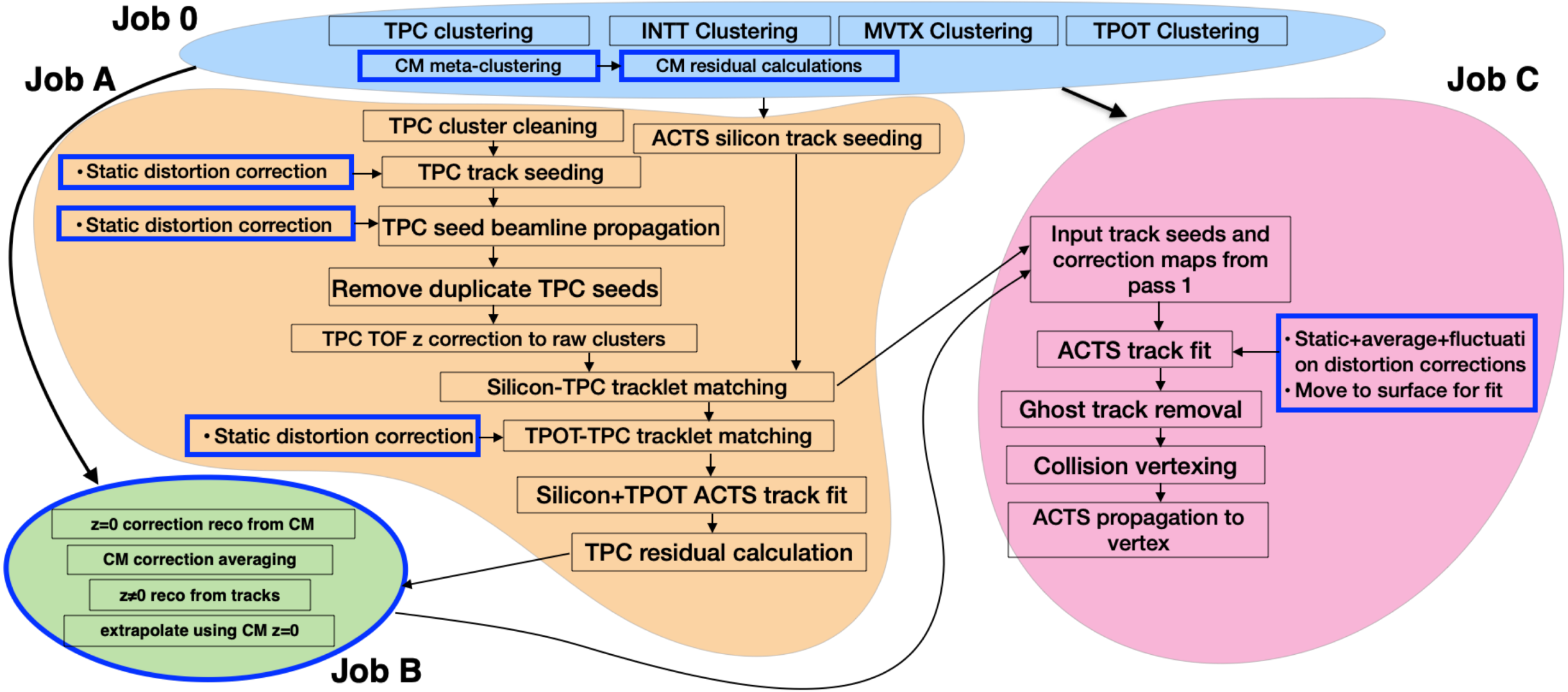


Distortion **fluctuations** monitored by **CM pattern/diffuse laser**
O(kHz) rep rate, interleaved with triggered events
Monitors only at z=0

Digital current infers IBF from readout. Provides orthogonal, but indirect, measure of SC distortion



Calibration in Triggered Mode Workflow



"TPC Distortion Corrections" @ 4th sPHENIX software and computing review:
https://indico.bnl.gov/event/15770/contributions/63196/attachments/40971/68536/Corliss_TPC_calibration.pdf

Calibration Workflow in Brief

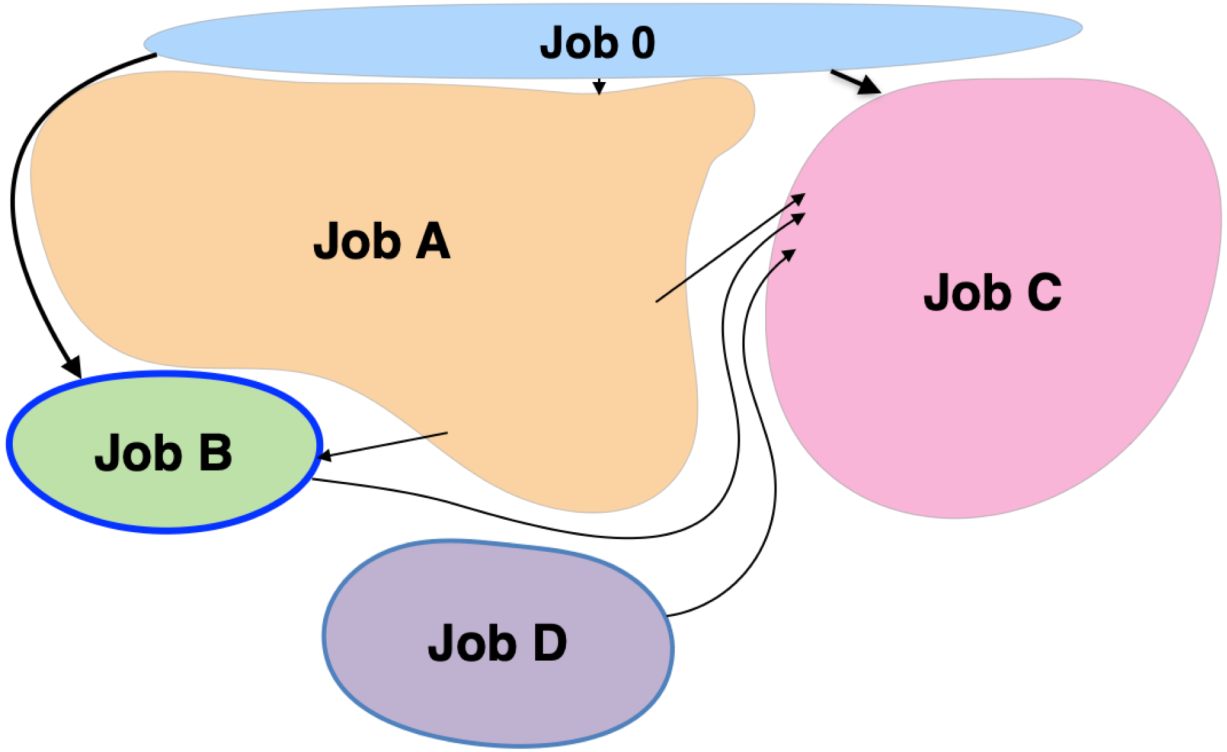
Job 0: Assemble Clusters
- Identify and cluster Central Membrane hits

Job A: Assemble Tracks
- Apply static corrections to all clusters
- Find all tracks
- Record track residuals for use in average corrections

Job B: Calculate Average Correction
- Once per ~30min aggregated Job A data
- Derive 3D correction in TPOT region from residuals
- Use average CM residuals to normalize and extrapolate to full coverage

Job C: Correct and Fit Tracks
- Apply static and average corrections to CM clusters
- Use CM residual to derive fluctuation correction*
- Apply static+average+fluctuation correction to track clusters and fit.

Job D: Derive distortions from Digital Currents
- Once per ~10ms wall clock time ⟹ 10k cores steadystate
- Assemble charge model from digital current
- Compute distortion from charge model



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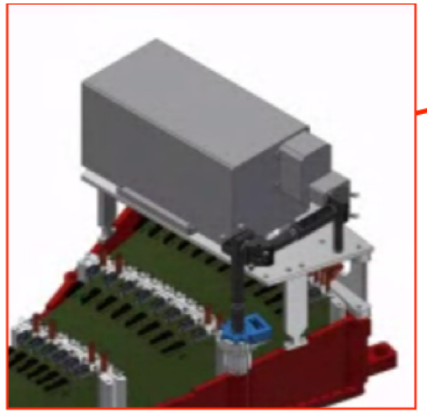
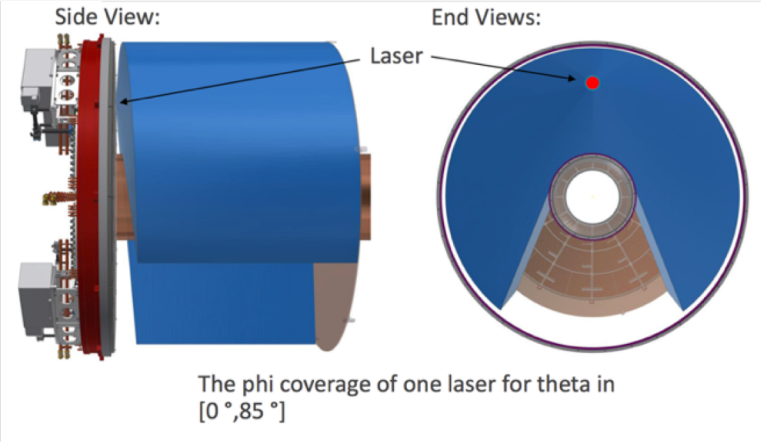
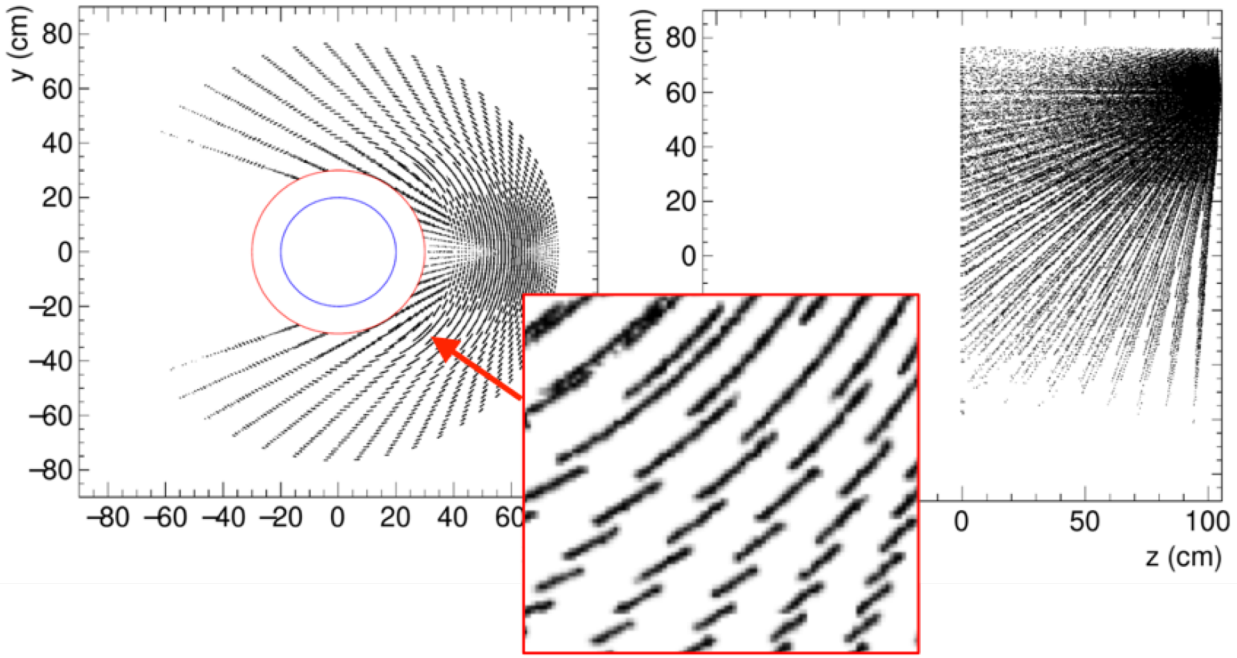
Direct Laser / Static Distortions

- 8 steerable lasers ionize the gas ⟹ straight tracks with known truth at 1Hz
- All points will be reached by 2+ lasers
- Code integrated into Fun4All:
    - Generates laser track hits for each laser at desired trajectories
    - Adds hits into same propagation process as all Geant hits
- Working to adapt track-residuals approach for laser tracks





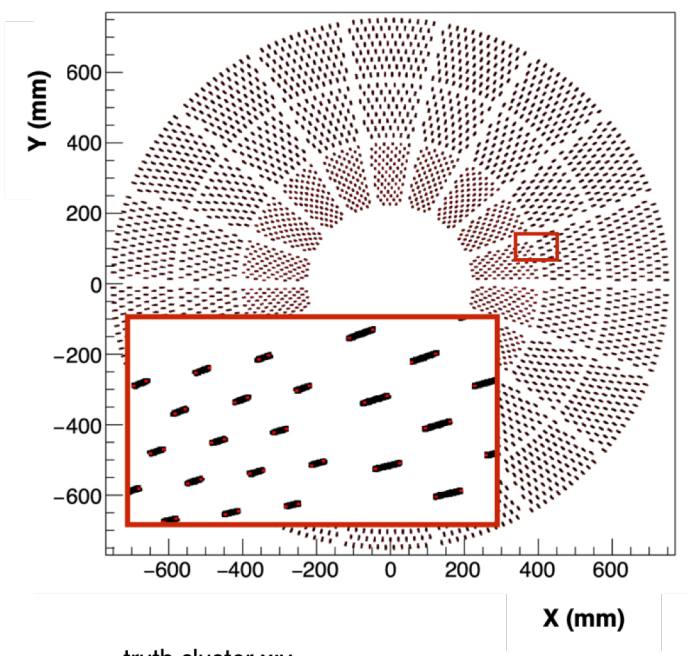


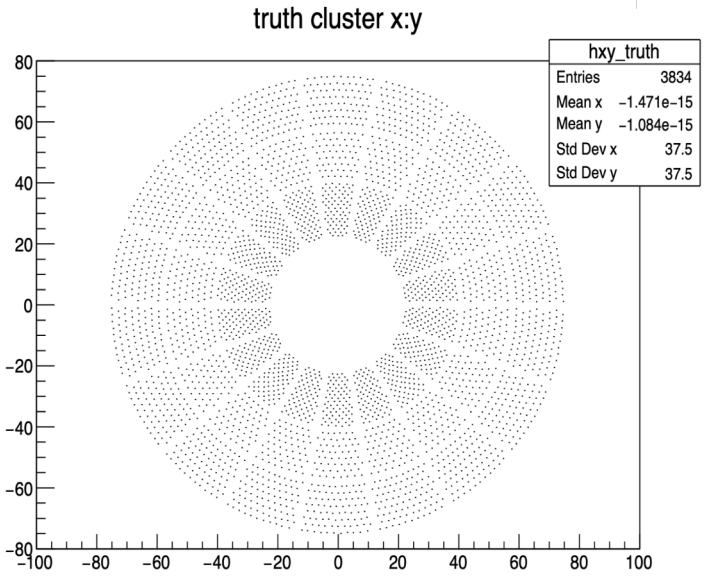
Central Membrane / Fluctuations

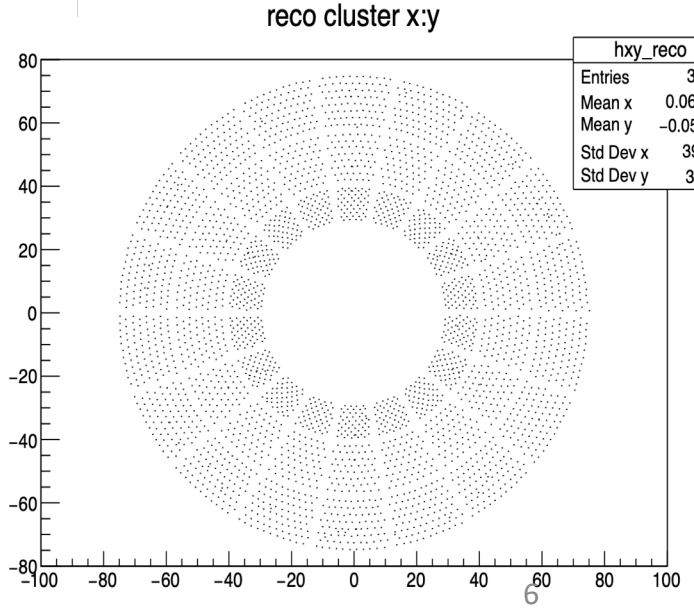
- All petals are evaporated & ready

- Diffuse UV laser flash will illuminate Al stripes ⟹ electron cloud pattern with known truth position

- Code integrated into Fun4All:
  - Generates CM hits events with a flag
  - Adds CM hits into same propagation process as all Geant hits
  - Pairs TPC clusters in adjacent radial rows to form CM clusters
  - Matches CM clusters to most likely truth cluster
  - Stores result in datastream
  - Generates correction map from CM cluster association

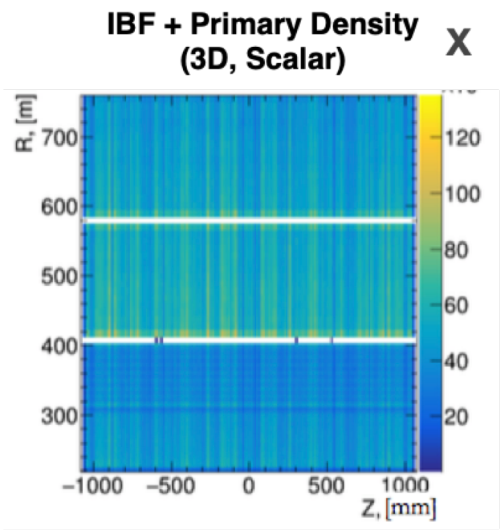


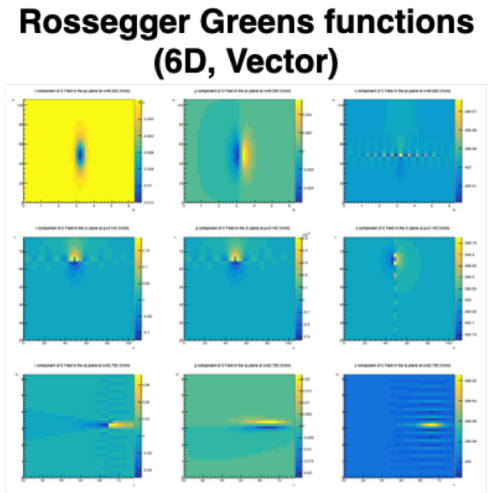


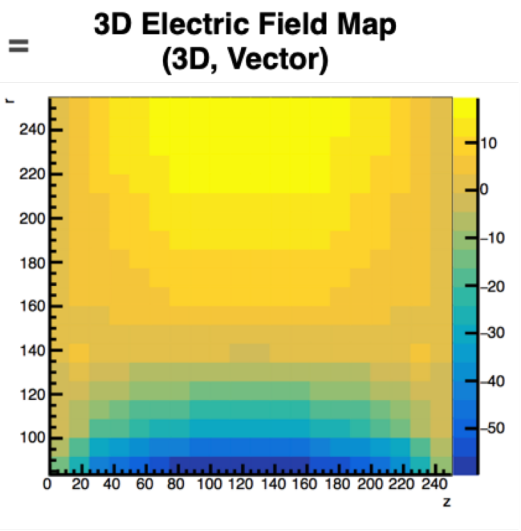


Digital Current Framework

- integrate e- arriving at logical blocks of readout pads over O(10ms)
- scale by IBF gain to get "digital current" density
- model estimate of primaries, build spacecharge map
- Combined with measured+calculated external E+B fields
- Same code that generates MC truth distortions generates digital current correction:



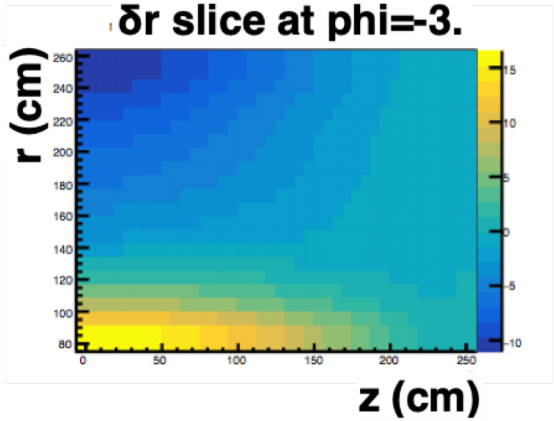


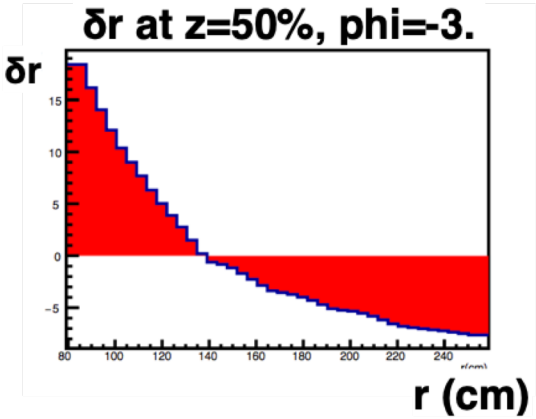


Cylindrical Coordinates:

$$\begin{pmatrix} \delta_{rE} \\ r\delta_{\phi E} \end{pmatrix} = \begin{pmatrix} c_0 & c_1 \\ -c_1 & c_0 \end{pmatrix} \begin{pmatrix} \int \frac{E_r}{E_z} dz \\ \int \frac{E_\phi}{E_z} dz \end{pmatrix}$$

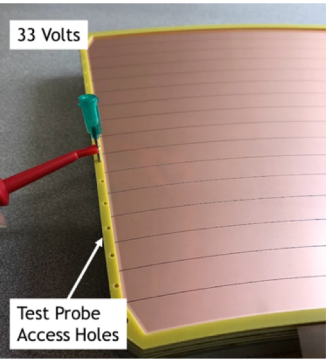
$$\begin{pmatrix} \delta_{rB} \\ r\delta_{\phi B} \end{pmatrix} = \begin{pmatrix} c_2 & -c_1 \\ c_1 & c_2 \end{pmatrix} \begin{pmatrix} \int \frac{B_r}{B_z} dz \\ \int \frac{B_\phi}{B_z} dz \end{pmatrix}$$

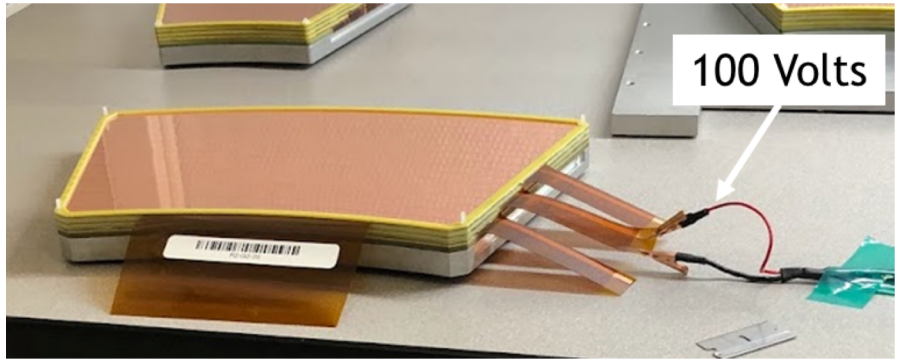


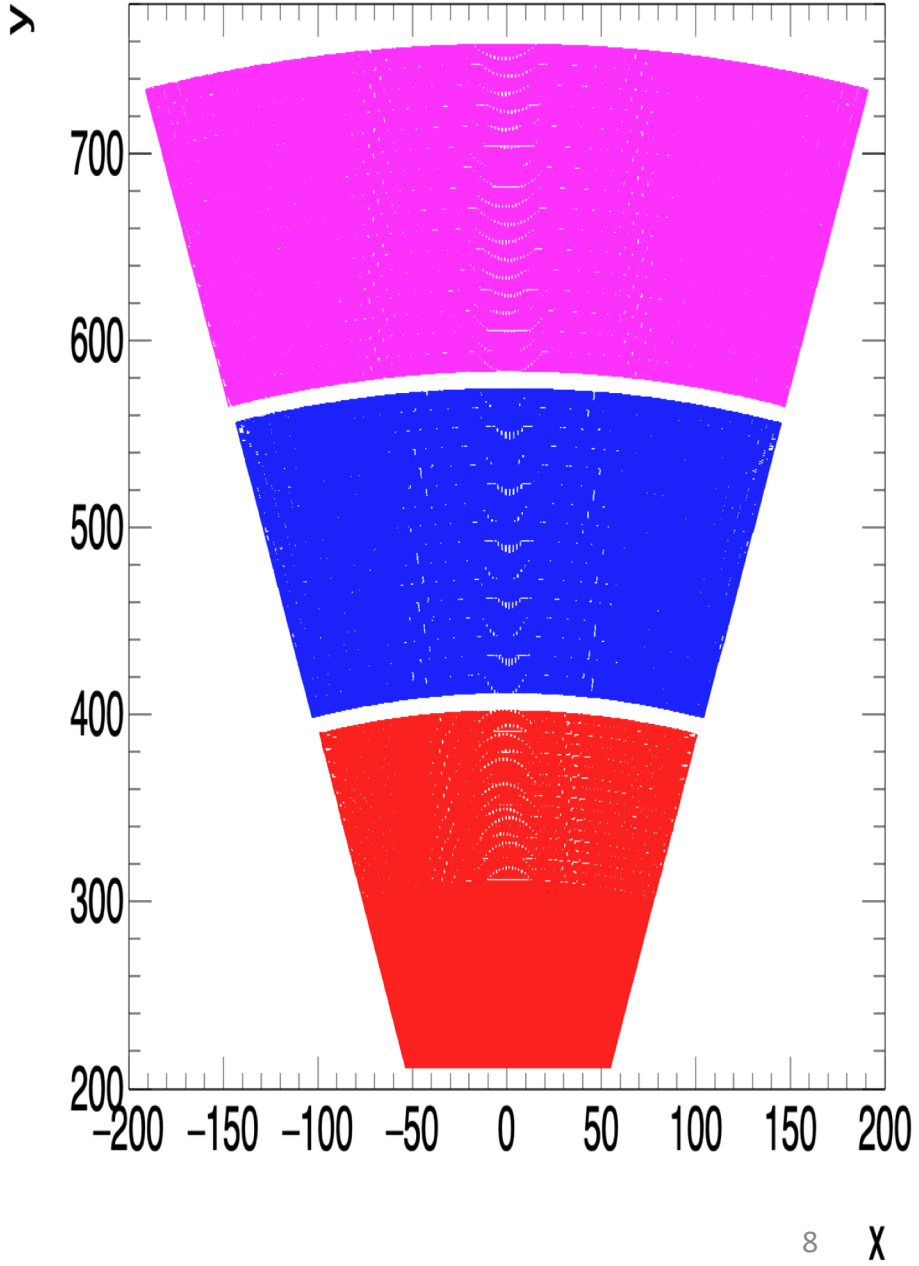


Gain & IBF measurements

- The IBF characterization is ongoing
- X-ray tube is used to provide enough charges for the measurement
- ~0.3% is the IBF flux

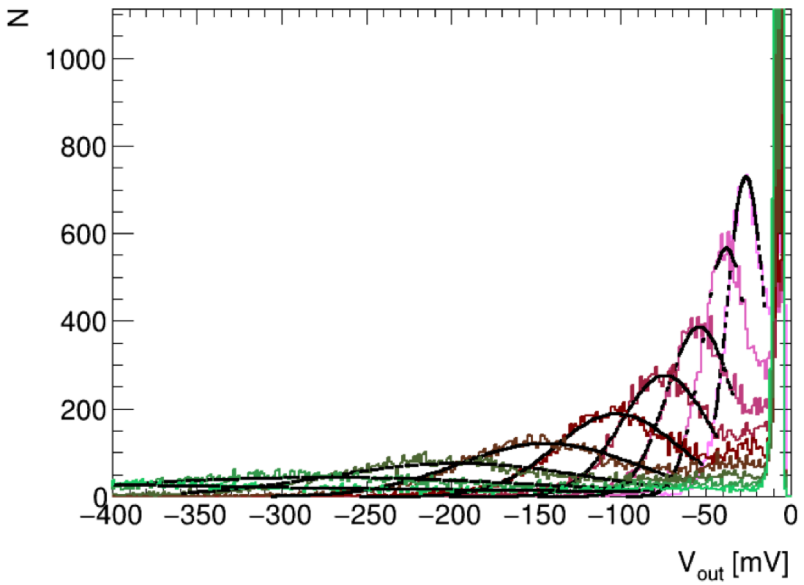


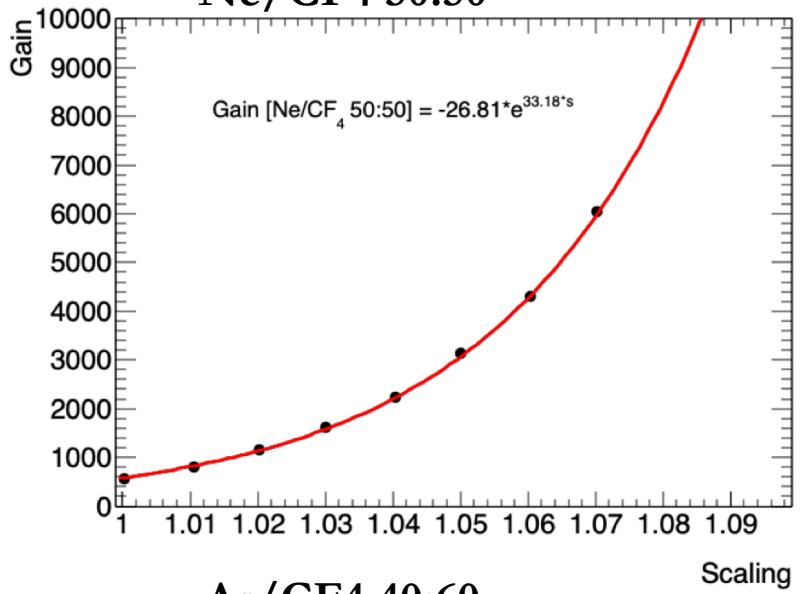


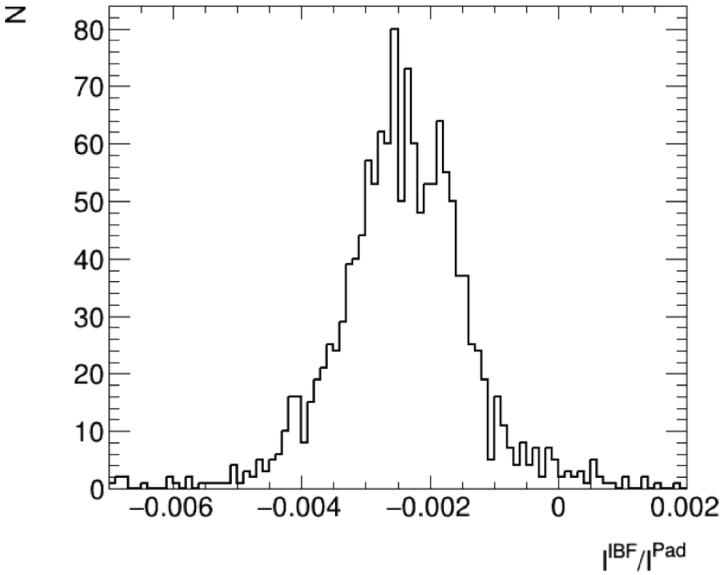


Gain & IBF measurements

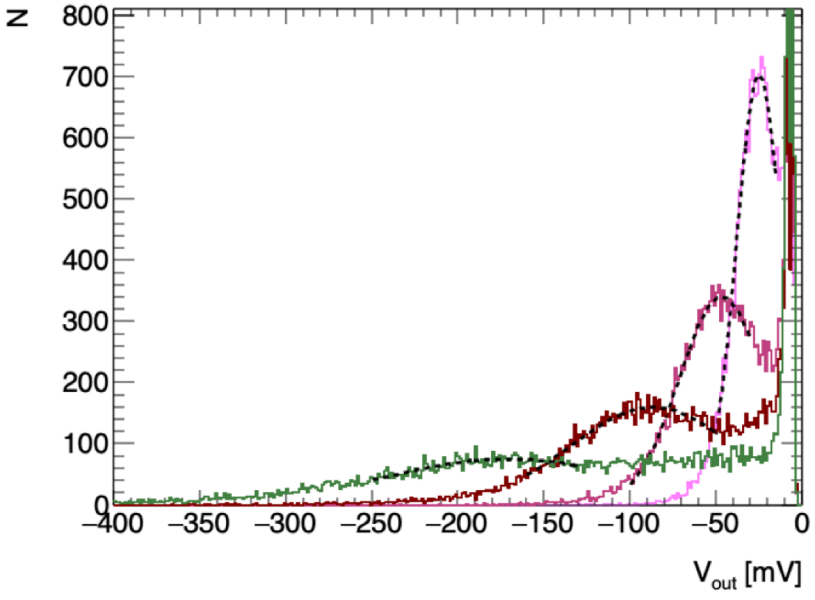
Ne/CF4 50:50

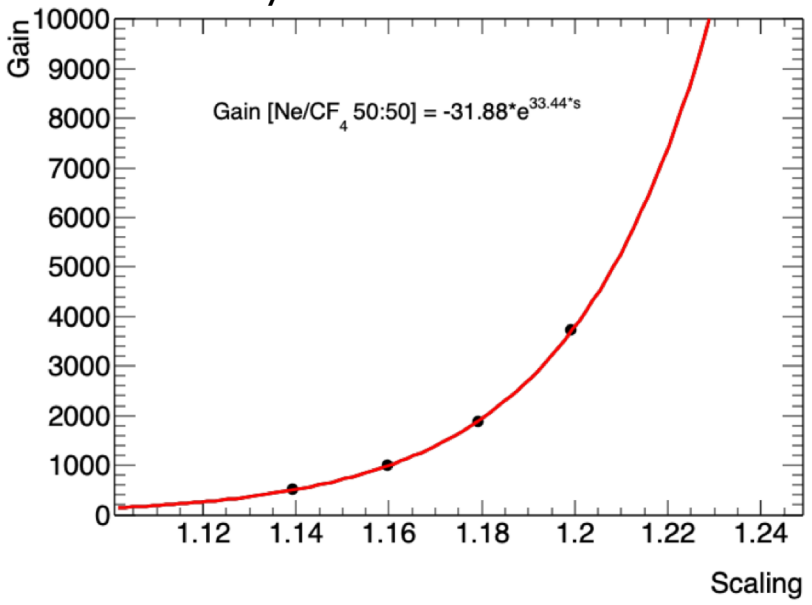


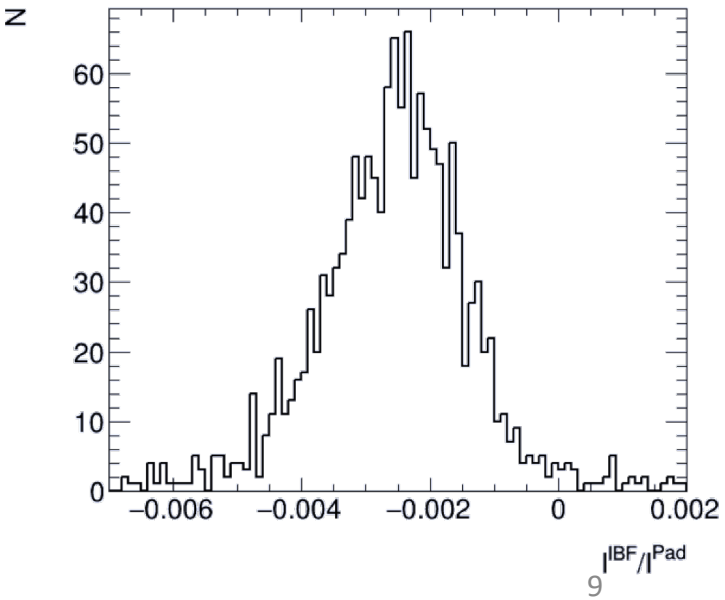




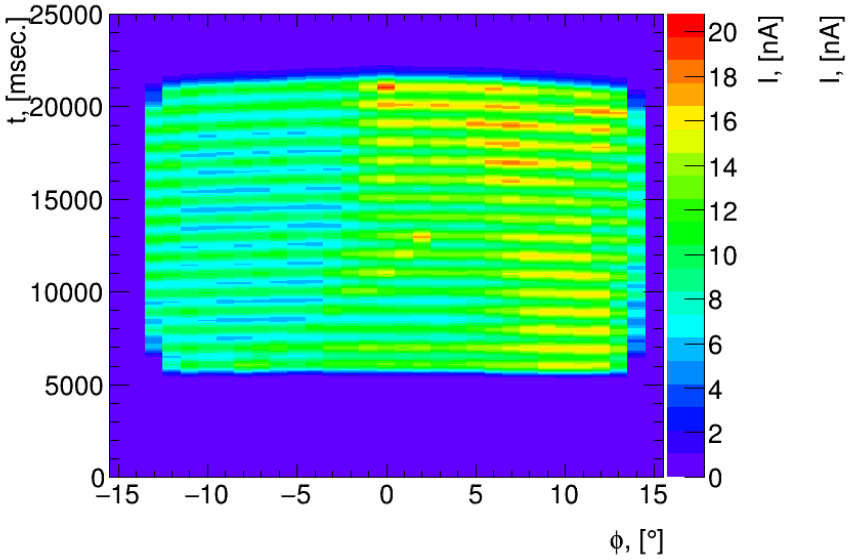
Ar/CF4 40:60

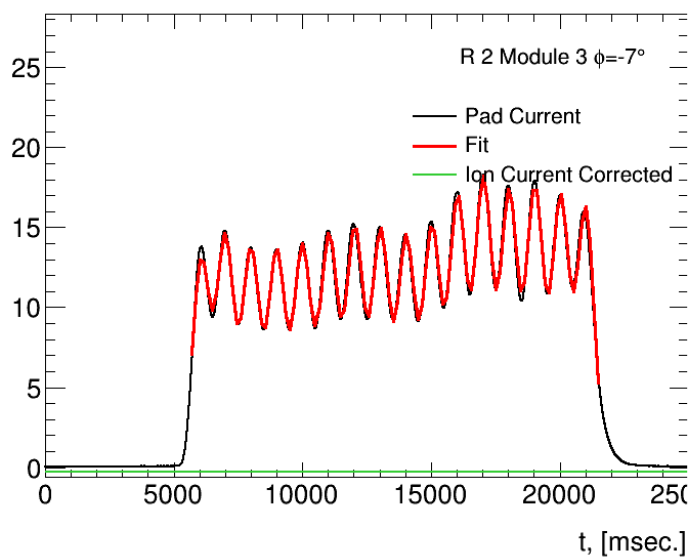


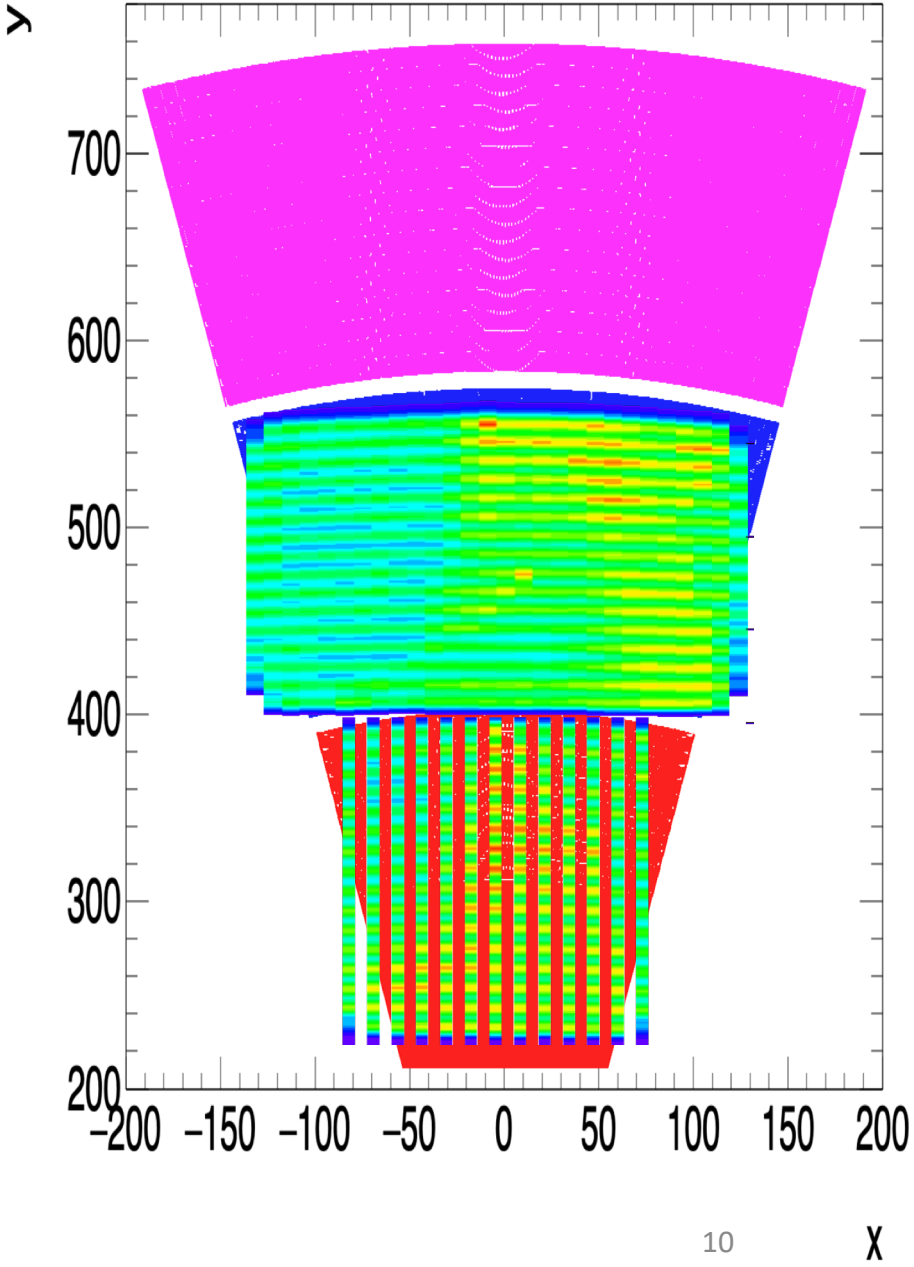




Gain & IBF measurements







- >50% of scans are done
- The fits and the results of the scans will be used for IBF values estimation

Status and plans

- Calibration strategy thoroughly fleshed out and integrated with tracking workflow
- Framework for all hit-driven components tested by unit:
  - Inject a data-driven distortion into a simulated event
  - Extract average and fluctuation corrections from the resulting distorted event
  - Apply corrections and provide de-distorted tracks

Soon:

- *Finish porting CM fluctuation code into Fun4All*
- Run full corrections chain in production

Roadmap for 2022

Now

- Complete implementation of distortion calibration workflow in Fun4All -nearly there (code not in MDC production yet, and optimization will continue into summer)

Summer 22:

- Develop TPC internal alignment software
- Study drift speed calibration
- Develop QA of calibration
- Add GEM Calibrations, CM intensity maps and other measured quantities as available

Fall 22:

- Complete definition of Direct Laser run pattern
- Complete integration of CM flash into trigger
- Complete integration of Digital Current into Fun4All framework

Winter 22 (when TPC services are available):

- Perform the Direct Laser runs.
- Exercise the CM flash with or without beam

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