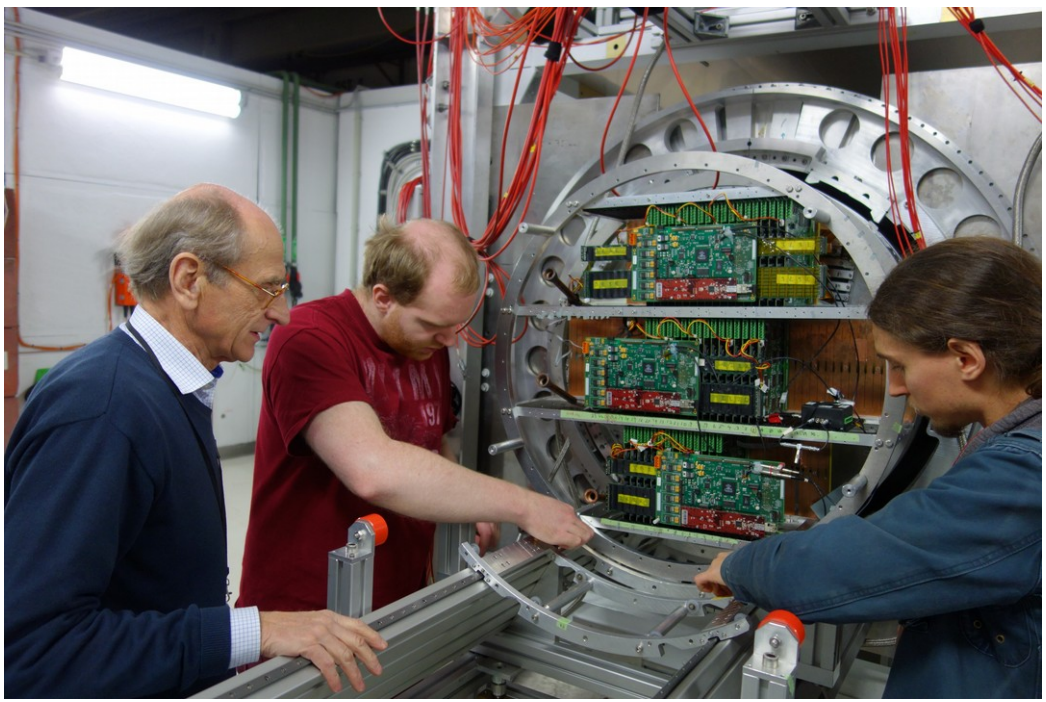
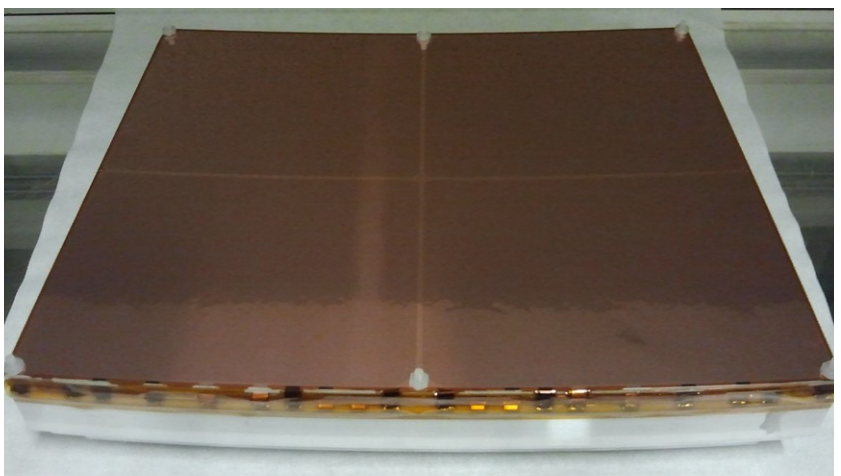
Latest Results from a TPC Test Beam with a triple GEM Module





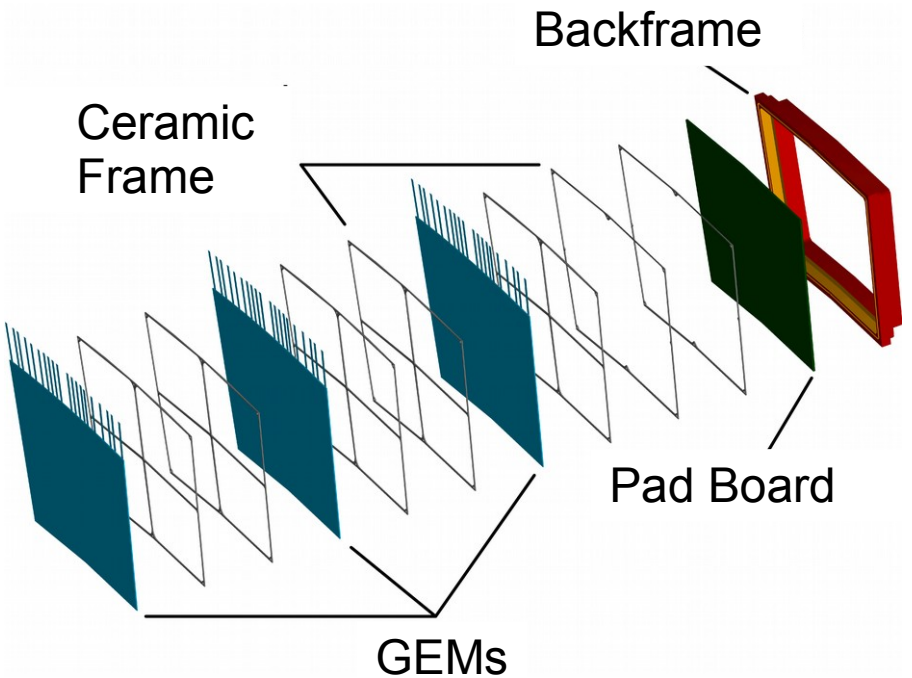
Ralf Diener, Oleksiy Fedorchuk, Paul Malek
LCWS17, Strasbourg, 24.Oct.2017

HELMHOLTZ ASSOCIATION

DESY

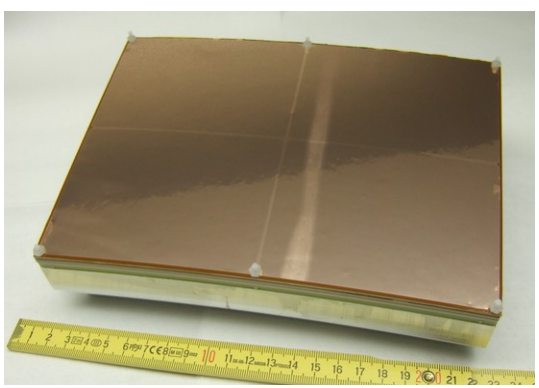
DESY GridGEM Module

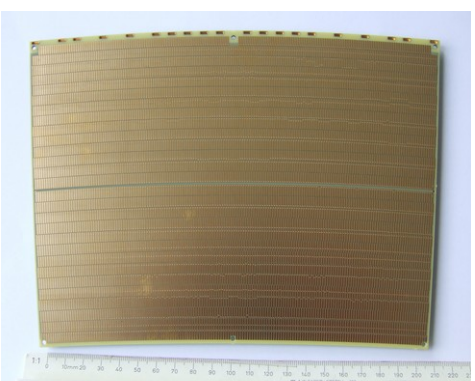
- Goals:
  - Minimal material budget
  - Maximal sensitive area
  - Minimal gaps



- Integrated, self supporting GEM/ceramics structure
  - Stack of 3 GEMs on thin ceramic frames

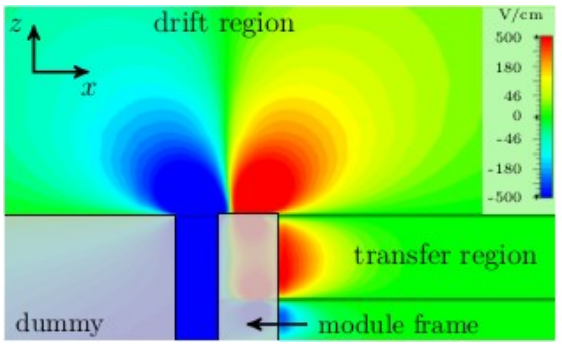
- Size, shape as planned for ILD TPC endplate
  - Area ~ 17 x 23 cm²
- Padplane
  - 28 rows
  - Pad size: 1.26 x 5.85 mm²

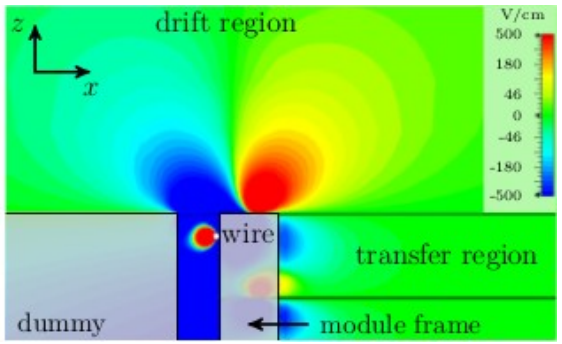


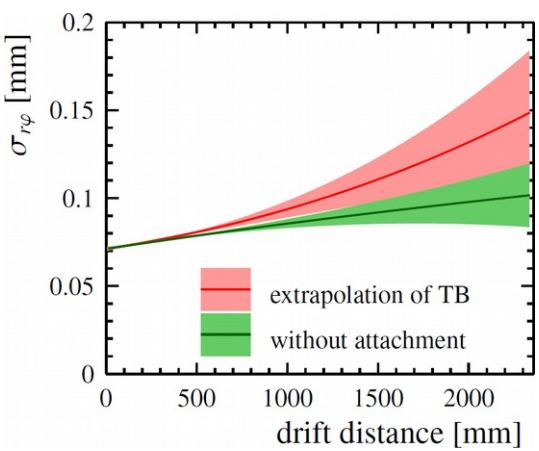


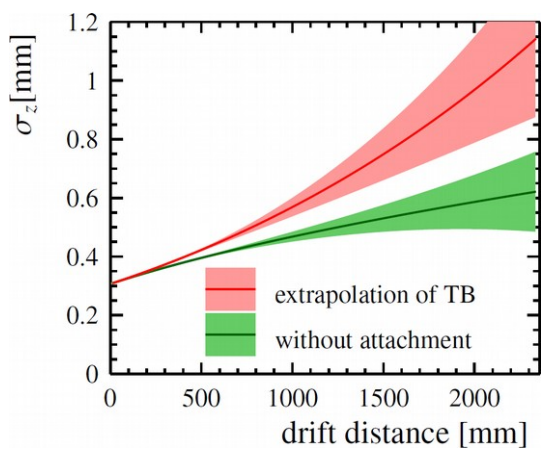
New Iteration

- Last module iteration worked well during testbeam effort in 2013
  - HV stable during testbeam
  - Guard ring reduced field distortions significantly
  - Excellent hit efficiency > 99.5%
  - ILD point resolution requirements in z (0.5 - 1.4 mm) and rφ (< 100 µm) reached





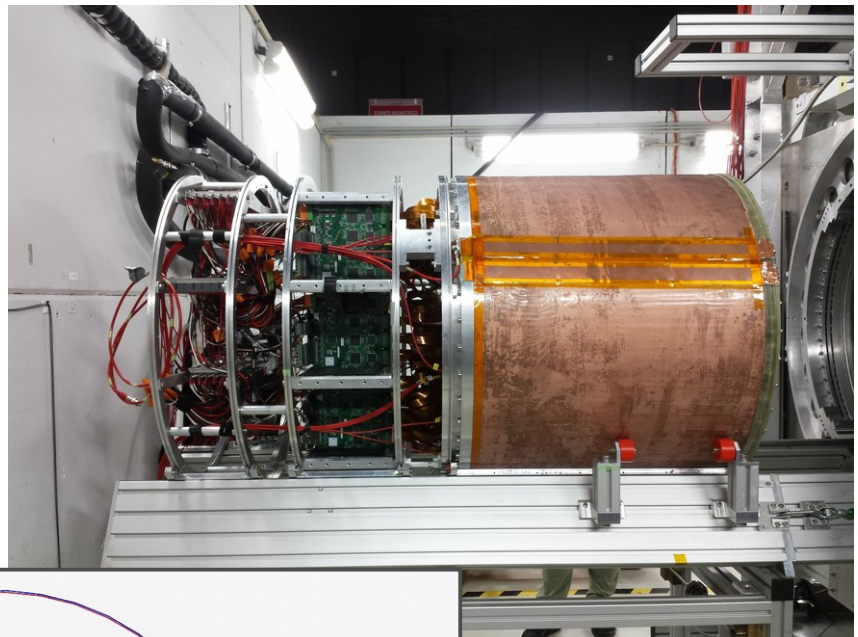




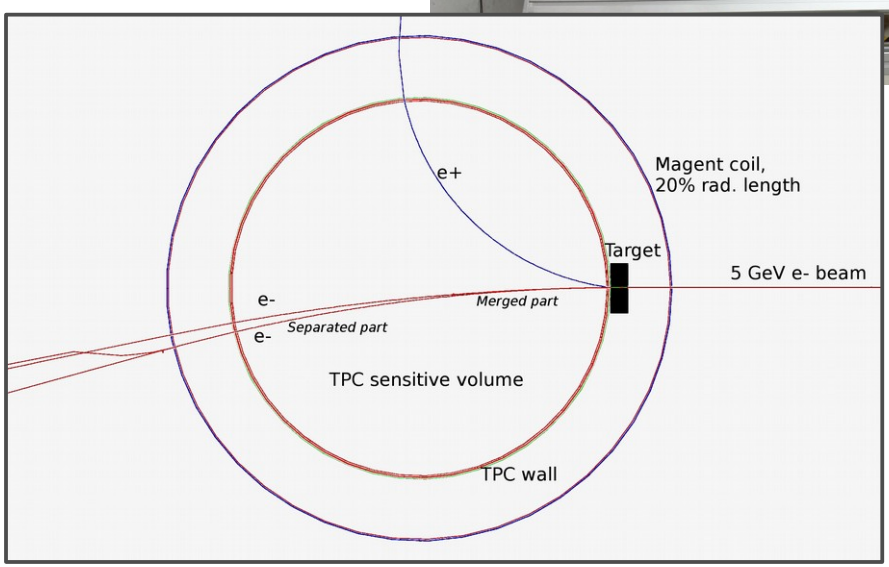
- R&D and goals for new iteration
  - Improved, reproducible production techniques
  - Controlled, improved GEM flatness
    → Improved from 50-90 to 30-50 µm (RMS)
  - Revised mechanics and drawings

Test Beam Measurements

- Test beam period in Nov./Dec. 2016 at the DESY II Test Beam Facility
  - Test new module iteration
  - Runs at 0, 0.5, 1T magnetic field at different drift lengths and angles
    - Standard drift field: 240 V/cm
  - Runs with minimal diffusion drift field: 130 V/cm
  - Runs with minimal ion backflow GEM settings



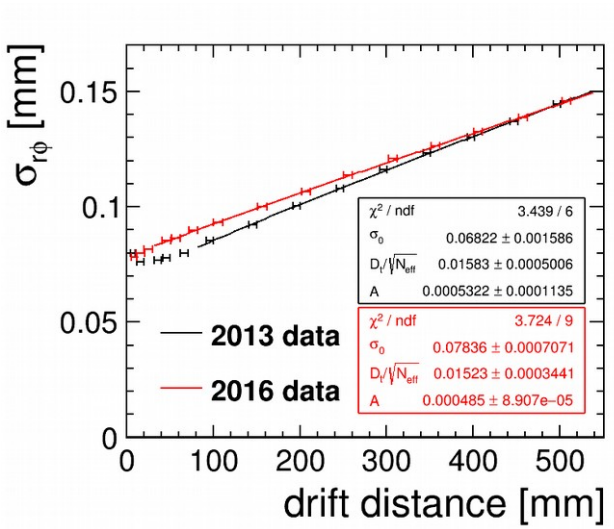
- Perform double track studies
  - Measurements with target (~ ½ X_0):
  - Rate of usable double track events: ~6-7 % for 1 T magnetic field



- 9.5 M events recorded

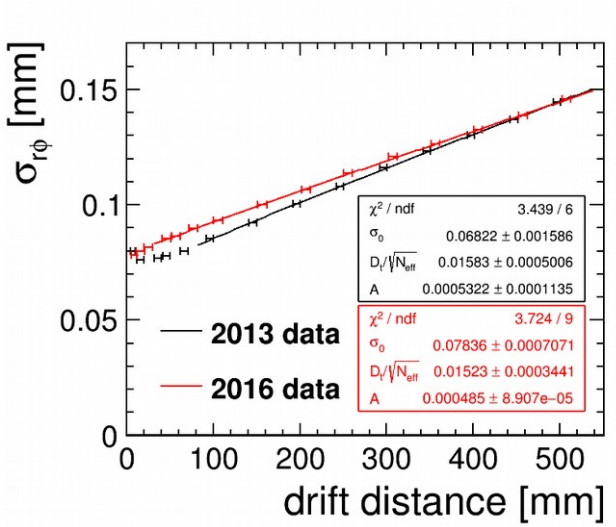
Test Beam Period Comparison: 2013 ↔ 2016

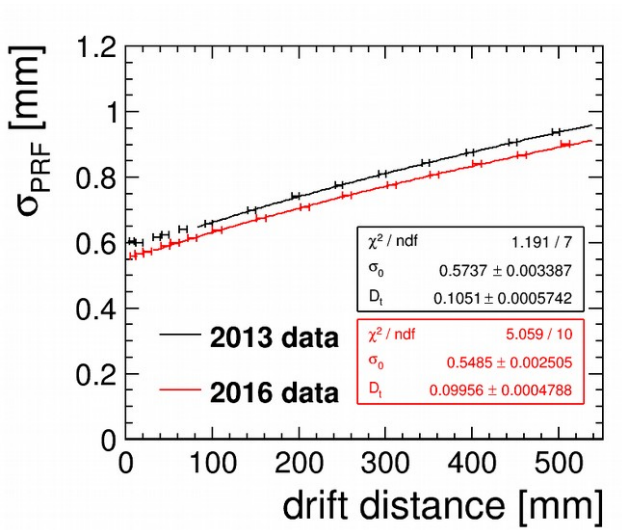
- Comparison of rφ resolution shows discrepancy between 2013 and 2016 measurements

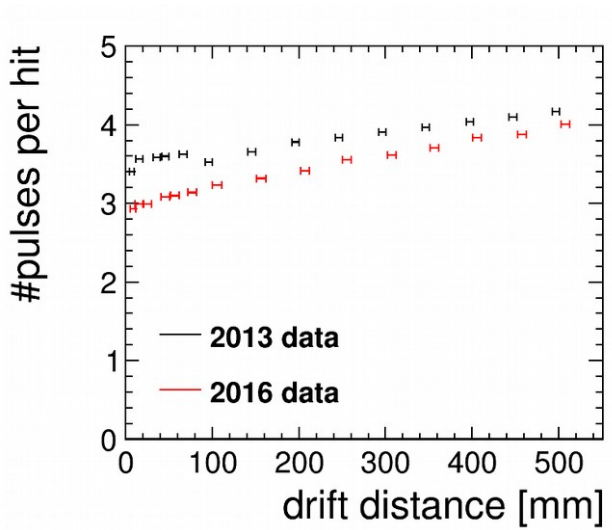


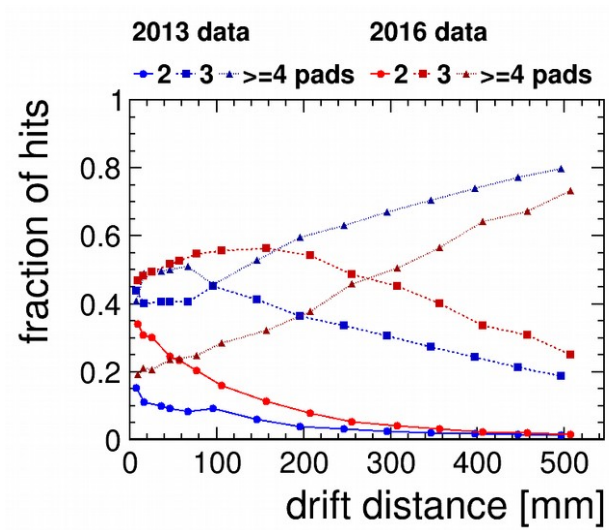
Test Beam Period Comparison: 2013 ↔ 2016

- Comparison of rφ resolution shows discrepancy between 2013 and 2016 measurements
- This is also reflected in PRF width and the number of pulses / hit



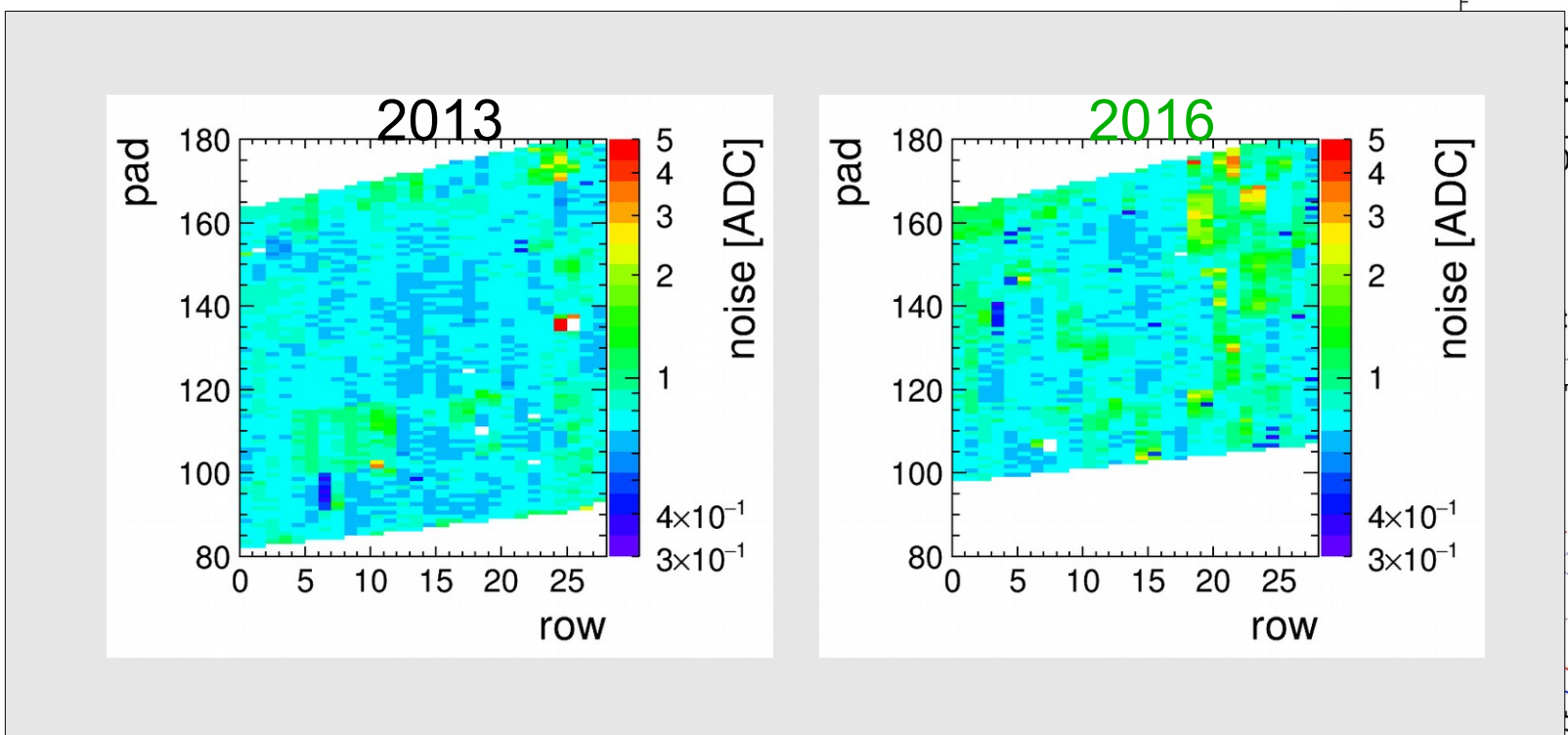






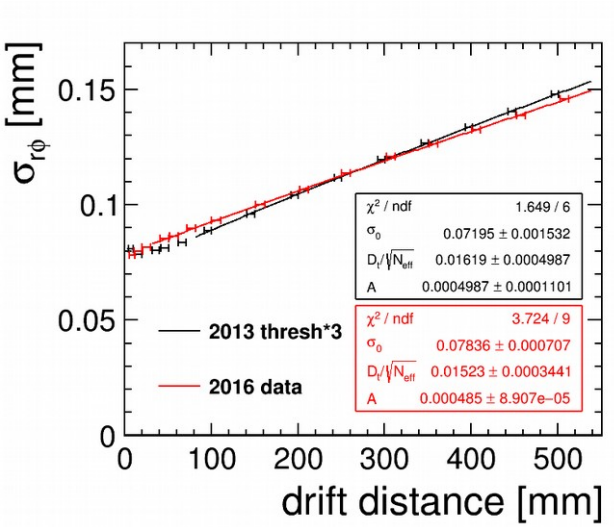
Test Beam Period Comparison: 2013 ↔ 2016

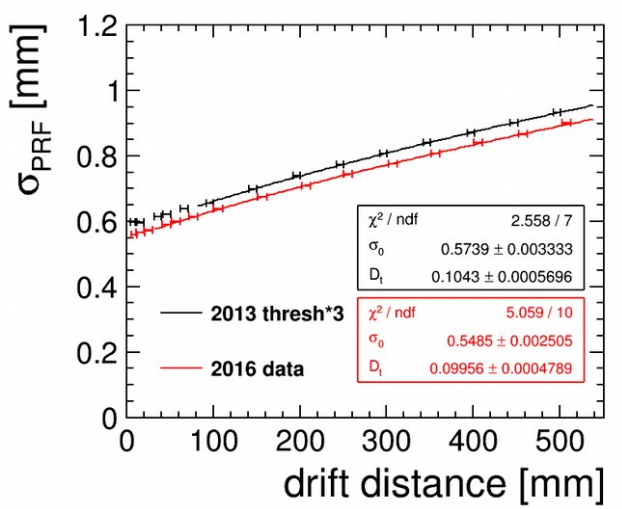
- Comparison of rφ resolution shows discrepancy between 2013 and 2016 measurements
- This is also reflected in PRF width and the number of pulses / hit
- More noise in the beam path in 2016

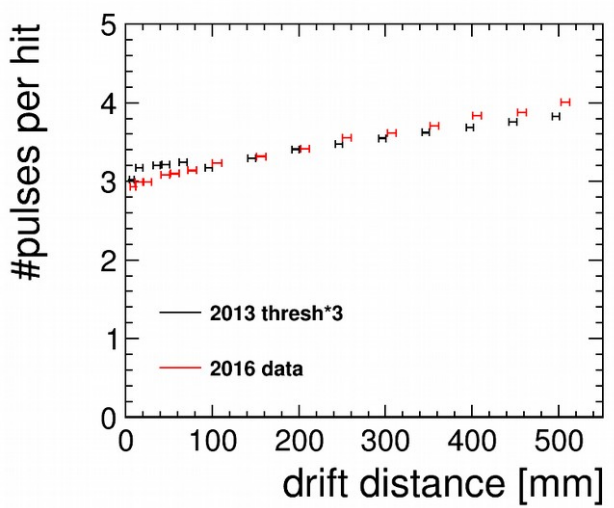


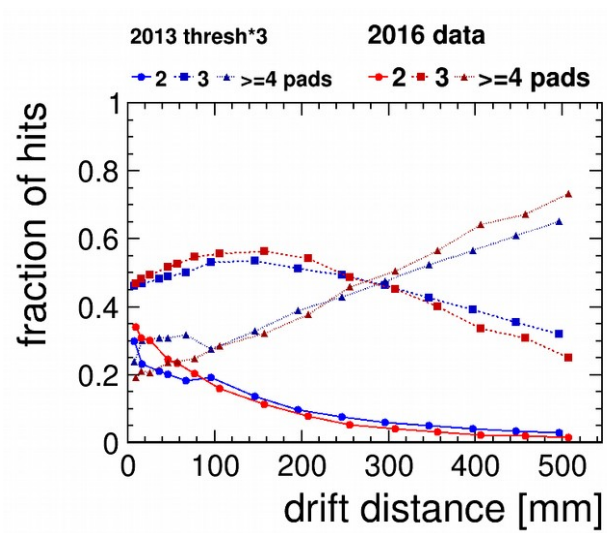
Test Beam Period Comparison: 2013 ↔ 2016

- Comparison of rφ resolution shows discrepancy between 2013 and 2016 measurements
- This is also reflected in PRF width and the number of pulses / hit
- More noise in the beam path in 2016
- Adjust noise threshold in the reconstruction by factor of 3
  → analysis results closer together
  - Resolution similar, but 2013 has a steeper rise with drift length
  - PRF width / diffusion unaffected
- Studies are ongoing



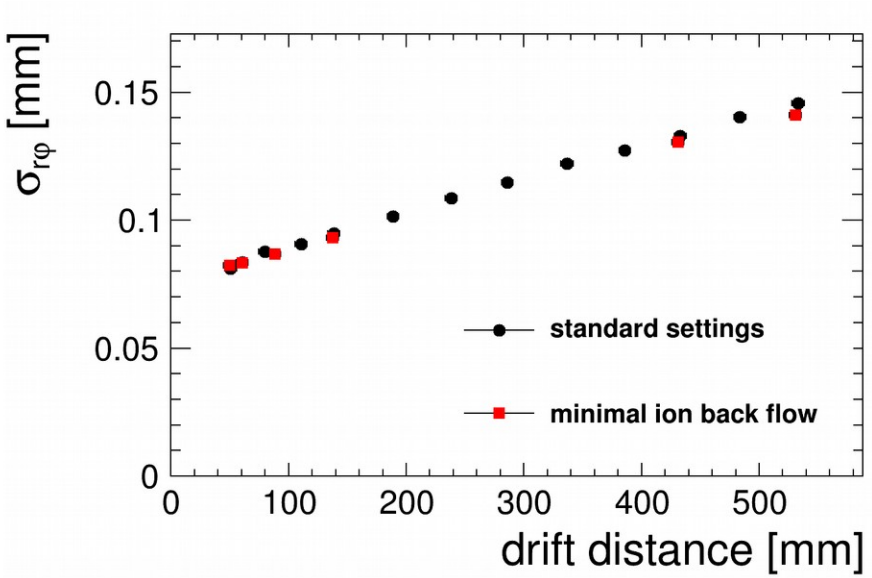




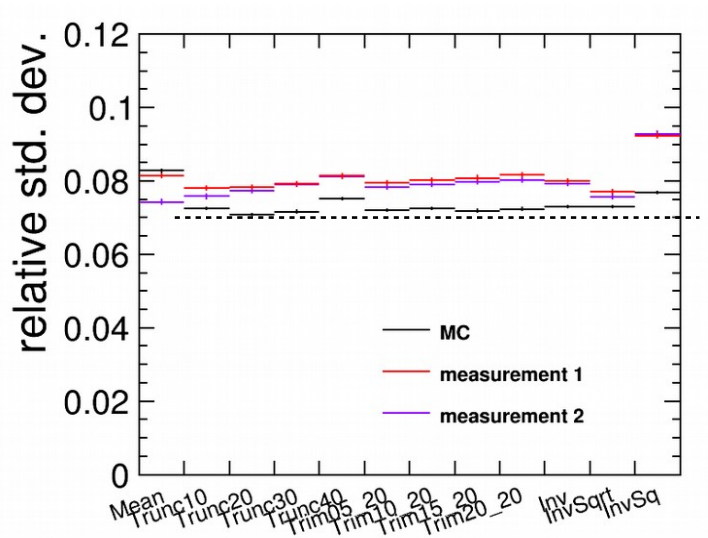


Minimal Ion Backflow and Specific Energy Loss

- Tested Minimal Ion Backflow (MIB) settings of the GEM voltages in 2016 period
- Resolution unaffected

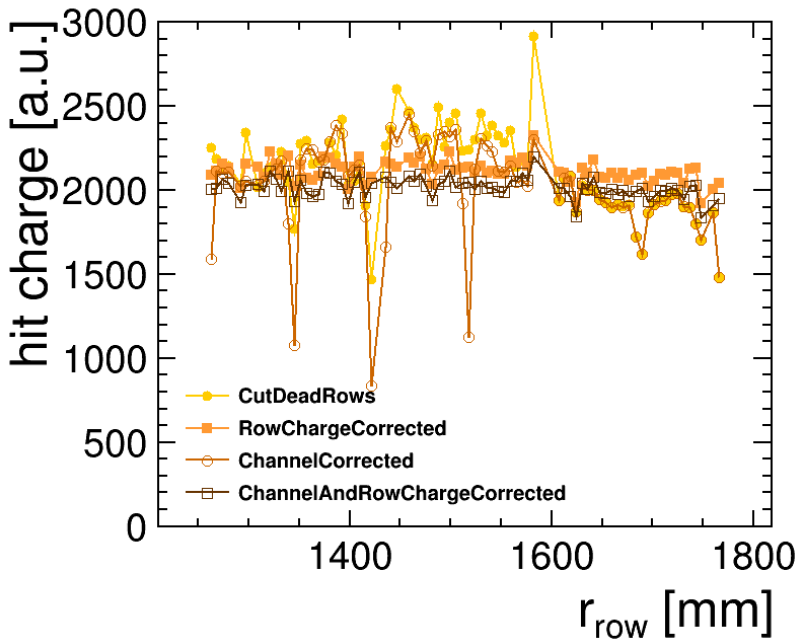


- dE/dx studies
  - Choice of estimator
    →
    Truncation of upper 20% chosen based on simulation results



dE/dx Studies

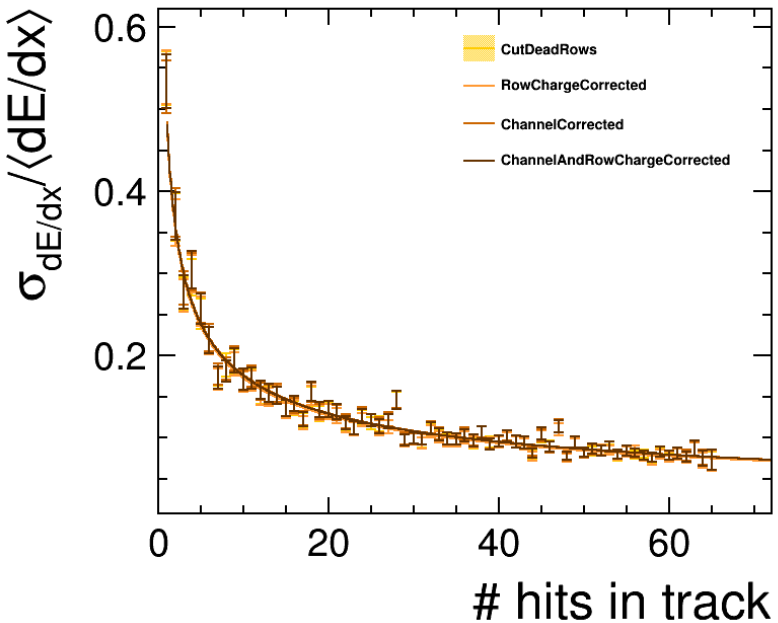
- Test of correction / calibration methods and their impact
  - Starting point:
    CDR – Cut Dead Rows
  - RCC – Correct by average row charge
  - CC – Single channel correction (module 1+2)
  - CRCC – Combined



	Mean	RMS	RMS %
CDR	2150	219	10.1
RCC	2115	67	3.2
CC	2100	168	8.0
CRCC	2017	62	3.1

dE/dx Studies

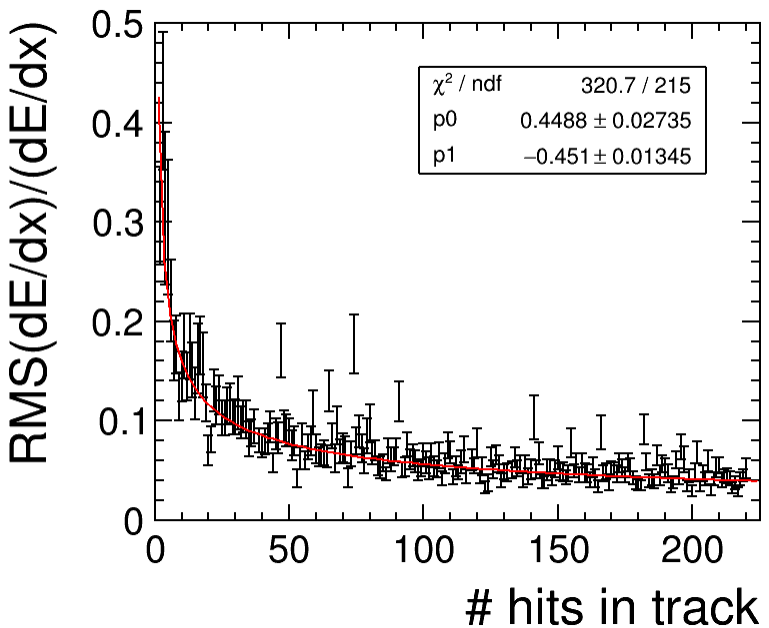
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  - Starting point:
    CDR – Cut Dead Rows
  - RCC – Correct by average row charge
  - CC – Single channel correction (module 1+2)
  - CRCC – Combined
  - Negligible impact on dE/dx resolution
    dep. on number of track hits



	σ_0	power
CDR	0.49±0.02	-0.45±0.01
RCC	0.48±0.02	-0.45±0.01
CC	0.49±0.02	-0.44±0.01
CRCC	0.49±0.02	-0.44±0.01

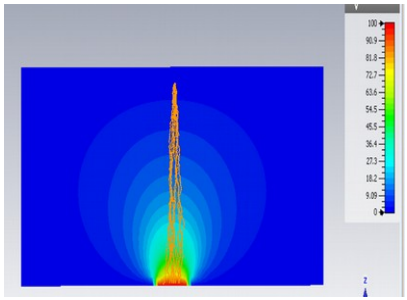
dE/dx Studies

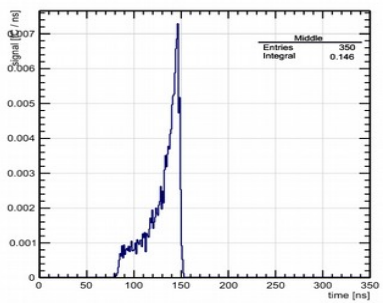
- Test of correction / calibration methods and their impact
  - Starting point:
    CDR – Cut Dead Rows
  - RCC – Correct by average row charge
  - CC – Single channel correction (module 1+2)
  - CRCC – Combined
  - Negligible impact on dE/dx resolution
    dep. on number of track hits
- Combine hits from multiple tracks/events
  to create “toy tracks” of arbitrary length.
  - Extrapolate dE/dx resolution to longer tracks
- dE/dx resolution of 4 % reachable at ILD TPC
  (requirement: 5 %)

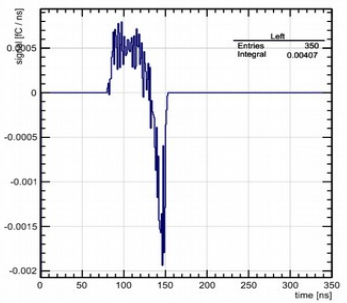


Pad Response Function Studies

- Detailed simulation of pad response
  - Including induced signals on neighboring pads

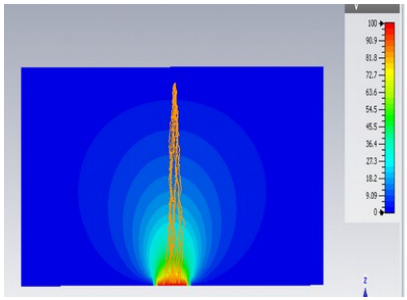


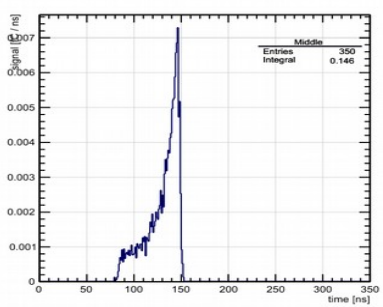


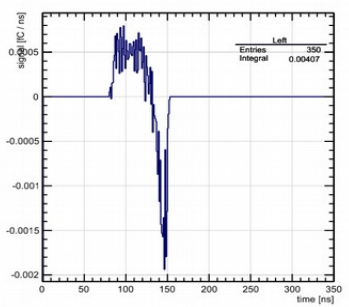


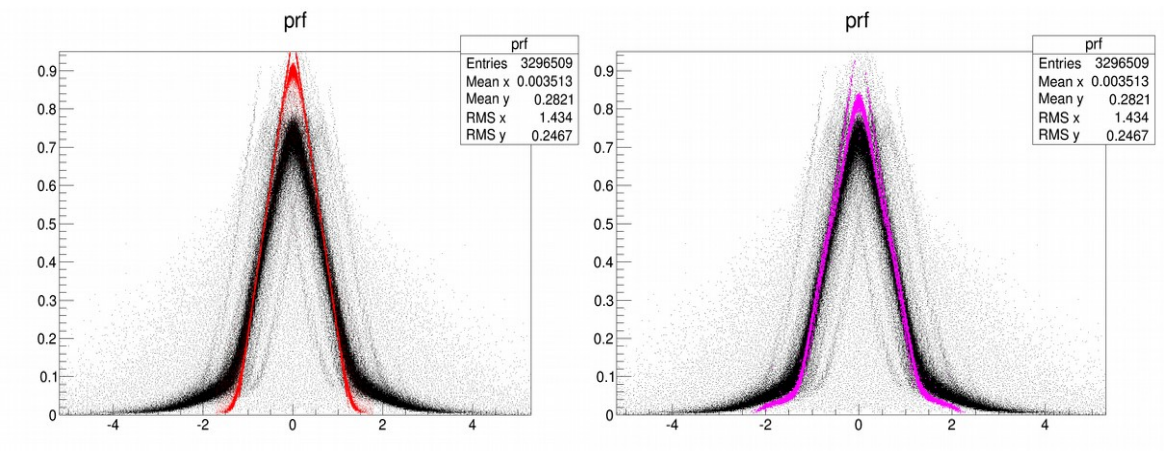
Pad Response Function Studies

- Detailed simulation of pad response
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  - Results implemented in MarlinTPC
  - Improved description of data



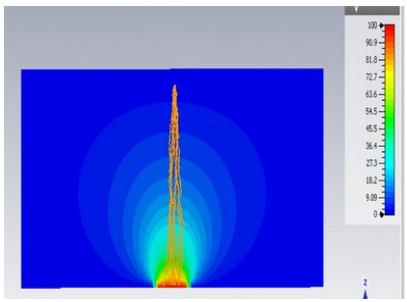


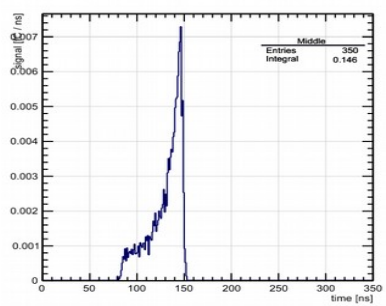


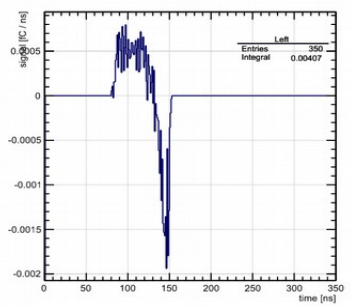


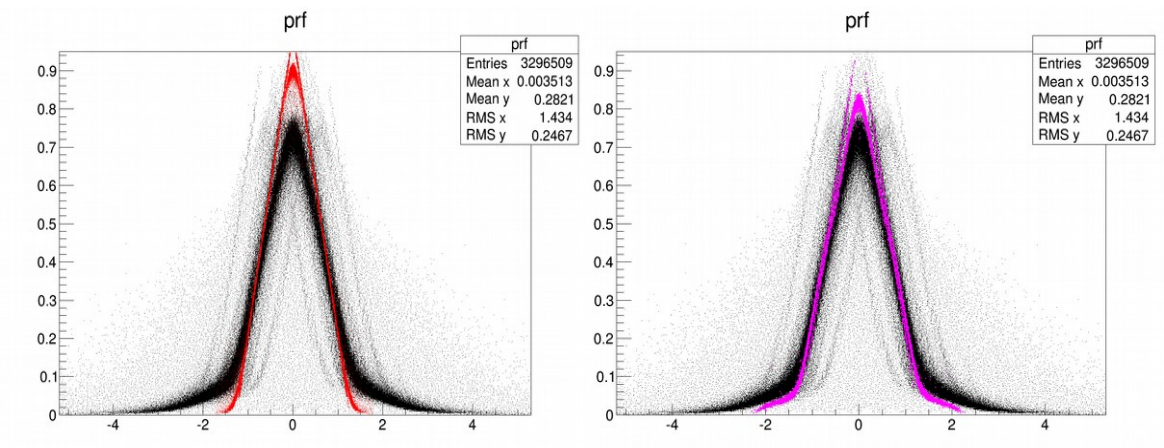
Pad Response Function Studies

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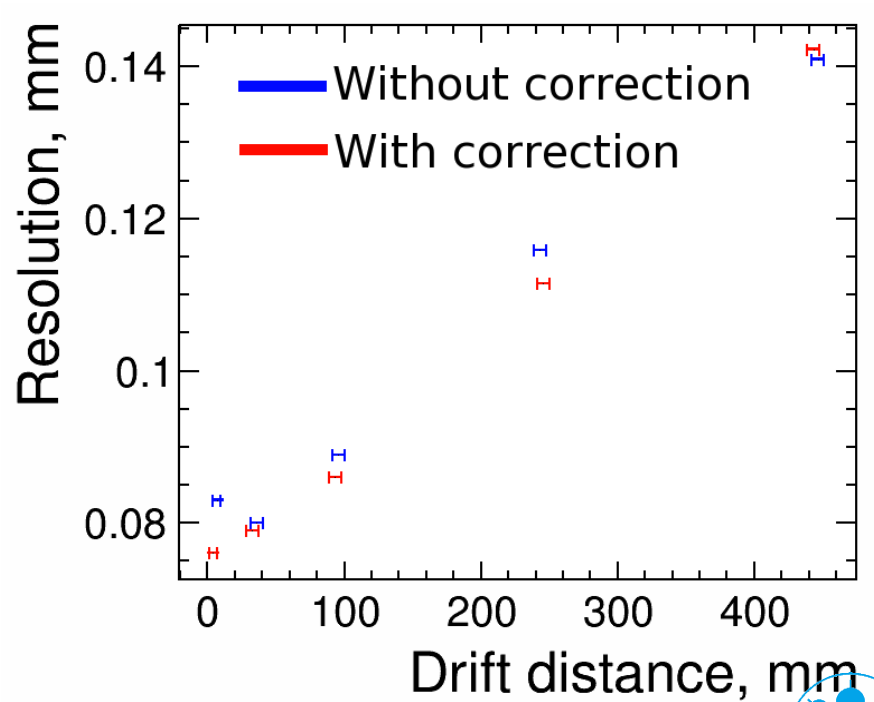






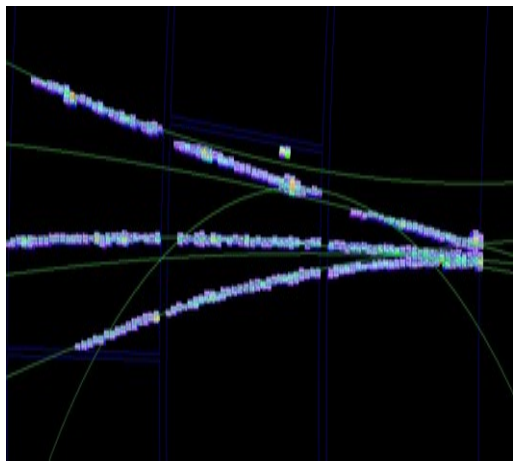


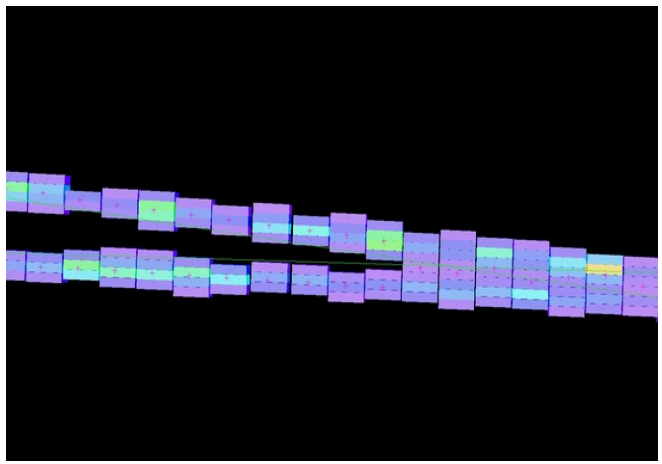
- Implemented correction for hodoscope effect at low drift distances



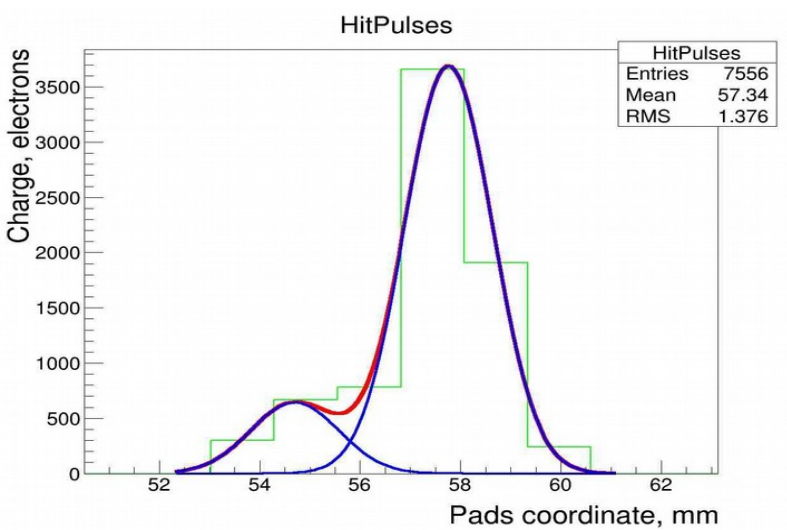
Double Track Studies

- Produced multiple track events by target right in front of Large Prototype
- Selecting events with tracks with
  - Overlap at the first few pad rows
  - Clear separation at the last rows



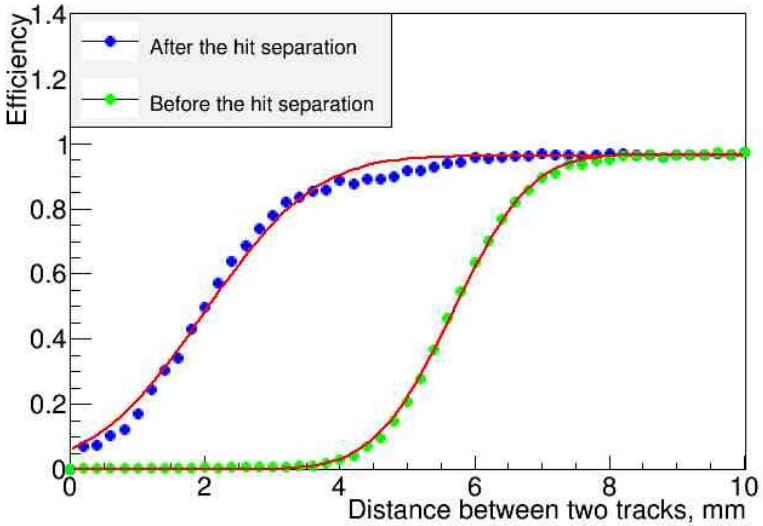


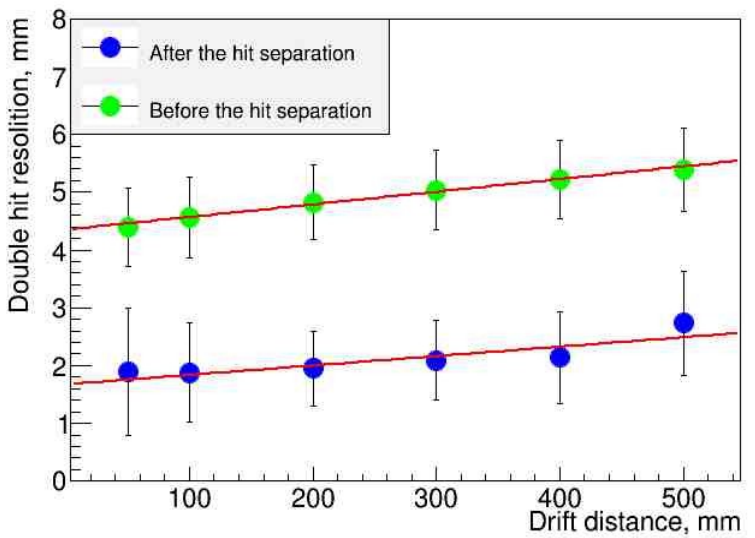
- Implemented fit of two PRF functions for double hit candidates
  - Reconstruction takes into account track information to identify double hit candidates
  - Decision for separation based on X^2 of PRF fit



Double Track Studies – Hit Separation

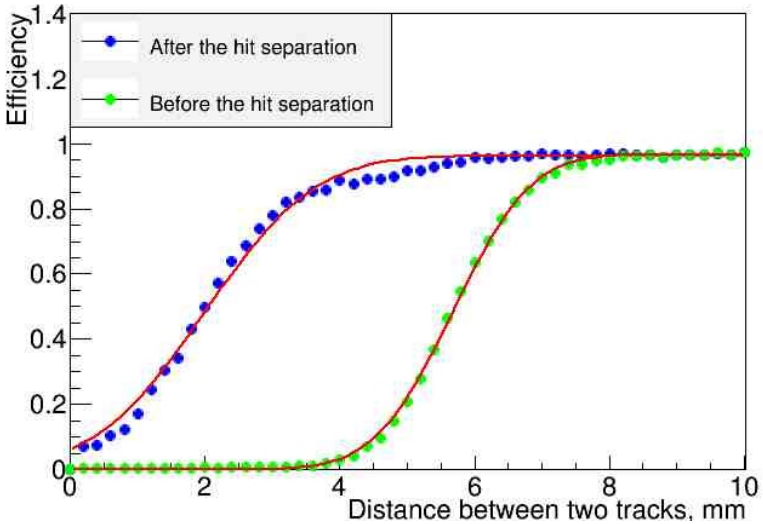
- Studies of efficiency of double hit separation depending on track distance
- Improvement of mean minimal separation distance by factor of two from 4 to 5 → 2 to 2.5 mm

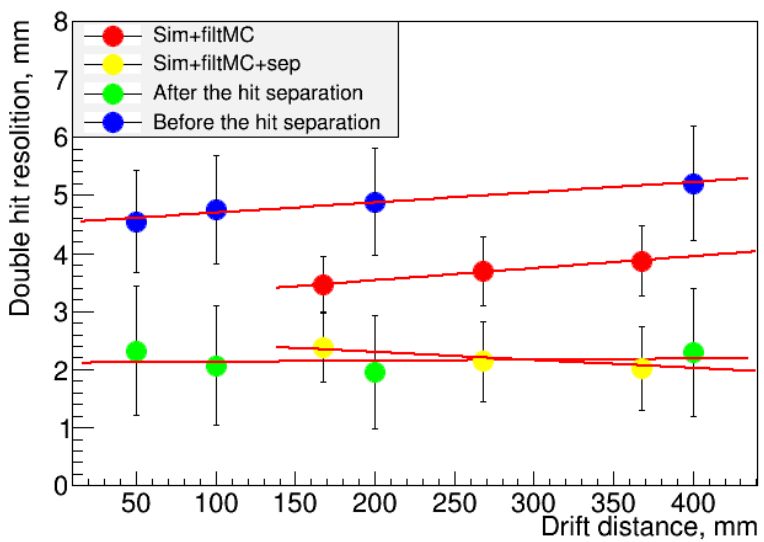




Double Track Studies – Hit Separation

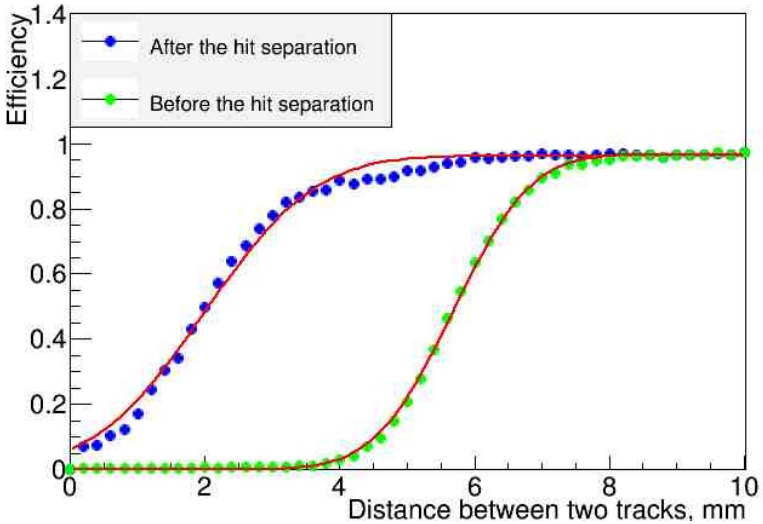
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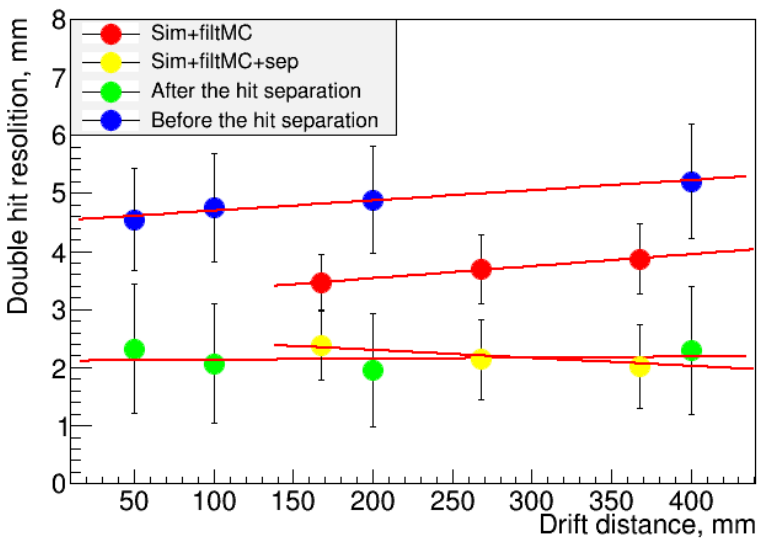


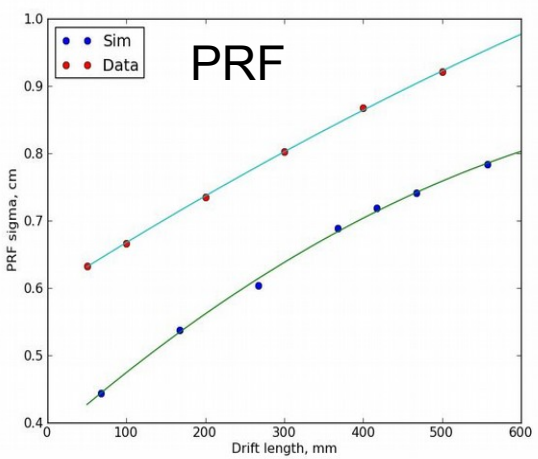


Double Track Studies – Hit Separation

- Studies of efficiency of double hit separation depending on track distance
- Improvement of mean minimal separation distance by factor of two from 4 to 5 → 2 to 2.5 mm
- Comparison to simulation shows discrepancy
- Mismatch of defocussing identified

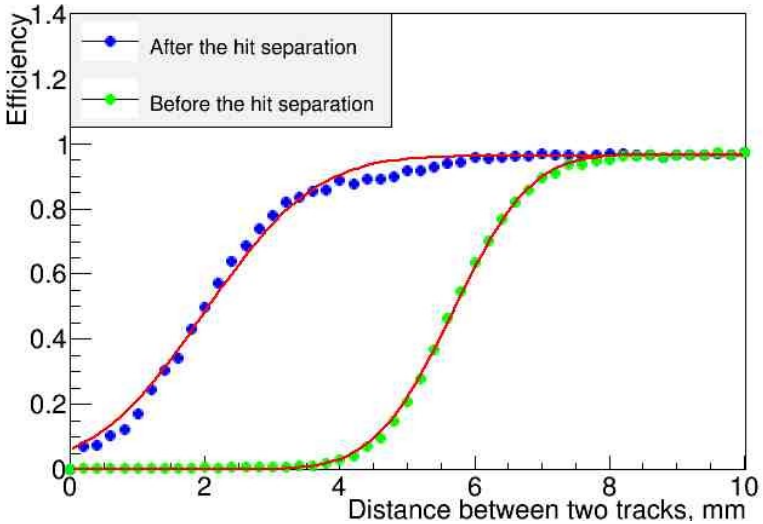


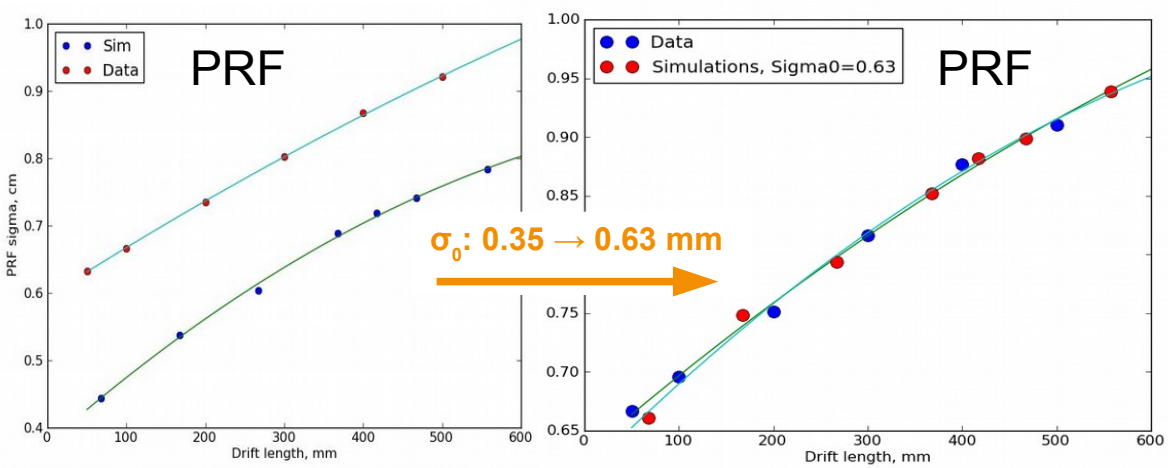


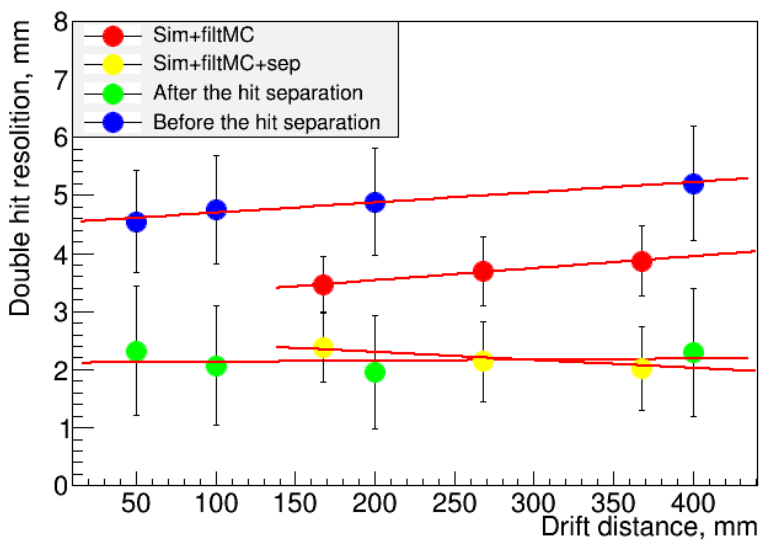


Double Track Studies – Hit Separation

- Studies of efficiency of double hit separation depending on track distance
- Improvement of mean minimal separation distance by factor of two from 4 to 5 → 2 to 2.5 mm
- Comparison to simulation shows discrepancy
- Mismatch of defocussing identified:
  artificial increase in simulation from 0.35 → 0.63 mm

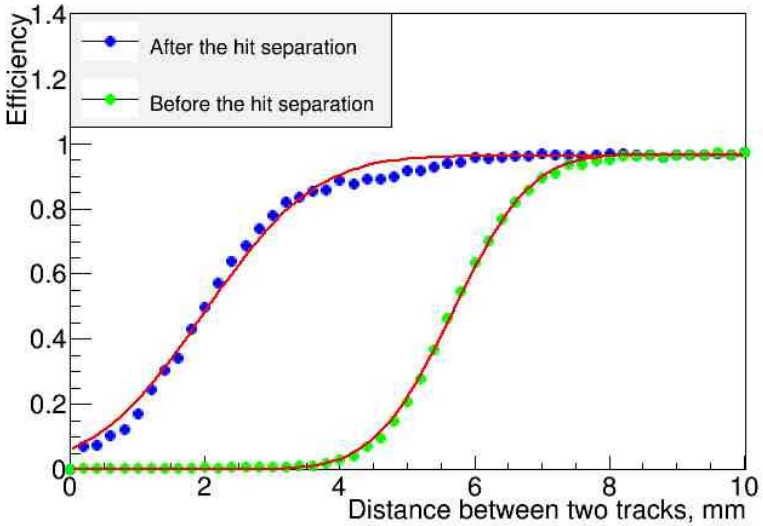


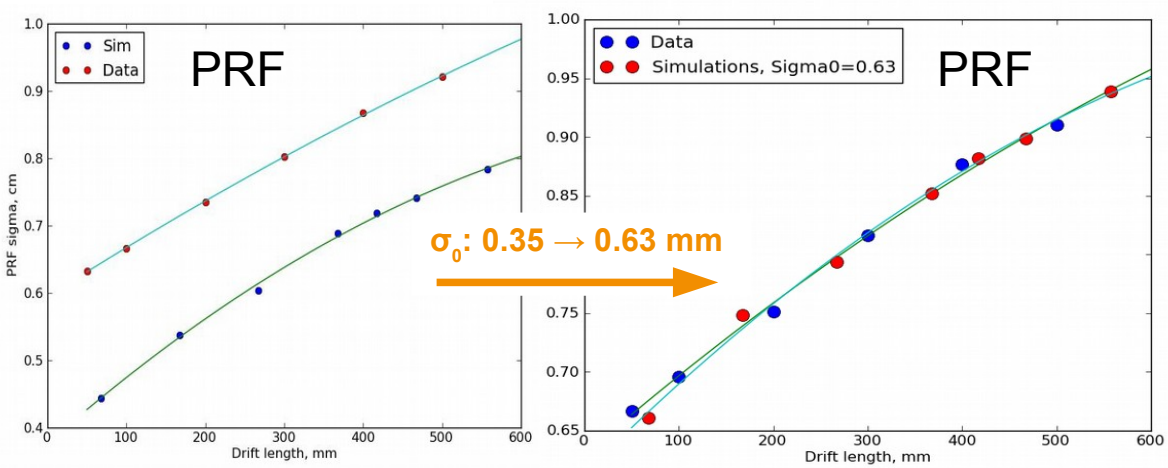


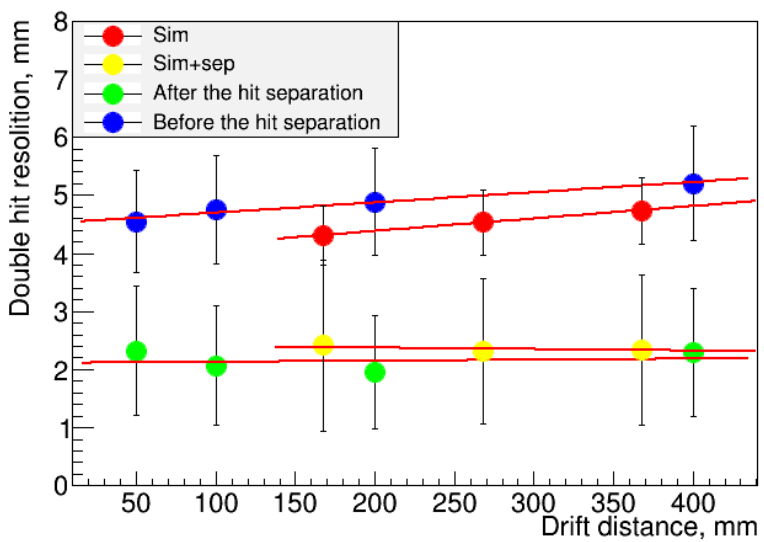


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  → Better match
- Studies ongoing







Conclusion

- New iteration of GridGEM Modules with improved construction techniques
- Performed a successful test beam effort end of 2016
- Reasonable agreement of analysis results from previous test beam effort
- dE/dx resolution extrapolation meets requirements for ILD TPC
- Double hit separation limit improved by a factor of two
- Studies still ongoing
  - Two PhD thesis studying test beam results close to being finalized