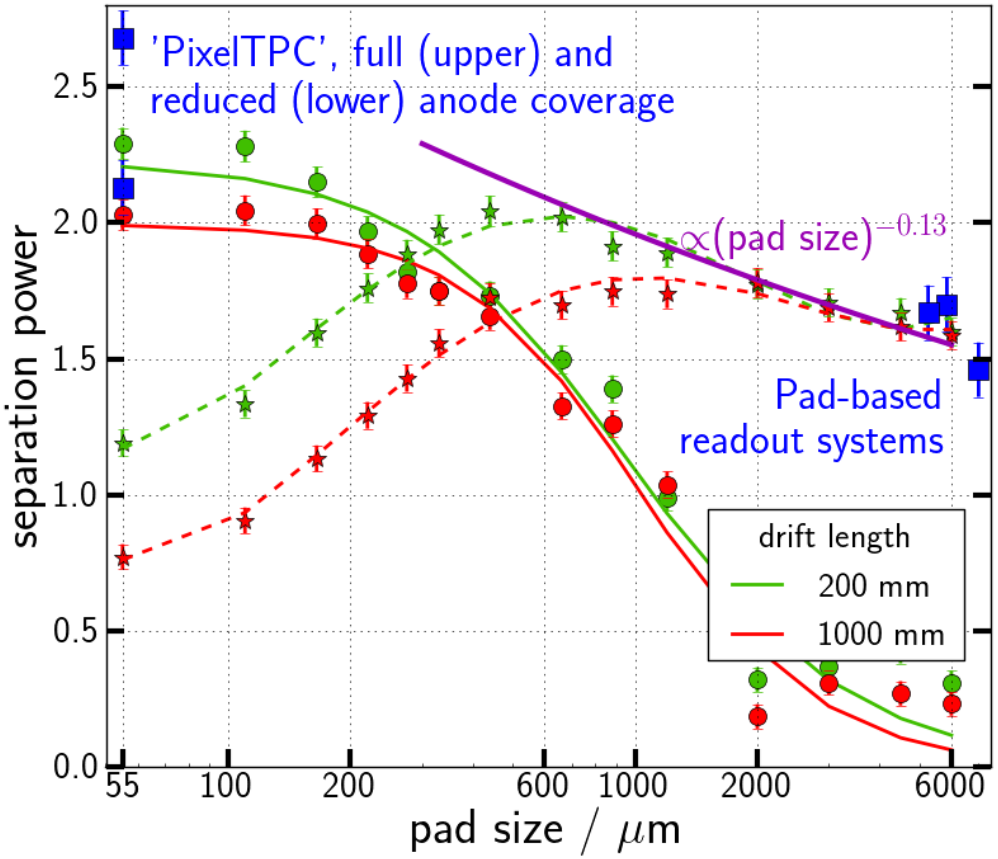
High Granularity Simulation

LCTPC Collaboration Meeting
Uli Einhaus, 14.01.2020

Overview

- Software Structure
- Results
- Extras & Outlook



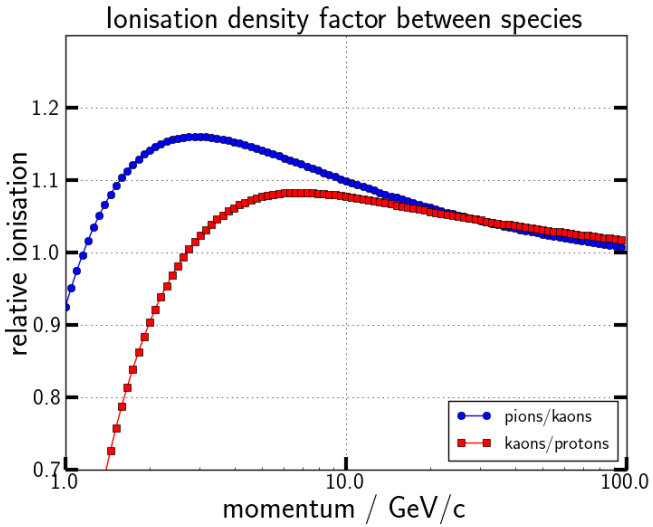
Structure

- Simulation with MarlinTPC in ILCSoft, source-extractor for reconstruction
- Detailed simulation of detector: ionisation, drift, amplification, digitisation
- Reconstruction:
  export to .fits, source-extractor scans 2D-image for source-like excesses

Primary Ionisation with Clusters
Drift
GEM
Charge Distribution
TP Digitisation
Export to .fits
Source-Extractor
Import to .slcio
Analysis - Charge Summation - Cluster Counting

Geometry and Setup

- Track of 30 cm in x-dir., varying drift in z-dir.
- Anode length (x): 30 cm; height (y): 256 pads
- Parametrised T2K gas for ionisation, drift, amplification and charge cloud distribution
- MCMuons used with cluster distance factor of 1.03 for pions, 1.19 for kaons

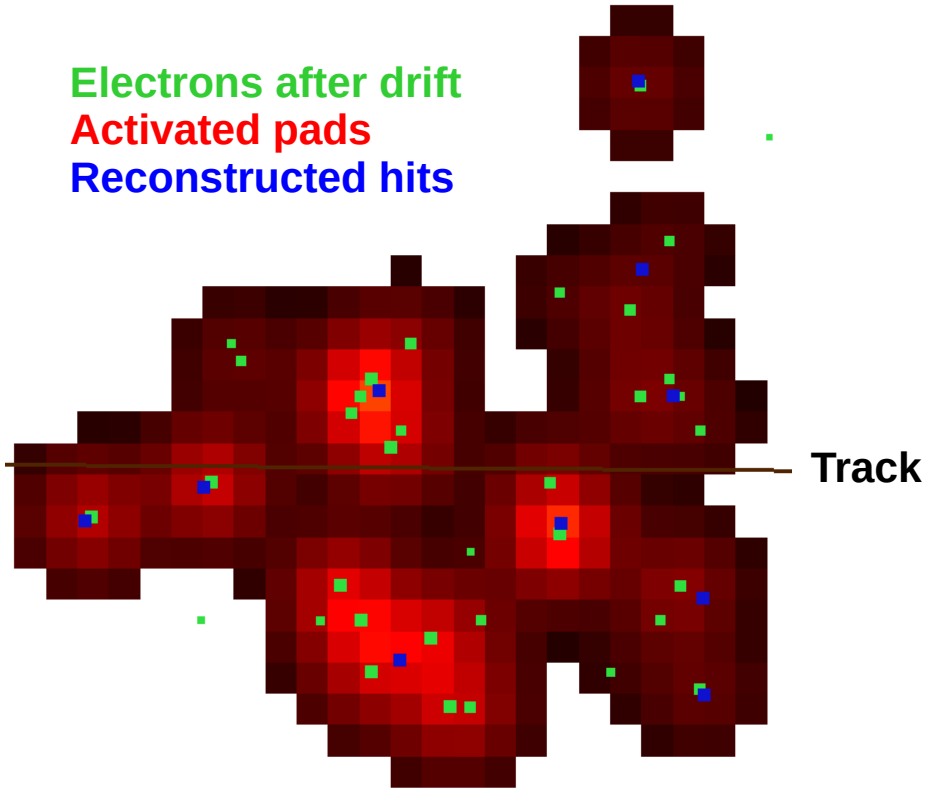


Parameters

parameter	short	default value	range
cluster distance factor	CDF	1	0.25-1.25
magnetic field	B	1 T	(0-4) T
drift length	DL	1000 mm	(10-2000) mm
distances between GEMs, and third GEM and anode	Gd	(1,1,1) mm	[(.1,.1,.1)-(2,2,3)] mm
GEM voltage (each GEM)	GU	280 V	(230-300) V
pad pitch (x and y)	PP	220 µm	(55-6000) µm
equivalent noise charge	ENC	0 e^-	(0-1000) e^-
hardware threshold	HWT	561 e^-	(561-1000) e^-
number of events (tracks)	NEV	1000	1-10000
convolution filter	CF	mexican hat with FWHM of 2.5 pads	mexican hat with FWHM of 2-7 pads
hit finding min. no. of active pads	minA	4	4-9
hit finding max. no. of active pads	maxA	1000	1000-10000

Results: Cluster Counting Efficiency

- Double-unique ID:
  - Identified hit only received electrons from one primary cluster
  - This cluster only fed this one hit
- Lower limit on traditional ID efficiency



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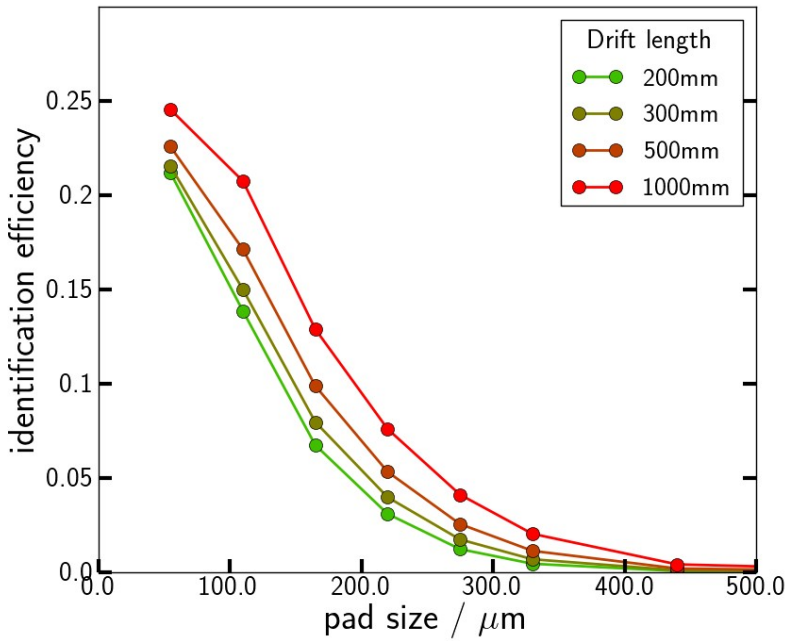
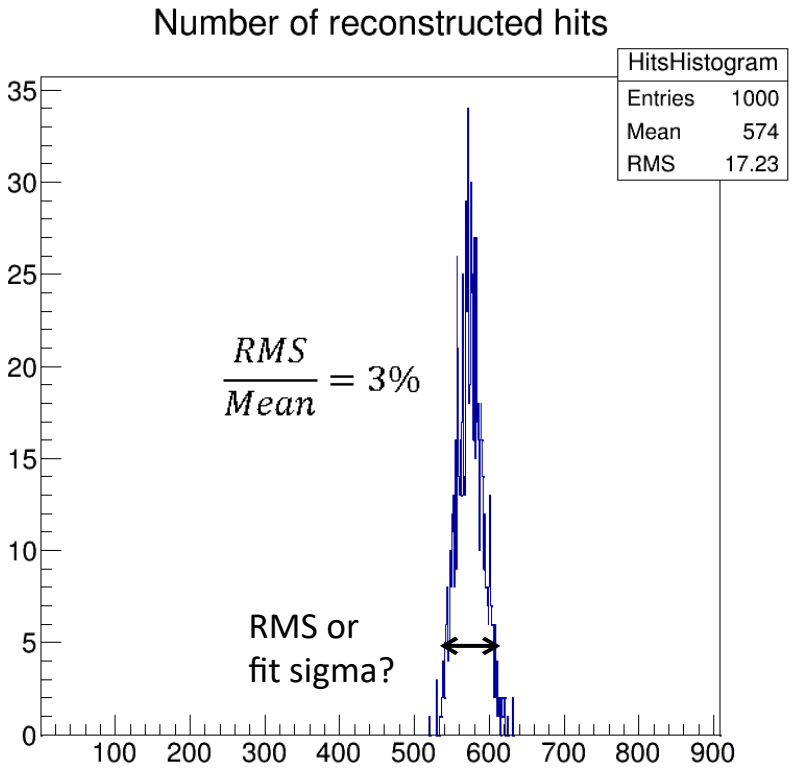
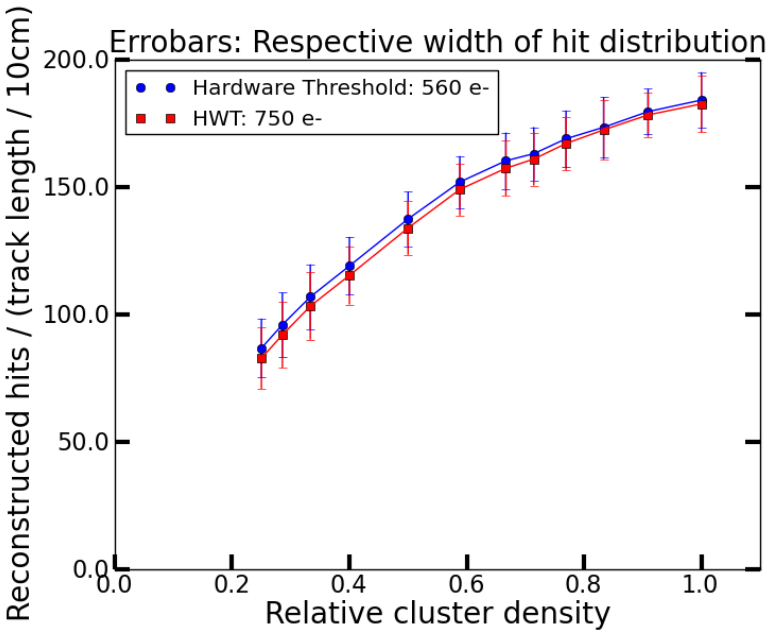


Results: Cluster Counting Resolution



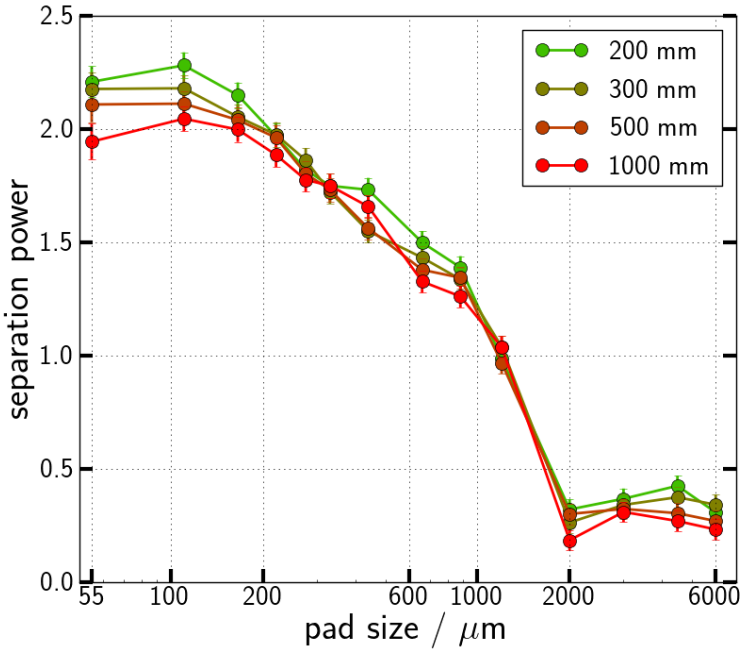


Cluster Counting Resolution is not a good estimator
- use Separation Power instead!

Results: Cluster Counting Separation Power

Compare SP between pions and kaons at maximum ionisation difference.

$$S = \frac{|\mu_\pi - \mu_K|}{\langle\sigma\rangle} \quad \text{with} \quad \langle\sigma\rangle = \sqrt{\frac{1}{2}\left(\sigma_\pi^2 - \sigma_K^2\right)}$$ and μ, σ from mean, RMS or fit.

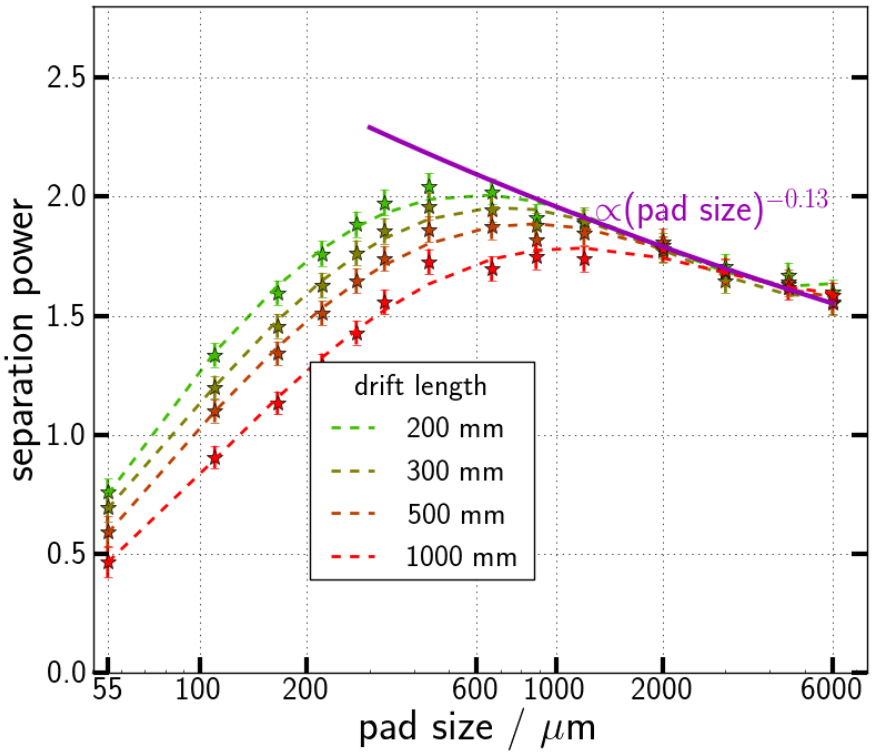


Decrease of SP with growing pad size.

At small pad sizes, drift length becomes relevant because of insufficient charge per pad.

Levelling out at very small pad sizes also because of GEM grid scale of 140 μm.

Comparison: Charge Summation



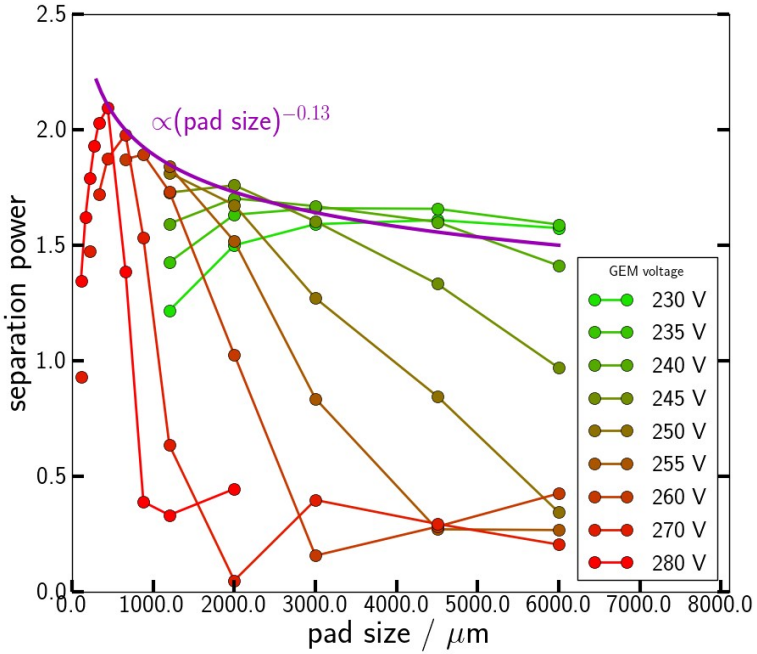
Decrease of SP with growing pad size.

At small pad sizes, drift length becomes relevant and drops because of insufficient charge per pad.

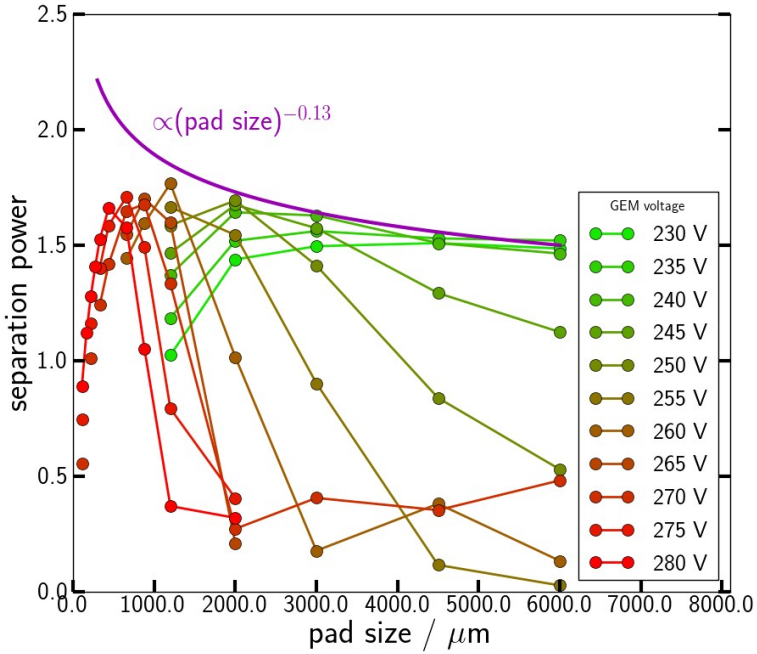
Each point is optimised for GEM voltage (~ gain), limited by maximum GU = 280 V.

Optimisation Example: Charge Summation SP-Scan over PP, GU

DL = 200 mm

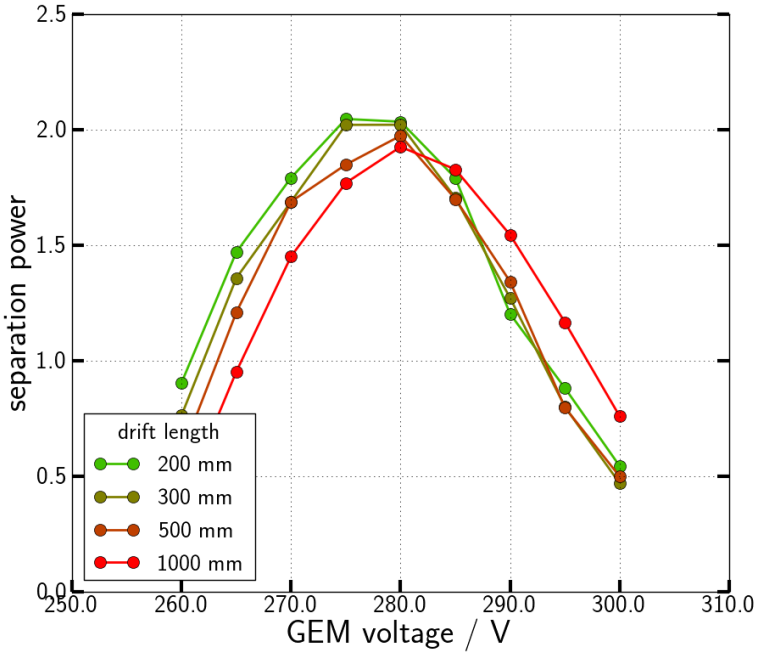


DL = 1000 mm

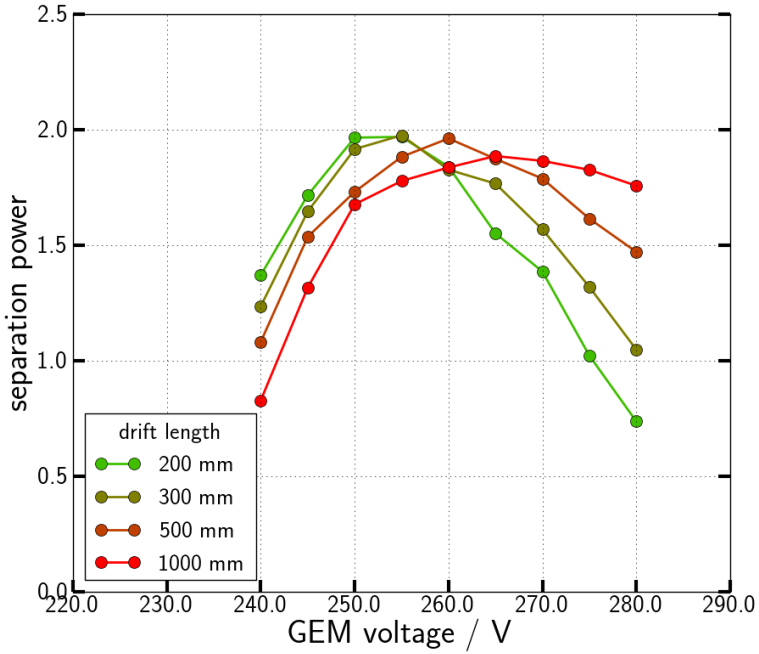


Optimisation Example: Cluster Counting: SP-Scan over GU, DL

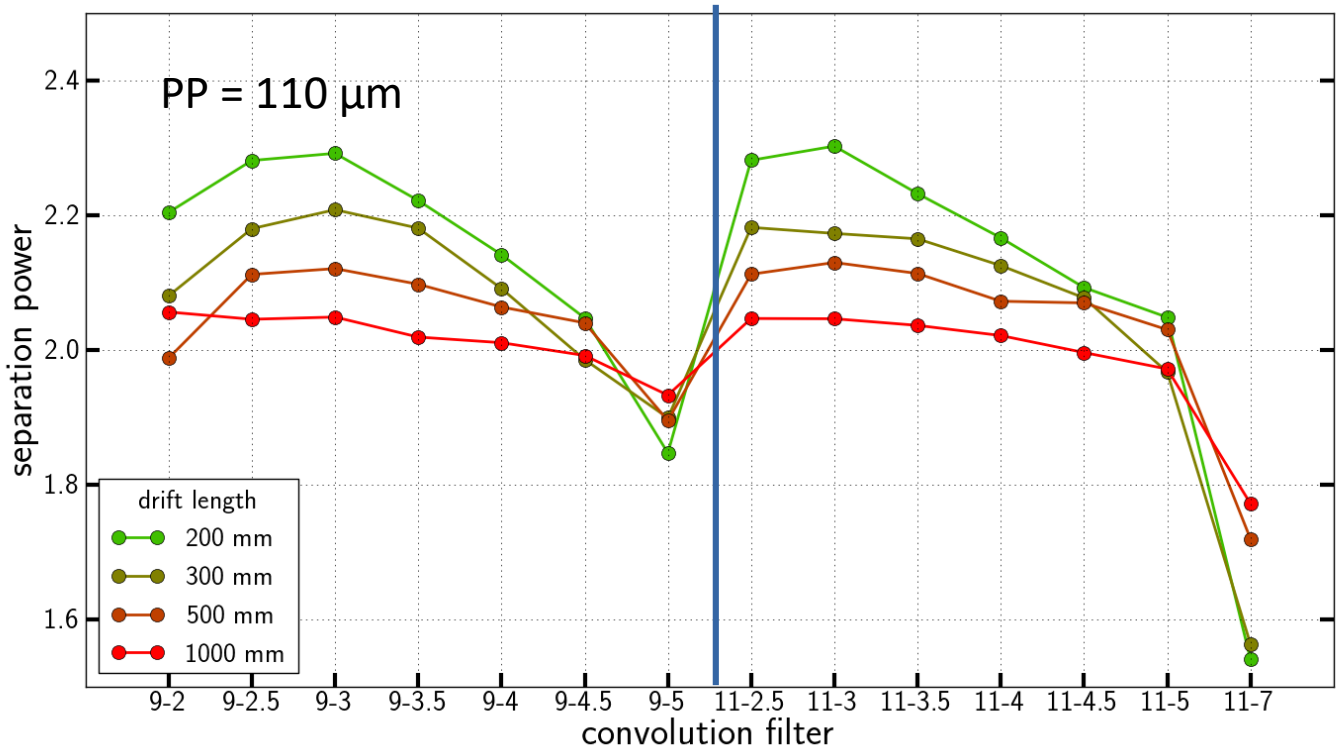
PP = 55 µm



PP = 220 µm

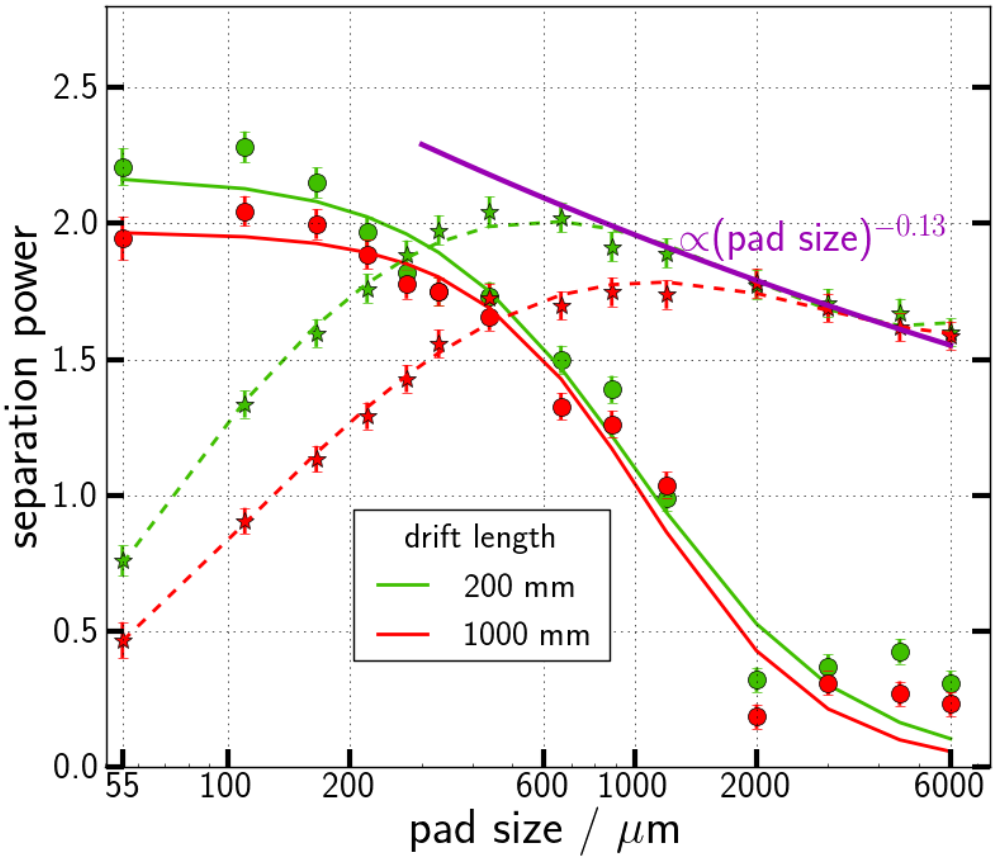


Optimisation Example: Cluster Counting SP-Scan over CF, DL



CF: Convolution Filter, applied to 'image' matrix before cluster counting.
First number is total size, second is scale of Mexican hat (in pads).

Results: Total Combined Plot

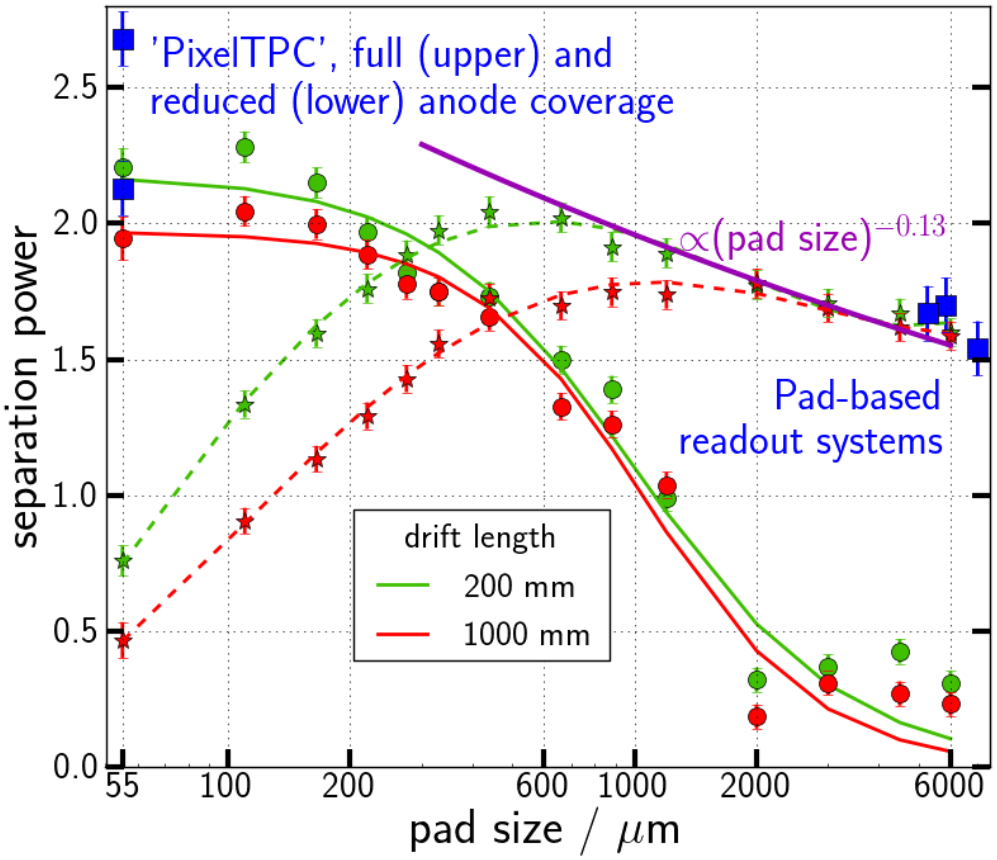


Granularity is king:
decreasing pad size improves performance – if one can deliver sufficient gain!

CS scaling works until ~ 1 mm pads with an improvement of 15 – 20 % in SP.

CC kicks in below 300 µm, giving another 20 – 25 % SP at 110 µm.

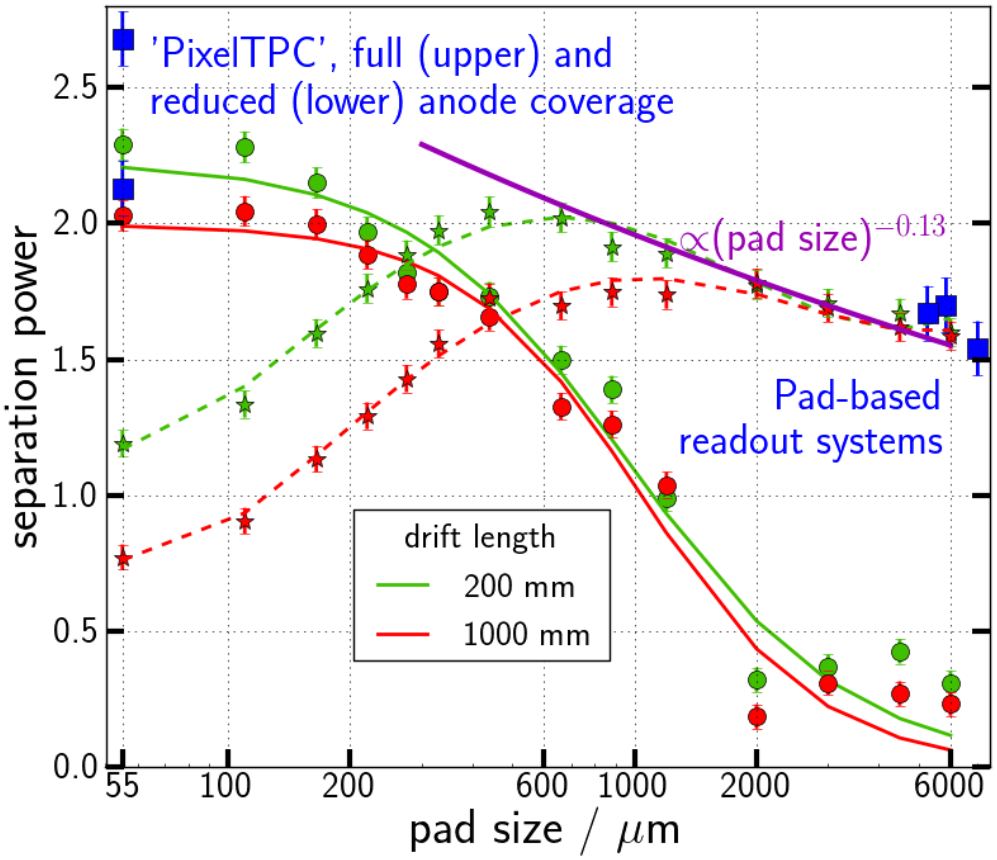
Results: Total Combined Plot



Reproduces performance of pad based systems, shows dependence.

Unlcear which PixelTPC anode coverage to use, since curves were made with 100 % coverage.

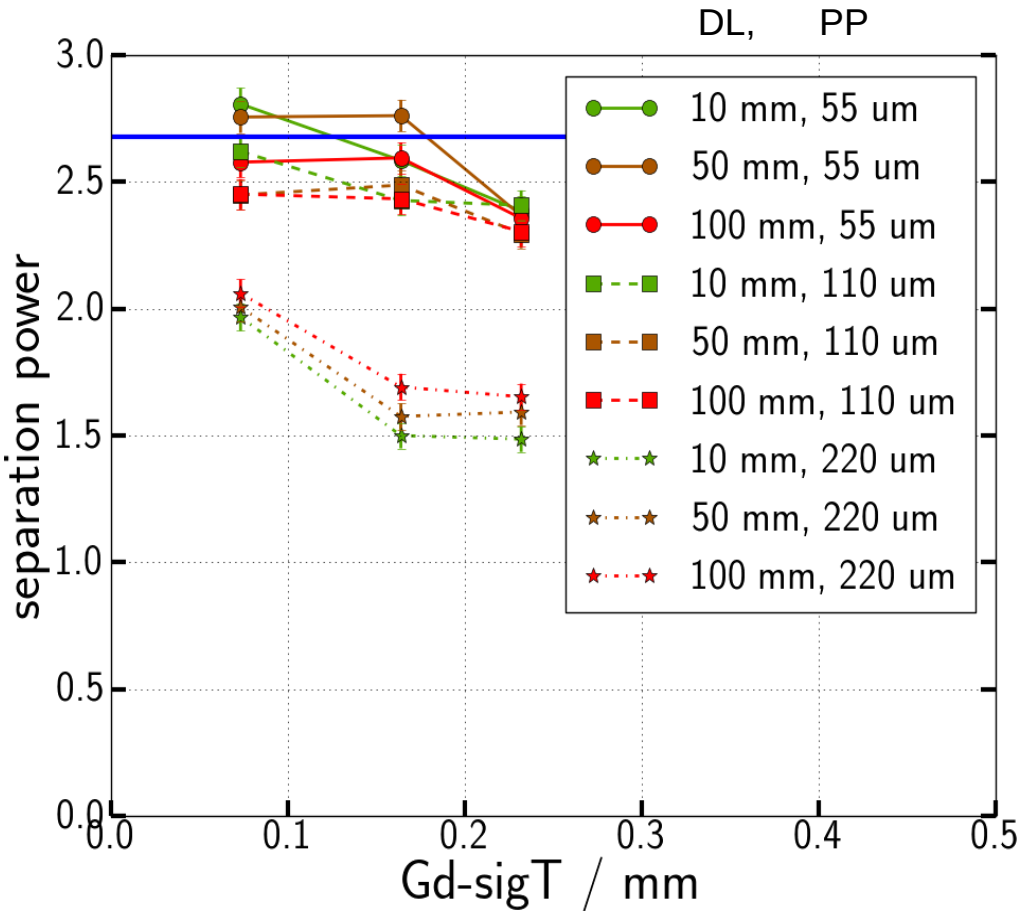
Results: Total Combined Plot



'Recover' 55 µm CC points with higher GEM voltage GU = 290 V.

Note: this way, also the CS SP increases for 55 µm pads.

Extras: How to reach GridPix?

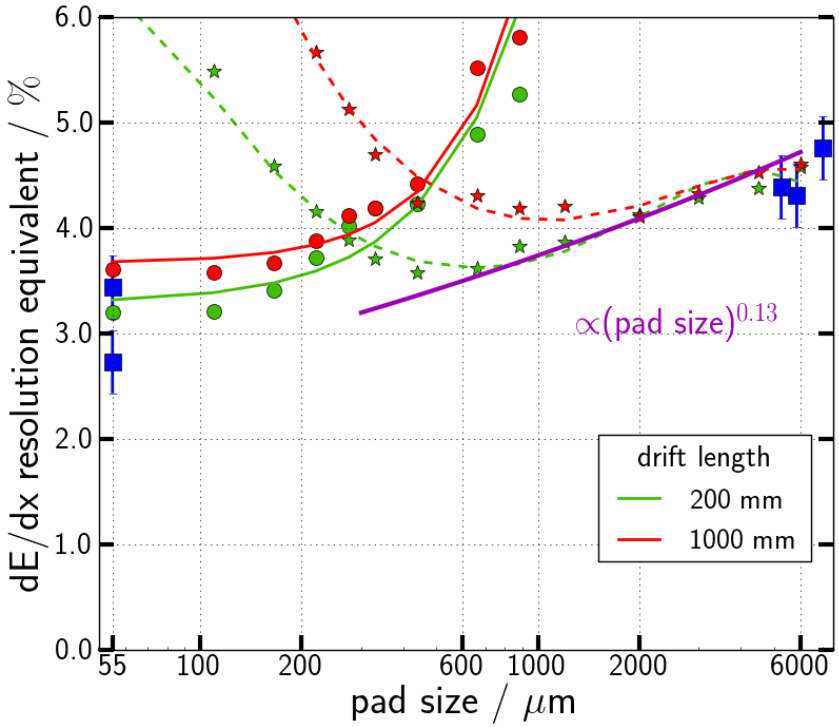


With:
- GU = 300 V
- 55 µm pads
- O(cm) drift lengths
- unphysically small GEM distances to reduce diffusion in the GEM stack

Gd-sigT: width of transverse diffusion distribution

Extras: Display as Resolution Equivalent

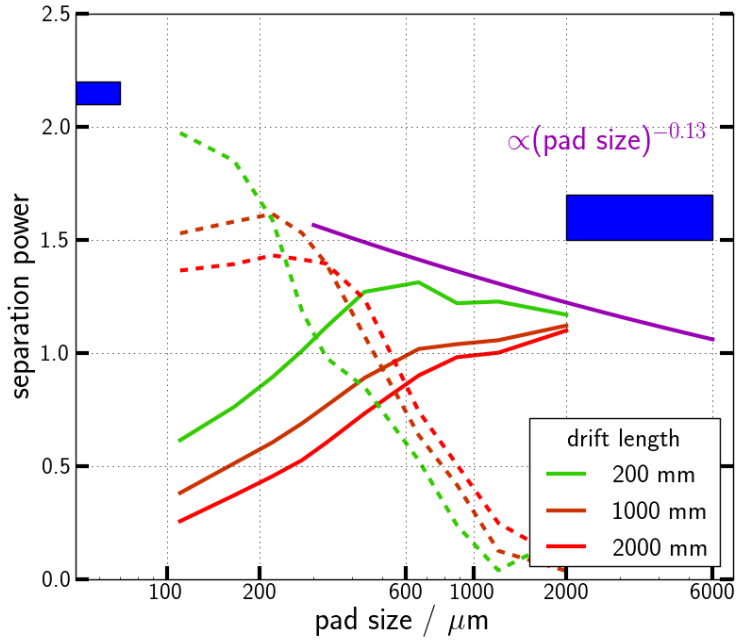
Scaled to ILD TPC (roughly).



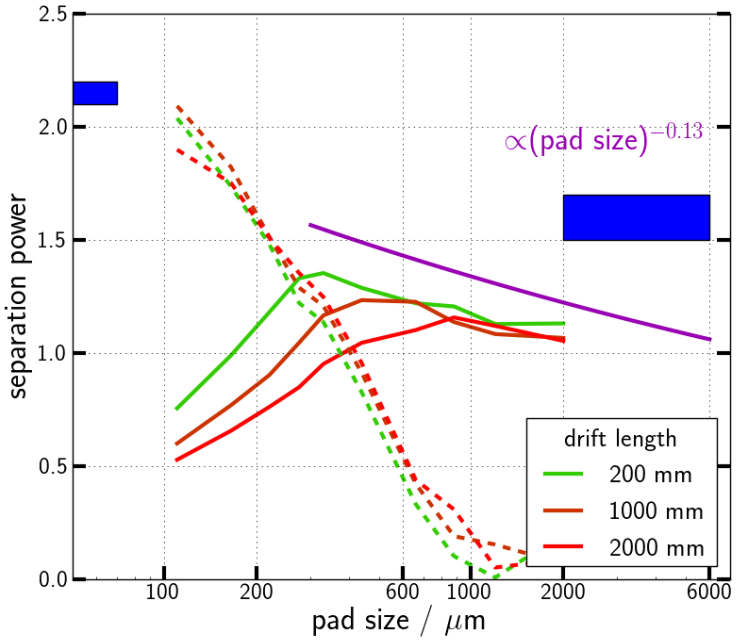
Extras: Mock-Neon

CDF increased by factor 2, nothing else changed.

B = 1 T



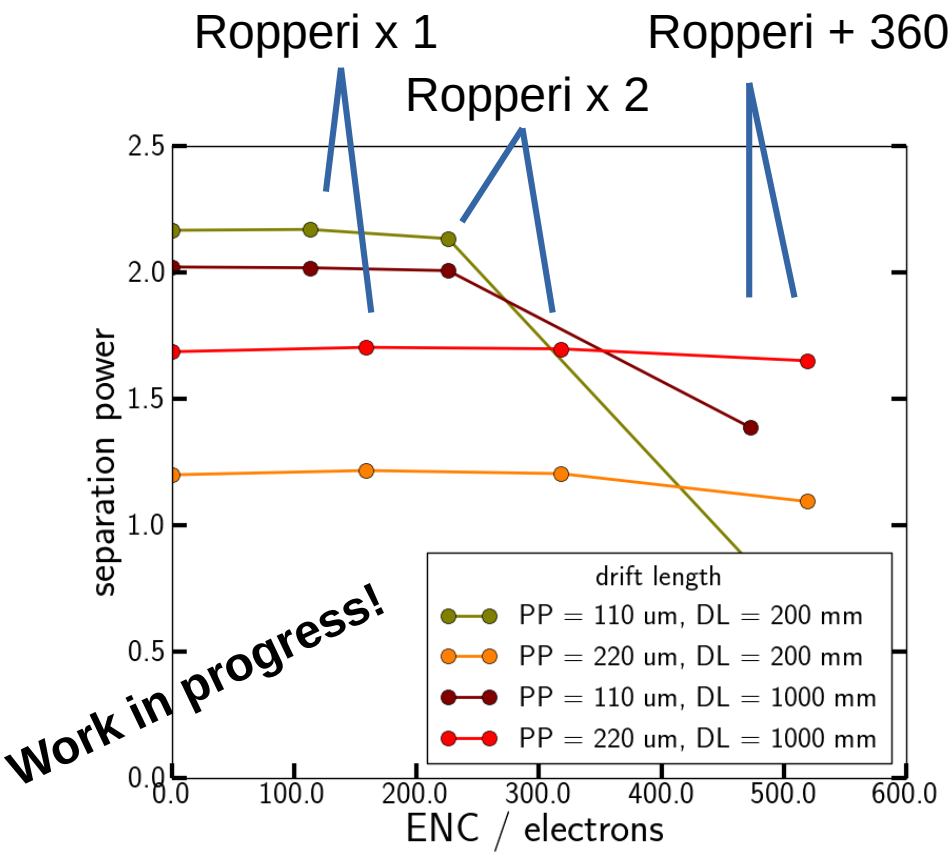
B = 4 T



Advantage of CC over CS increases, but not above performance in Ar.

Extras: Implementing Pad-Size-Dependent Noise in Cluster Counting

Noise extrapolated from Ropperi estimates.

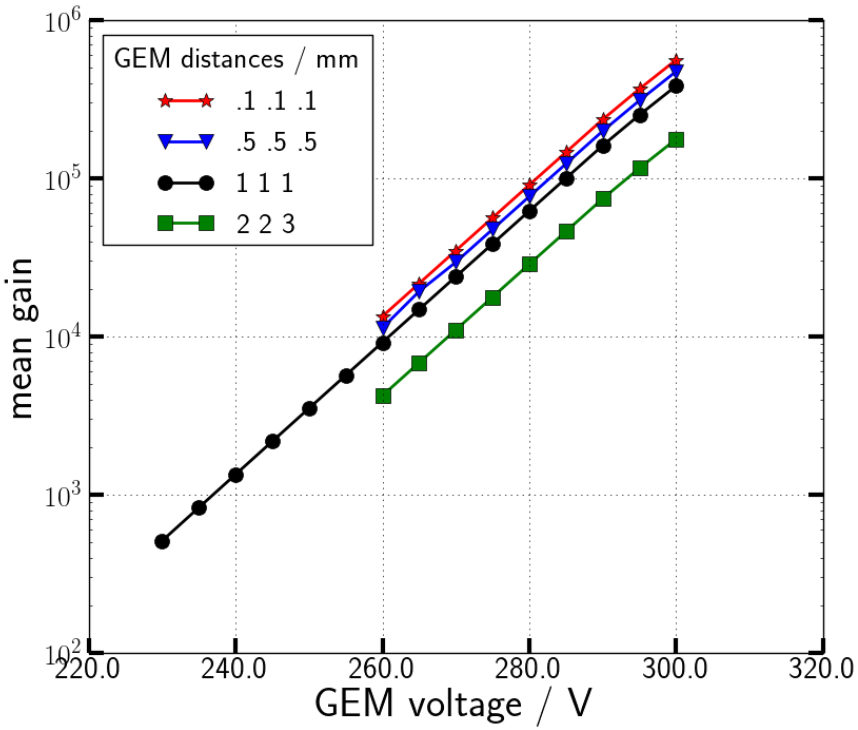


Outlook / Open Questions

- Dedicated subsection in thesis for ´to-do-list´
- Simulation optimisation:
  - T2K parametrisation, in particular ionisation step
  - Use hit width and amplitude for a better CC-estimator
  - Various SE-parameters available to vary and optimise
  - SE convolution filter shape optimisation (by hand or neural network)
- Connect with GridGEM and GridPix simulations

Backup

Gain of Triple GEM Stack
Depending on GEM Voltage and Distances



Ropperi Noise Estimates