HEPHY Testbeam 2008: First tracking results

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2. June 2008

HEPHY Wien

* The presenter is supported by EU I3 contract 026 126-R II3 (EUDET)

Outline

- HEPHY beam test at CERN in 2008
  - (very) basic data, tasks and challenges
- Zones on DUTs
  - Zone η corrections and edge effects
- DEPFET tracking and resolution calculations
- Zone resolutions – very first results
  - Overview – what we did
  - Results: reproducibility across runs
- EUDET telescopes
  - Independent analysis path

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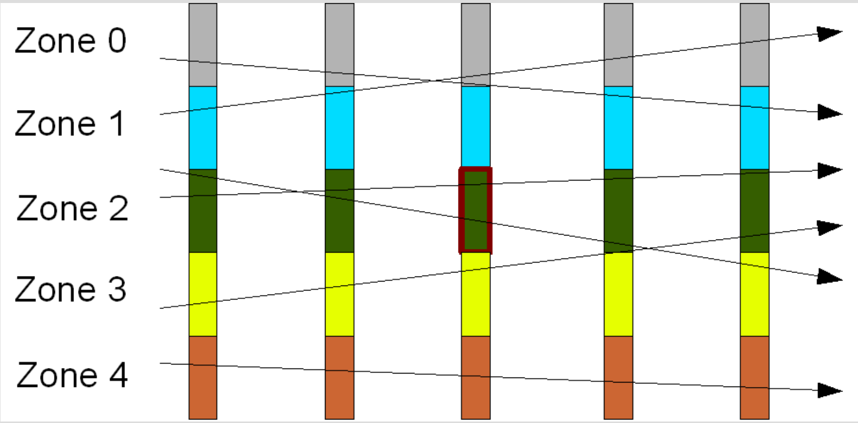
- 8 strip detectors between 2 and 3 EUDET telescopes
- 120 GeV π^+ beam on SPS
- Strip detectors with 16 zones of 16 strips, pitch 50 µm. Each zone with different properties (strip width / intermediate strips)
- Low multiplicity on EUDET telescopes: about 5 hits per event
- Measurement plan includes high-statistics runs and runs with inclined detector

Zones on DUTs

- 16 zones of 16 strips
- Account for / Describe position-dependent detector properties
- Must have enough tracks passing through each zone
- Non-standard properties in border regions between zones. We cannot simply discard tracks passing through boundaries – we would lose TOO MANY!



Zone	Strip width [μm]	Intermediate strips
1	6	no
2	10	no
3	12,5	no
4	15	no
5	20	no
6	25	no
7	6	single
8	7,5	single
9	10	single
10	12,5	single
11	15	single
12	17,5	single
13	6	double
14	7,5	double
15	10	double
16	12,5	double

Hit reconstruction: the zone η correction

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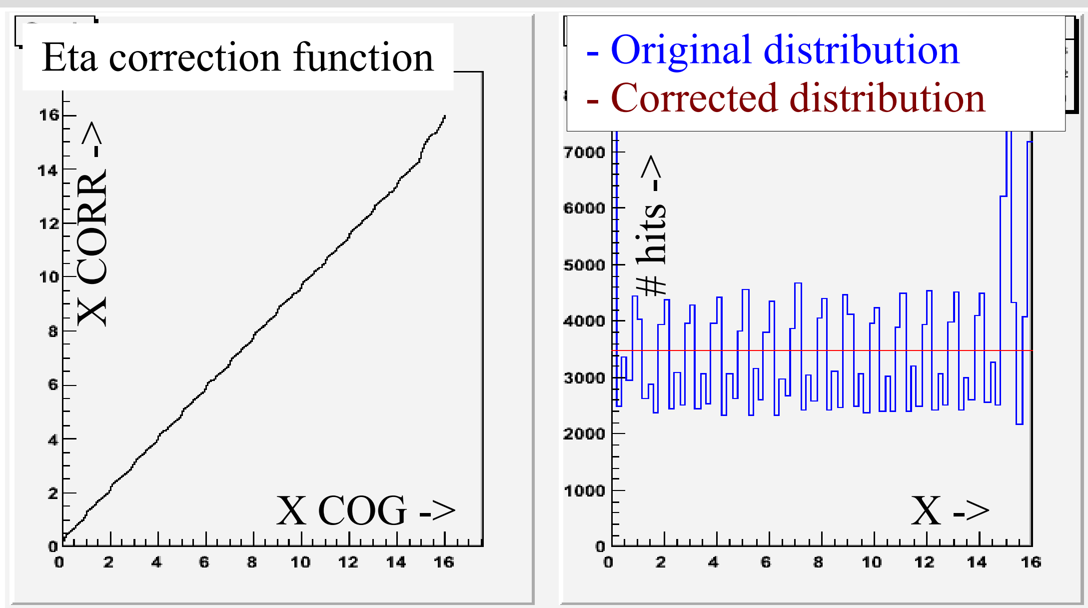
- We need to handle (unknown) boundary effects between zones with different strips. This is done automatically by the zone eta.
- A simple and straightforward method, relying on the large statistics that we have.



Zone η correction: Create uniform distribution over whole 16 strips of a zone rather than over a single strip.
This also takes care of zone boundary effects.

Zone resolutions

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- Resolutions are calculated simultaneously for all detectors
- First approximation in case of zones:
  - Calculate resolutions for zones on detector 3, using tracks going through the respective zone
  - On other detectors, use average resolution

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- Tracing sw created for tracking of DEPFET pixels
- A standard analysis chain, comprising
  - i hit reconstruction
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- Several new methods:
  - i a track selection algorithm based on the principal components analysis (PCA)
  - ii robust linearized alignment
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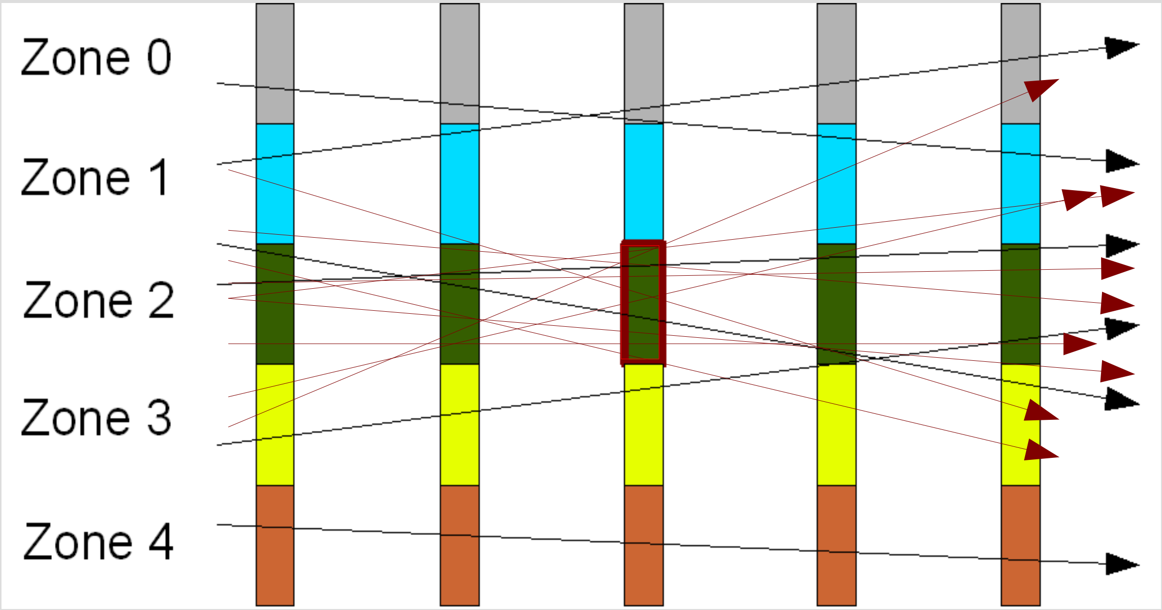
Calculation of resolutions

- In detector resolution calculations we decompose track projection errors (fit residuals) into contributions of
  - **measurement error** (detector resolution)
  - **telescope error** (error of track projection on the detector)
  - contribution of **multiple scattering** to telescope error
- We use straightforward matrix inversion combined with quadratic programming or bootstrap resampling of the residual covariances to assure positivity of squared resolutions.
- In particular, with the method we don't need infinite energy extra-polation or telescopes with known resolutions.

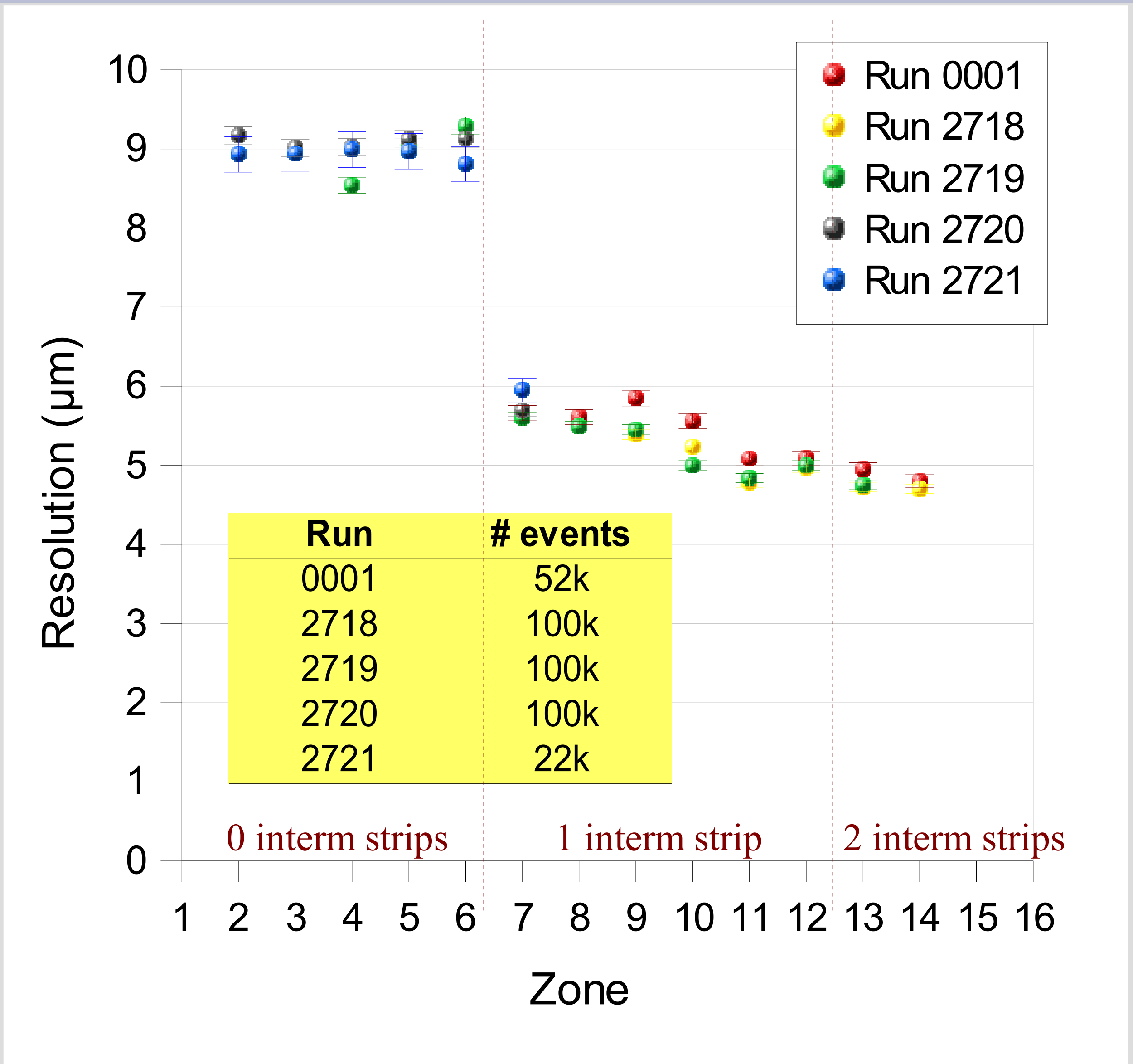
Zone resolutions - overview

- We calculated zone resolutions by using only tracks that passed the required zone on detector 3.
- Each time, resolutions are calculated for all detectors, but we have “clean” resolution only for detector 3.



- Resolutions on other detectors are “mixed”, arising from tracks passing different zones.
- In a following step, the resolutions obtained this way can be used on other detectors as appropriate for individual tracks.
- No special treatment for edge zones was used.

Zone resolutions - results



- We have to combine results of several runs to reach sufficient occupancy over all area of the detector. Even so, we don't have enough data for edge detectors.
- This graph allows to assess the precision of calculated resolutions.

Zone resolutions - results

Strip width [µm]	Intermediate strips	Run 0001	Run 2718	Run 2719	Run 2720	Run 2721
6	no					
10	no				9.17±0.11	8.93±0.21
12,5	no				9.01±0.10	8.94±0.23
15	no			8.54±0.11	9.02±0.10	8.99±0.21
20	no			9.03±0.10	9.12±0.10	8.97±0.21
25	no			9.29±0.11	9.13±0.10	8.81±0.21
6	single	5.66±0.10		5.60±0.07	5.69±0.07	5.95±0.14
7,5	single	5.61±0.09		5.49±0.06		
10	single	5.85±0.09	5.39±0.07	5.45±0.07		
12,5	single	5.56±0.09	5.23±0.06	5.00±0.06		
15	single	5.08±0.08	4.78±0.05	4.84±0.06		
17,5	single	5.09±0.08	4.97±0.06	5.00±0.06		
6	double	4.95±0.08	4.72±0.05	4.75±0.06		
7,5	double	4.80±0.08	4.70±0.05			
10	double					
12,5	double					

Analysis plans: EUDET telescopes

- EUDET telescopes: provide another, independent path to the same analysis.
- Nearly in all cases, analysis can be carried out using HEPHY dets alone, or usingg telescopes to look at a single HEPHY det, accounting other HEPHY detectors only for multiple scattering.
  - Pro: Multiple scattering contributes tenths of microns to measurement errors
  - Pro: Hit multiplicity is not serious in the data.
  - Con: We have rougher hit reconstruction for EUDET telescopes
  - Con: We need mixed alignment among EUDET telescopes and HEPHY dets to carry outt the analysis

Hit reconstruction and edge effects: all those η functions

- η corrections are not presented here.
- Use zone η corrections for the analysis
- Only in post-processing, separate effects - create “standard” η corrections (for a single strip) and analyze edge effects.
- η functions are a good descriptor of sensor properties.
- What can we say about detector resolution when looking at an η correction function?

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Thanks for your attention.

Backup slides

Analysis: Calculation of Resolutions

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The problem to be solved has the form

$$diag^{-1}cov\left(u^{(c)}\right) = \mathbf{M}_{\boldsymbol{\Delta}} \cdot \boldsymbol{\Delta}^2 + \mathbf{M}_{\boldsymbol{\Sigma}} \cdot \boldsymbol{\Sigma}^2$$

vector of diagonal elements of the matrix

covariance matrix of residuals (known from tracking)

Vector of squared detector resolutions

vector of mean square angular deflections

Matrices depending on the method of calculation - whether projections are calculated using the given detector or not

It can be solved by SVD inversion of $\mathbf{M}_{\boldsymbol{\Delta}}$, but we also have to assure that we obtain positive $\boldsymbol{\Delta}^2$. For this, quadratic programming or bootstrap resampling of residual covariances can be used.

Analysis: Errors in alignment and resolutions

- Alignment and resolutions are calculated using linear algebra, but they contain inherent non-linearities. Therefore, linear regression error estimates are not usable and we have to use a different method of error calculation.
- Errors are calculated by **bootstrap resampling** of regression residuals:

1. **Generate a large number (several hundreds) of replicas of the original track set: combine parameters of each track with a set of residuals from another, randomly selected track.**
2. **Repeat the analysis for each replicated set**
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- Though computationally intensive, the method is simple and reliable.

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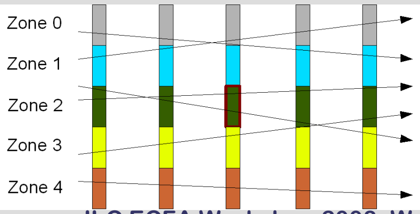

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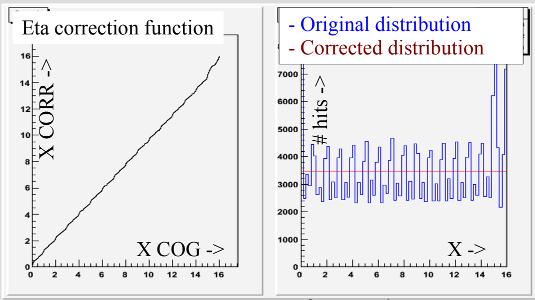

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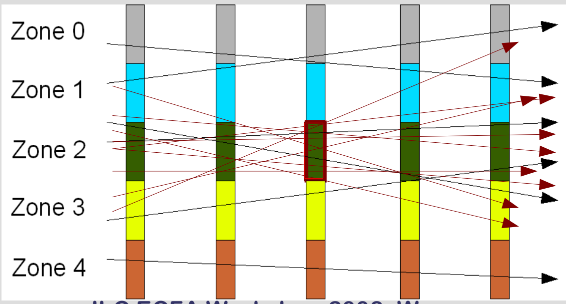

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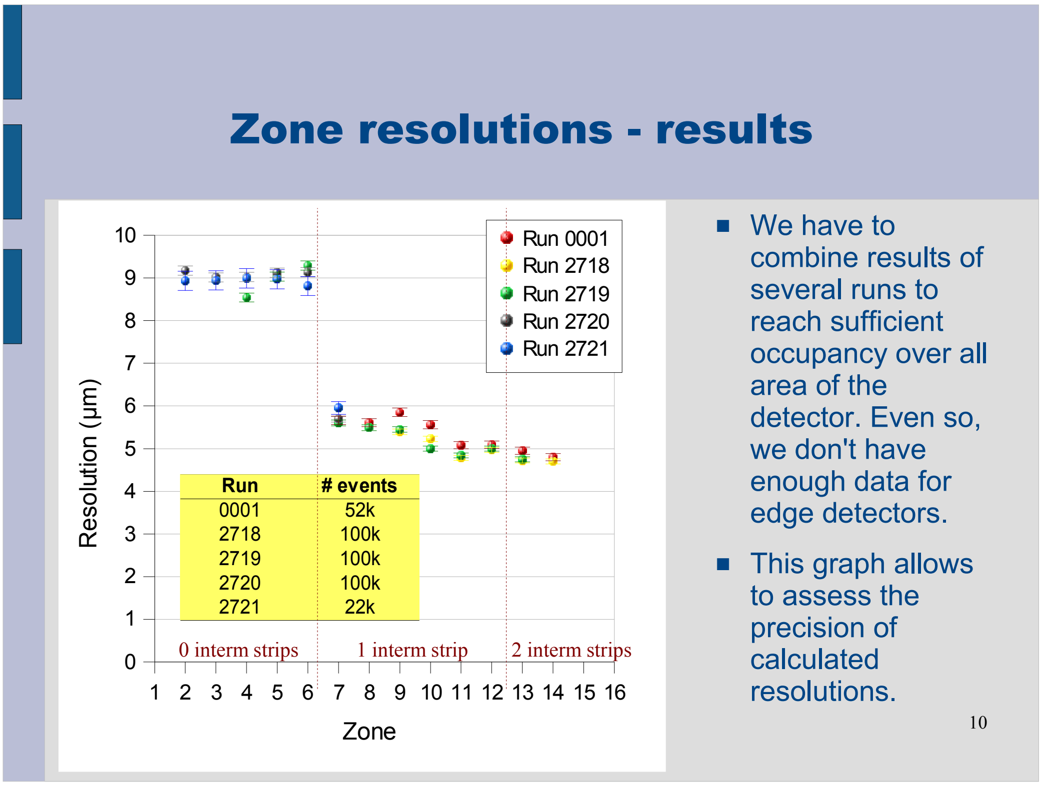
Notes:
if we discard tracks passing through edge zones (say, through the two boundary strips), we lose close to 100% of tracks – detectors are shifted.



Relative errors in resolutions:
2718-2720 1,2%, typicky 6000 trackov na zonu
0001 1,7%
2721 2,5%

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