

Energy Calibration for the Forward Detector at WASA-at-COSY

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Westfälische Wilhelms-Universität Münster, Institut für Kernphysik
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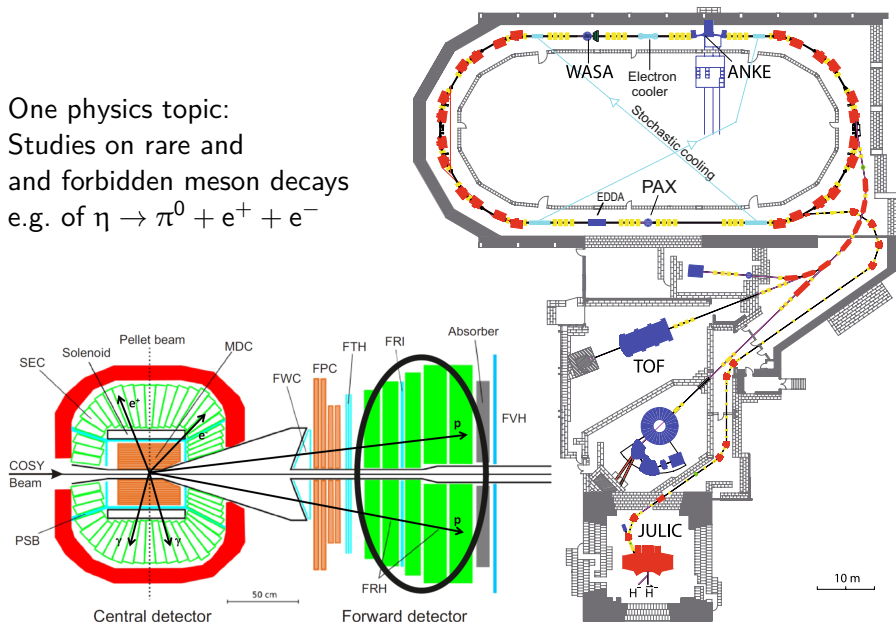
18. März 2013



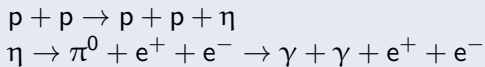
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Experimental setup WASA-at-COSY

One physics topic:
Studies on rare and
and forbidden meson decays
e.g. of $\eta \rightarrow \pi^0 + e^+ + e^-$



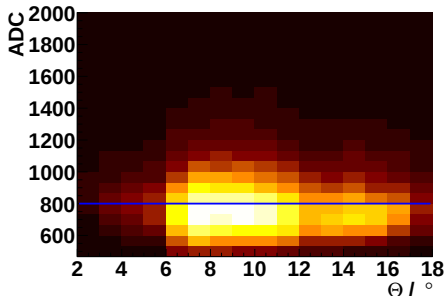
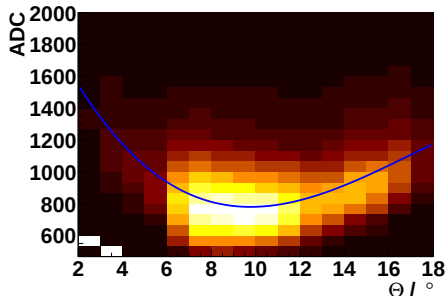
Motivation for an optimized calibration of the forward detector



- Forward detector energies for η identification (missing mass)
- Special case for forbidden decays:
 - Strict cuts to handle direct multi pion background
 - Very narrow missing mass peak for high signal/background ratio required
 - Kinematic fitting relies on precise kinematic values
- Calibration parameters observed to be time dependent (over days/weeks)

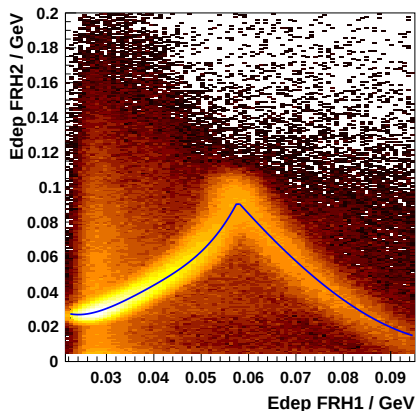
Energy reconstruction

- Scintillators/photomultipliers give ADC values
- Calibration needed to reconstruct ΔE
- Two corrections:
 - Non uniformity: dependence on the polar angle $\vartheta \Rightarrow f_{\text{NU}}$
 - Non linearity in the energy dependence $\Rightarrow f_{\text{NL}}$
- Non uniformity correction by means of elastically scattered protons

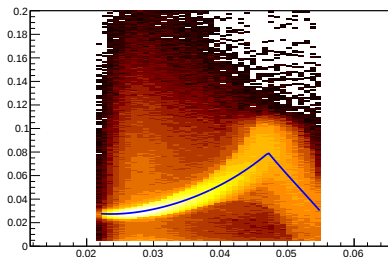


- Goal: Find calibration parameters for which real data (RD) und Monte Carlo (MC) data fit
1. Fit a function to simulated energy loss bands
 2. Fit real data to this function
- Use 2-dimensional fit algorithm for both steps
 - Handle background
 - Calibrate all FRH layers simultaneously
 - Use all possible layer combinations (e.g. 1-vs-2, 1-vs-3)
- ⇒ IMPORTANT: Use same fit algorithm for MC and RD to avoid systematic effects

Fitting Monte Carlo data - how it should look like



FRH layer 1 vs layer 2



layer 1 vs layer 3

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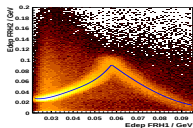
Fitting Monte Carlo data

- Adjusted χ^2 fitting for 2-dimensional histograms
- $\chi^2 = \sum_{bins} w_i \cdot \min(\delta_i^2, \delta_{max}^2)$
- $\delta_i = (y_i - f_{MC}(x_i))/\sigma(x_i)$
- (x_i, y_i) = center of bin i ; w_i = content of bin i
- $f_{MC}(x)$: fit function
- $\sigma(x)$: standard deviation of the distribution (from x-binwise y-projections)
- δ_{max} = predefined threshold,
- e.g., $\delta_{max} = 2$ means
*„fit all data within a 2σ environment,
everything outside is background“*

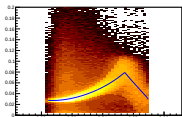
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Fitting Monte Carlo data - results

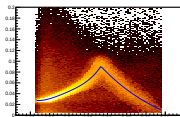
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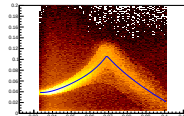
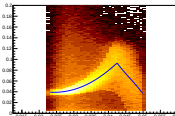
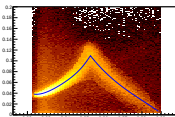
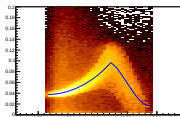
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3



4



2

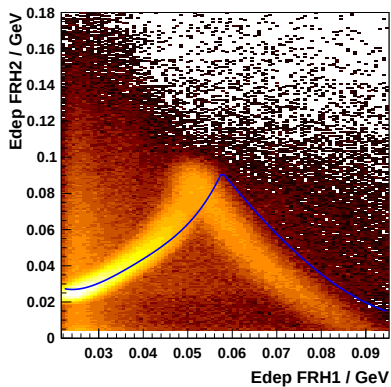
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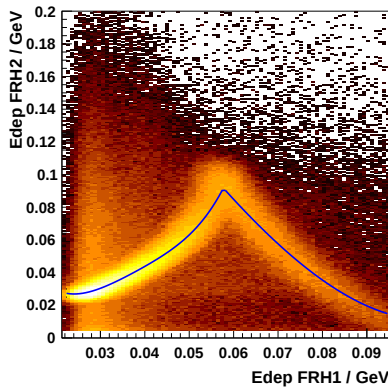
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Fitting real data

- Vary calibration parameters (TMinuit: Migrad+Minos)
- ⇒ Rescaling histogram axes
- Calculate χ^2 as in MC fitting for each ΔE plot
- Find parameter set that minimizes the overall averaged χ^2



Before fit



After fit

User control

WASA FD Calibration

Calibration Set: **FRH1 - FRH4**

☒ Display MC

FRH Element Nr: **1**

Theta Range: **full theta range**

Calibration function: **$c0 \cdot x^e \cdot (c1 \cdot x)$**

Chi2 threshold: **4.00**



Calibration parameters

FRH layer 1

Parameter	Value	Scale	Min	Max
c0:	1.84	$\times 10^4$	-5	5
c1:	5.99	$\times 10^4$	-16	16
c2:	0.00	$\times 10^4$	0	0

FRH layer 2

Parameter	Value	Scale	Min	Max
c0:	2.13	$\times 10^4$	-5	5
c1:	1.64	$\times 10^4$	-15	15
c2:	0.00	$\times 10^4$	0	0

FRH layer 3

Parameter	Value	Scale	Min	Max
c0:	3.49	$\times 10^4$	-5	5
c1:	7.00	$\times 10^4$	-15	15
c2:	0.00	$\times 10^4$	0	0

FRH layer 4

Parameter	Value	Scale	Min	Max
c0:	2.50	$\times 10^4$	-5	5
c1:	1.49	$\times 10^4$	-15	15
c2:	0.00	$\times 10^4$	0	0

FRH layer 5

Parameter	Value	Scale	Min	Max
c0:	0.00	$\times 10^4$	0	0
c1:	0.00	$\times 10^4$	0	0
c2:	0.00	$\times 10^4$	0	0

Fit Settings

Layer	Fit	MC	Data
FRH1	0	0	0
FRH2	0	0	0
FRH3	0	0	0
FRH4	0	0	0
FRH5	0	0	0

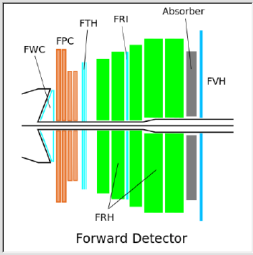
Chi2 statistics

Chi2 total: **1.777**

Chi2 details

Chi2	FRH2	FRH3	FRH4	FRH5
FRH1	1.355	2.103		
FRH2		1.165	2.389	
FRH3			1.858	2.125
FRH4				1.447

Forward Detector Diagram



Forward Detector

Buttons: Draw, Read Database, Read Monte Carlo, Read Parameters, Save Parameters, Create Fit Settings, Fit, Quit

Conclusion

- $p + p \rightarrow p + p + \eta$
- $\eta \rightarrow \pi^0 + e^+ + e^-$
- Calibration software to find energy reconstruction parameters
- Highly automated but full control
- Based on matching measured and simulated energy loss bands
- Algorithm to handle 2d histograms with background

Outlook

- Check existing calibration
- Careful recalibrations, run-by-run corrections
- Analysis of 10^9 $pp \rightarrow pp\eta$ events for a new upper limit of the C-parity violating decay $\eta \rightarrow \pi^0 e^+ e^-$
- Each analysis of these data sets will benefit from a careful calibration