New data acquisition systems at the Lintott & QCLAM Spectrometers

CRC 1245 / B02
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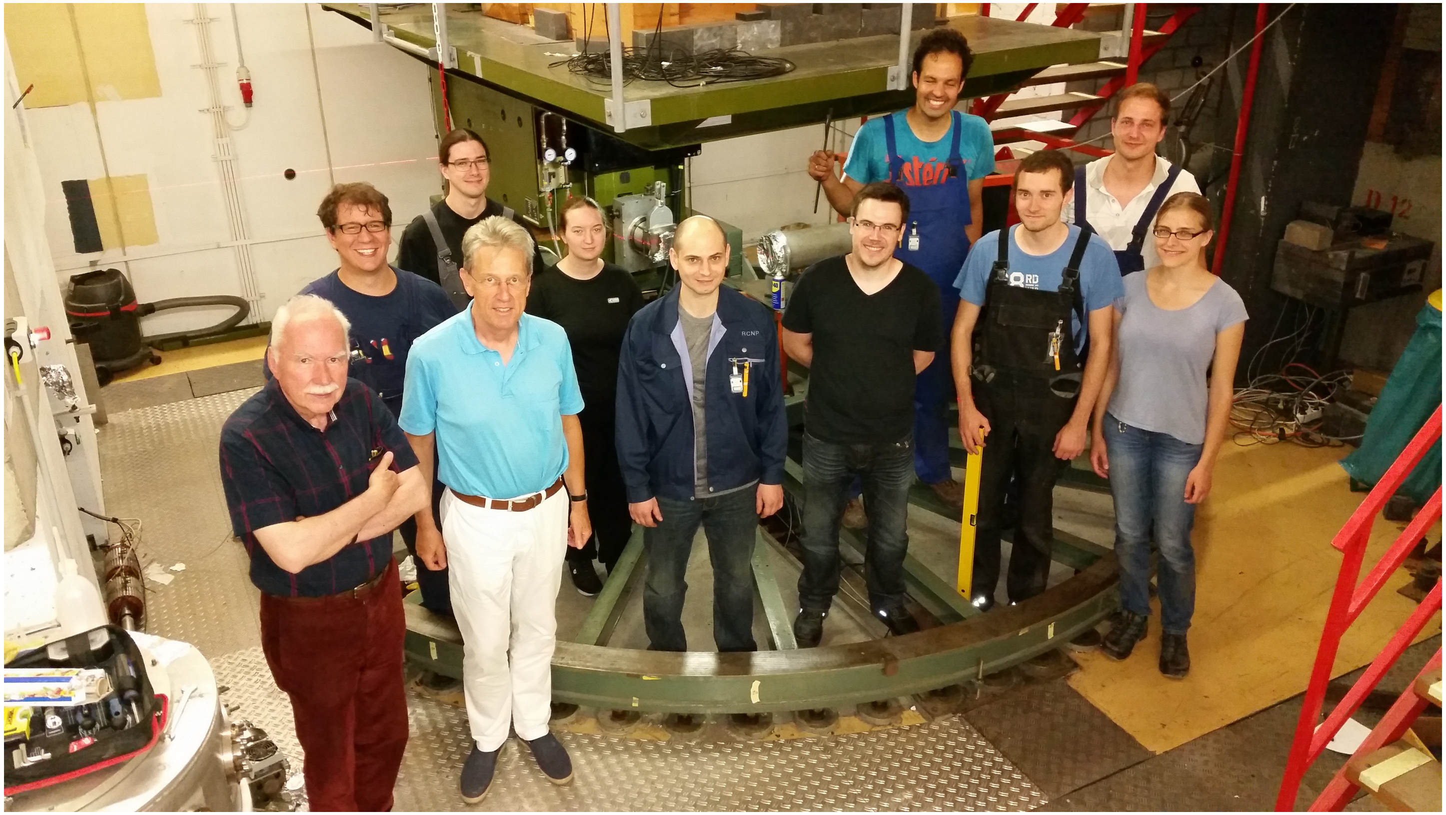
SFB 1245

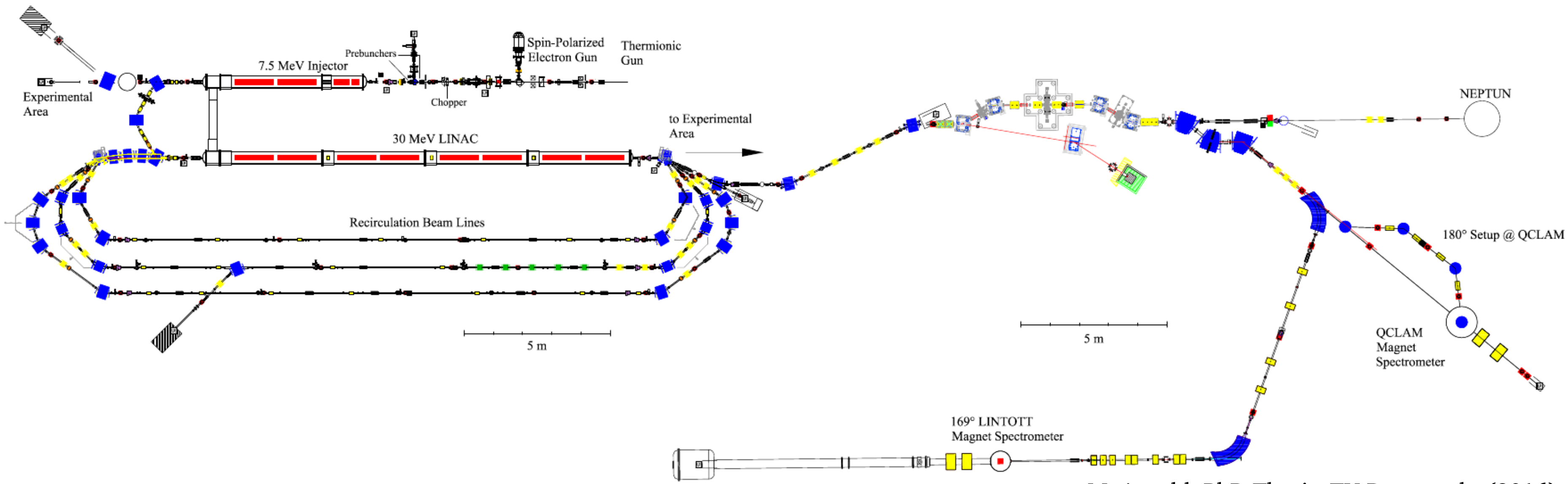


Outline

- New Data Acquisition at Lintott Spectrometer
- Progress on QCLAM Spectrometer

  → New Data Acquisition at QCLAM
- Summary & Outlook

S-DALINAC



M. Arnold, PhD Thesis, TU Darmstadt, (2016)

- 3 GHz bunched (continuous) electron beam
- 20-130 MeV, up to 10 μA , $\Delta p/p \leq 4 \cdot 10^{-4}$
- Polarized and pulsed mode in development

- New: third recirculation → more stable beam, 130 MeV are available
- New: high energy scraper for halo free beam → higher beam energy resolution

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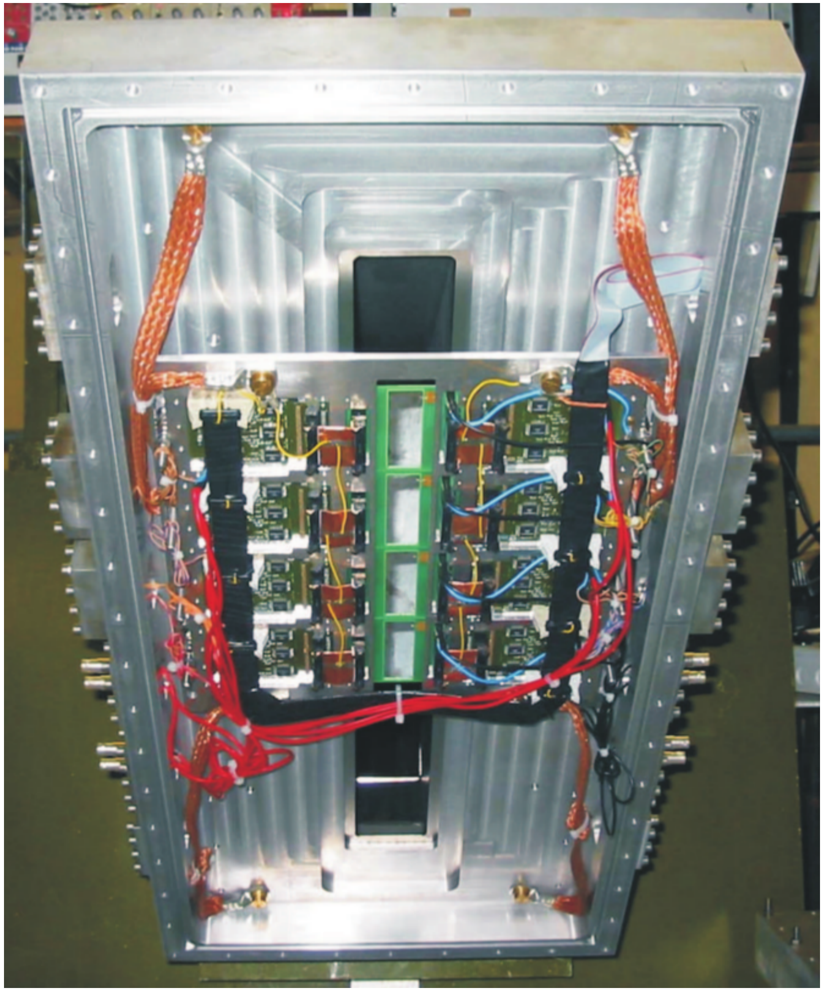
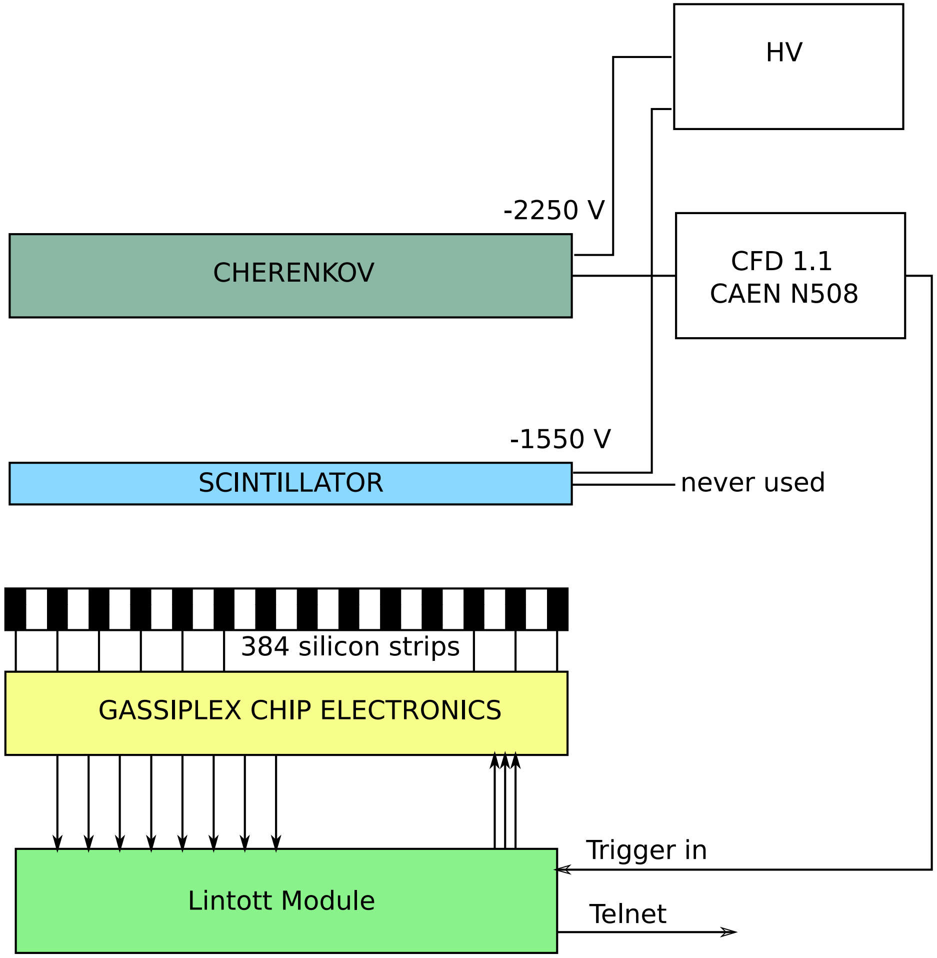
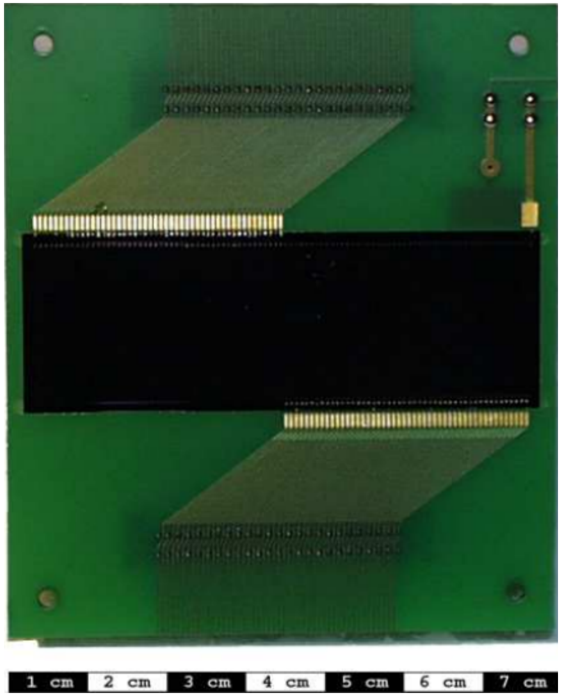
Lintott Spectrometer

Lintott in Short



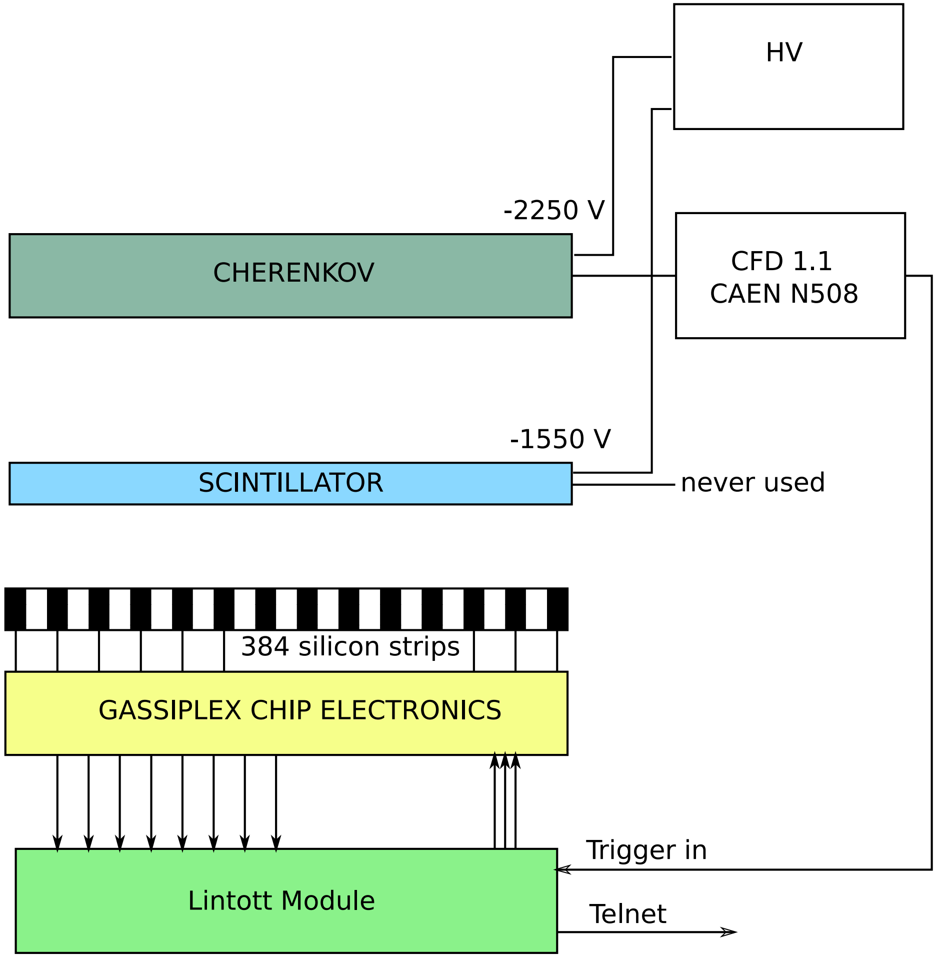
Data Acquisition at Lintott

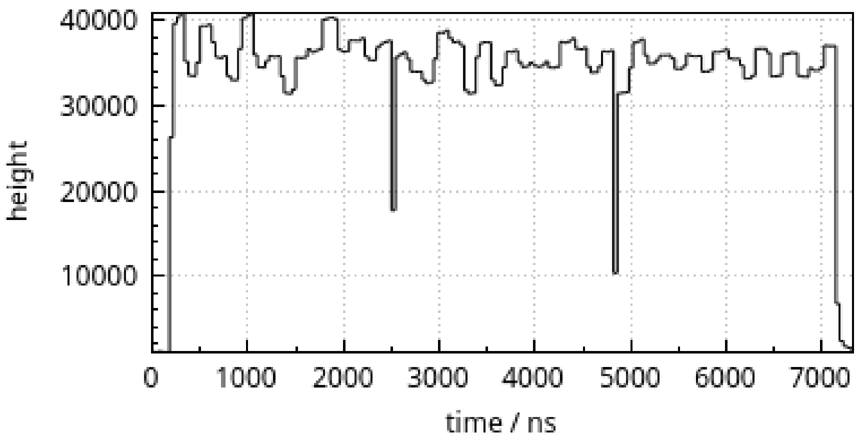




- 384 silicon strips
  → 500 μm thick
  → 650 μm pitch
- GASSIPLEX Chip
  → Signal shaper & multiplexer

Data Acquisition at Lintott



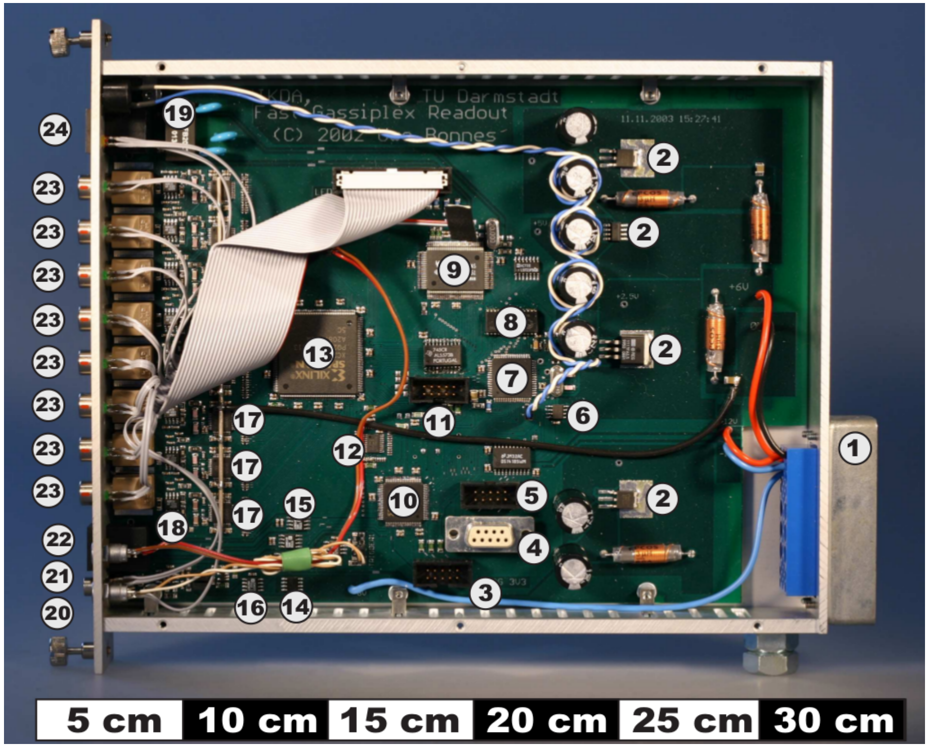


Problems of the Old Data Acquisition Module

- The readout module crashed often, in particular at trigger rates > 5 kHz
  → Open the exp. hall for hard reset

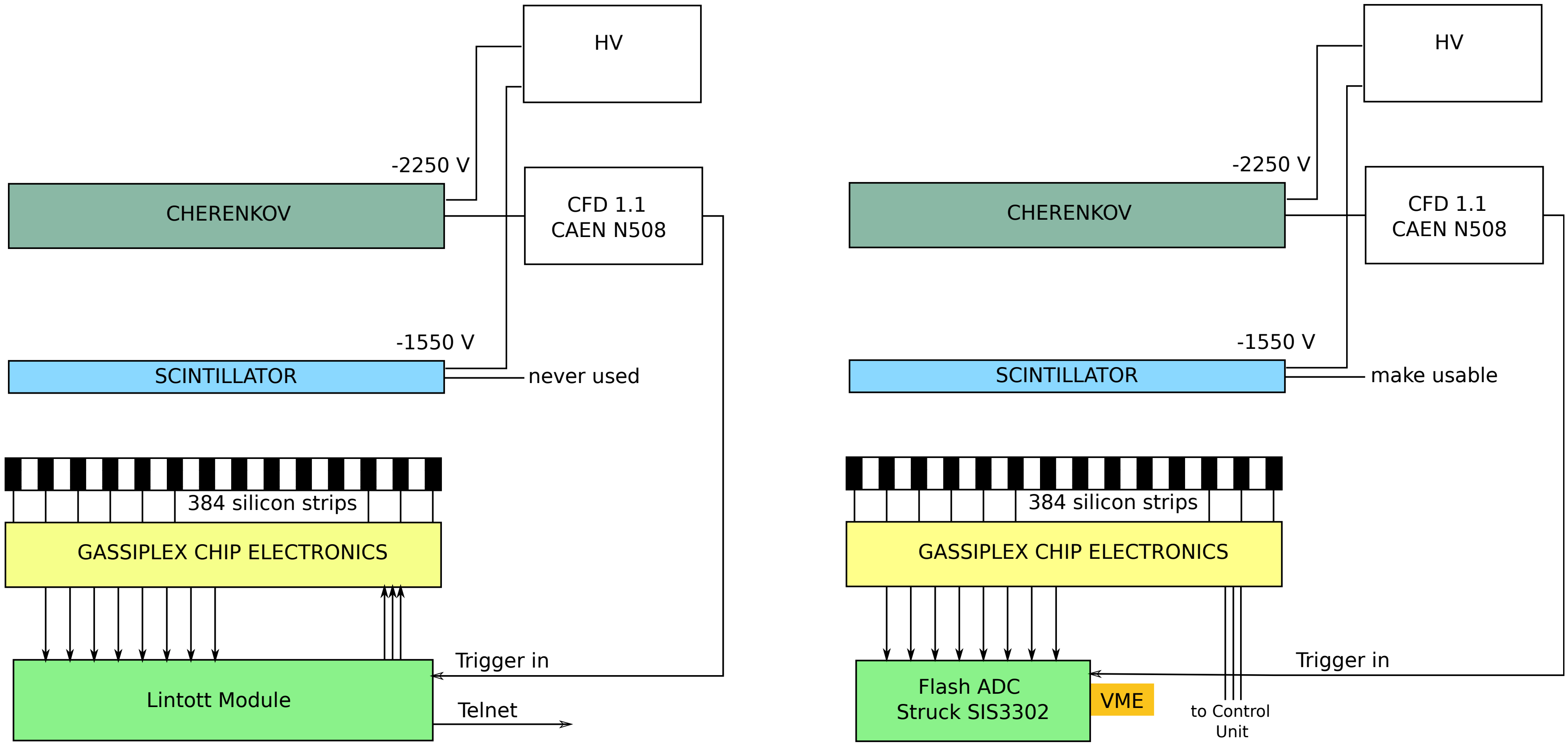
- It provides only a (e,e')-histogram
  → A run not usable after a frame hit
  → No energy coincidence possible

- We have only one!

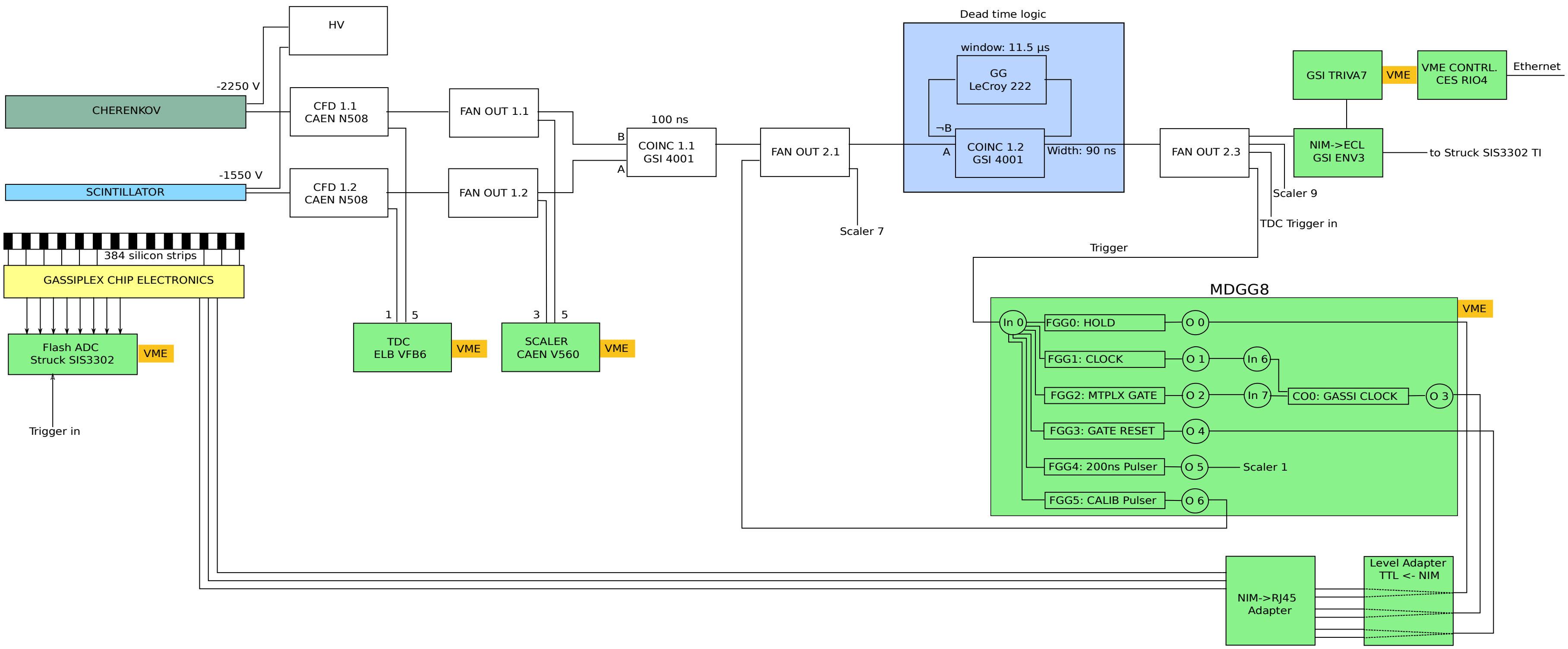


A. Lenhardt, PhD Thesis, TU Darmstadt, (2004)

First Idea...

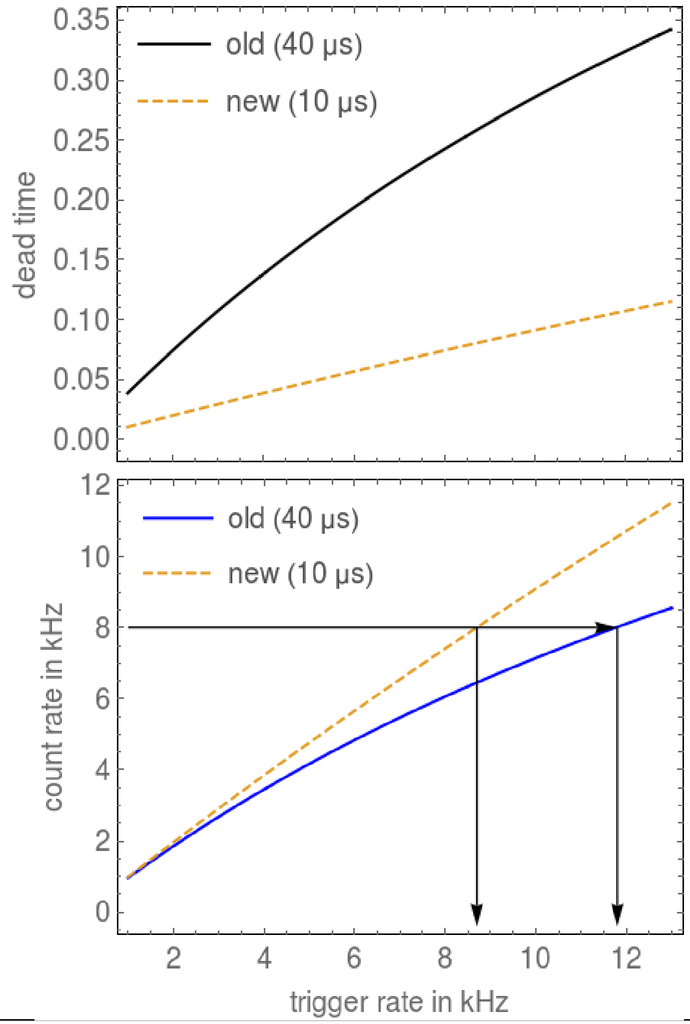

HV
-2250 V
CHERENKOV
CFD 1.1
CAEN N508
-1550 V
SCINTILLATOR
never used
384 silicon strips
GASSIPLEX CHIP ELECTRONICS
Trigger in
Lintott Module
Telnet
HV
-2250 V
CHERENKOV
CFD 1.1
CAEN N508
-1550 V
SCINTILLATOR
make usable
384 silicon strips
GASSIPLEX CHIP ELECTRONICS
Trigger in
Flash ADC
Struck SIS3302
VME
to Control
Unit

Current Status of the New DAQ at Lintott

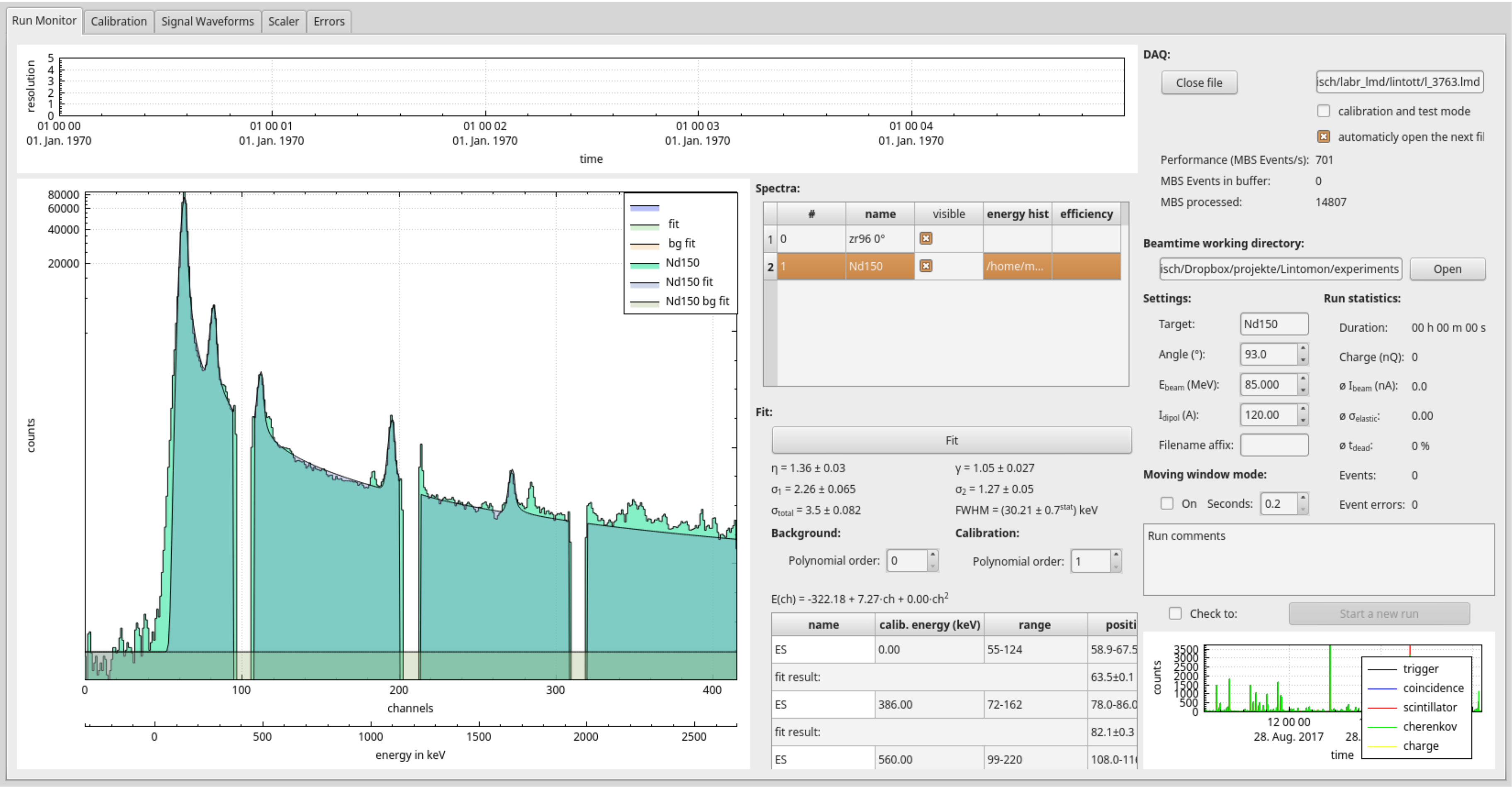


New DAQ at Lintott

- No changes at detector system
- Based on commercially available VME & NIM modules
  → Replacement is not a problem
- Event based
  → No unusable runs after a frame hit
  → Time & energy coincidence possible
  → Correlations between beam settings and energy resolution at Lintott
- Reduced dead time from 40 μs to 10 μs
  → Better signal to background ratio
- Trigger detector readout
- Faraday cup current readout



New Lintott Monitoring Software: Lintomon



Ongoing & Future Work

- New DAQ test (next week)
  → Documentation needed, Debugging & Some features are missing
- Hall sensor installation

Ongoing & Future Work

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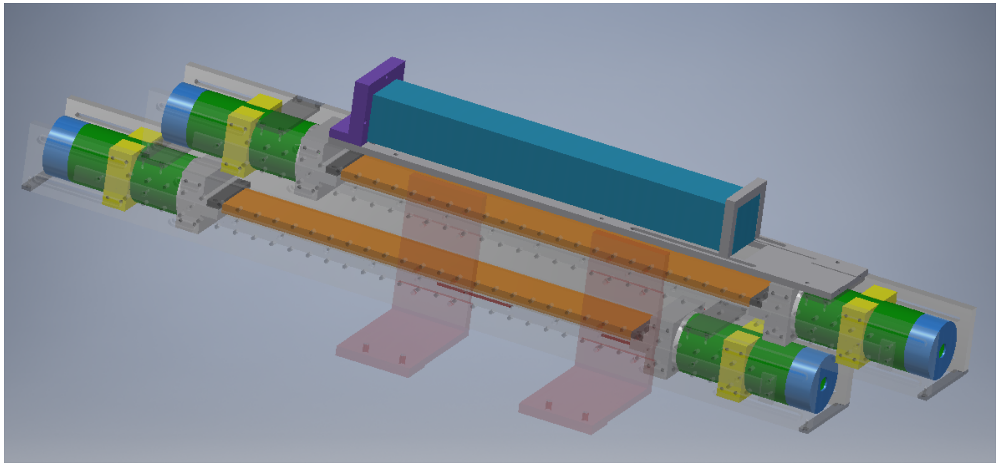
- Hall sensor installation

- New trigger detector for better time resolution (0.3 ns expected, now 2 ns)



I. Brandherm, Bsc. thesis, in preparation

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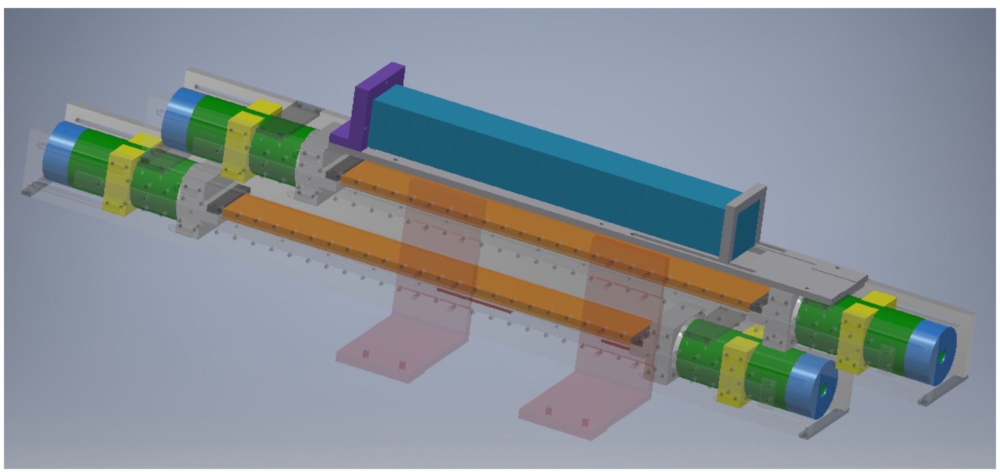

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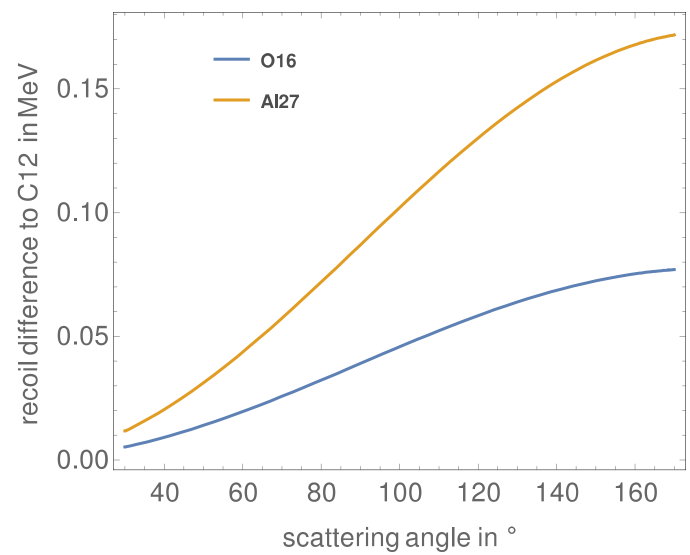
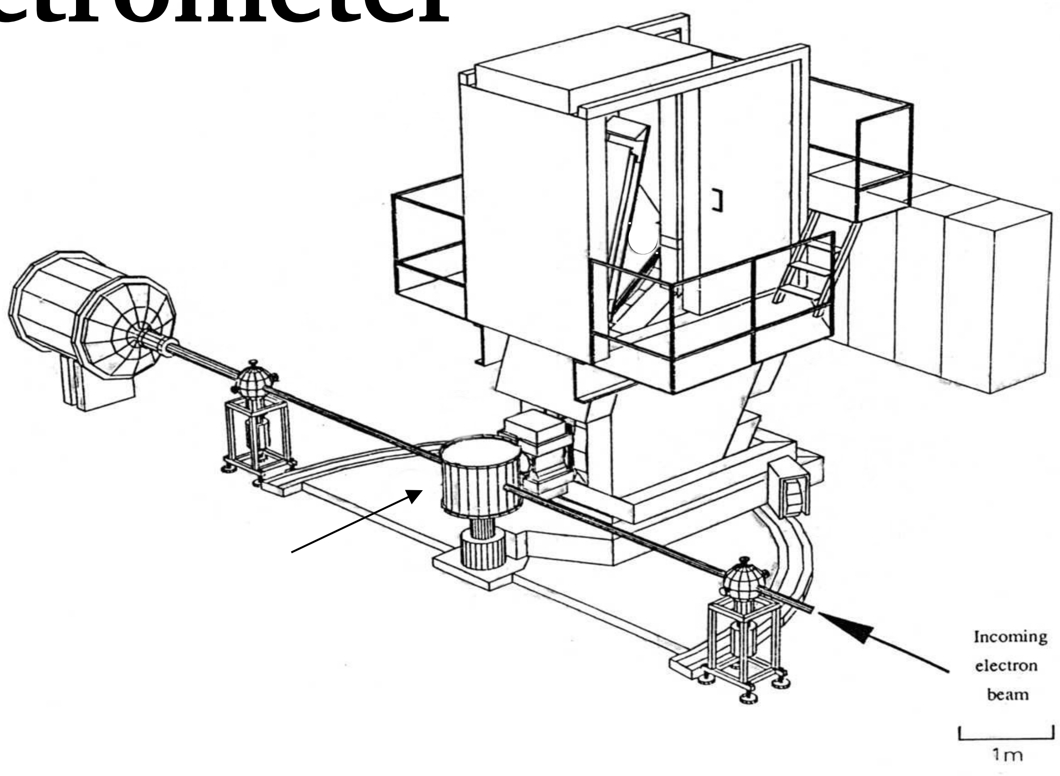


- Measurement of the scattering angle with a space blanket target (C10H8O4 + Al)

Quadrupole CLAM Shell Magnetic Spectrometer



QCLAM vs. Lintott

	QCLAM	Lintott
Momentum acceptance	± 10 %	± 2 %
Solid angle	35 msr	6 msr
Max. energy (design)	up to 200 MeV	up to 120 MeV
Energy resolution (detector)	$1.4 \cdot 10^{-4}$	$1.7 \cdot 10^{-4}$
Energy resolution (exp.)	$8 \cdot 10^{-4}$	$2.9 \cdot 10^{-4}$
Dispersion matching	No	Yes
Possible count rates	~ 15 kHz (prelim.)	< 8 kHz
Scattering angle	25°-155°, 180°	69°-165° in 12° steps
Gap-free detector	Yes (MWDC)	No (4x96 ch → 3 gaps)

Energy Resolution at QCLAM

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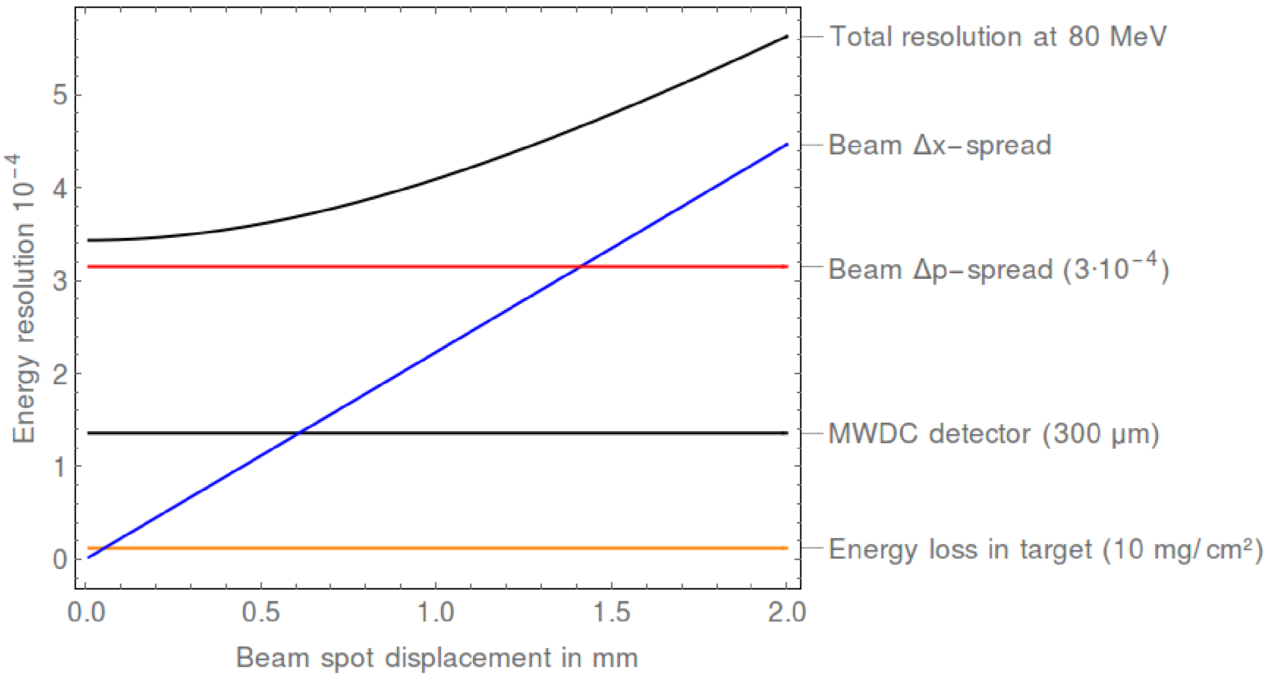
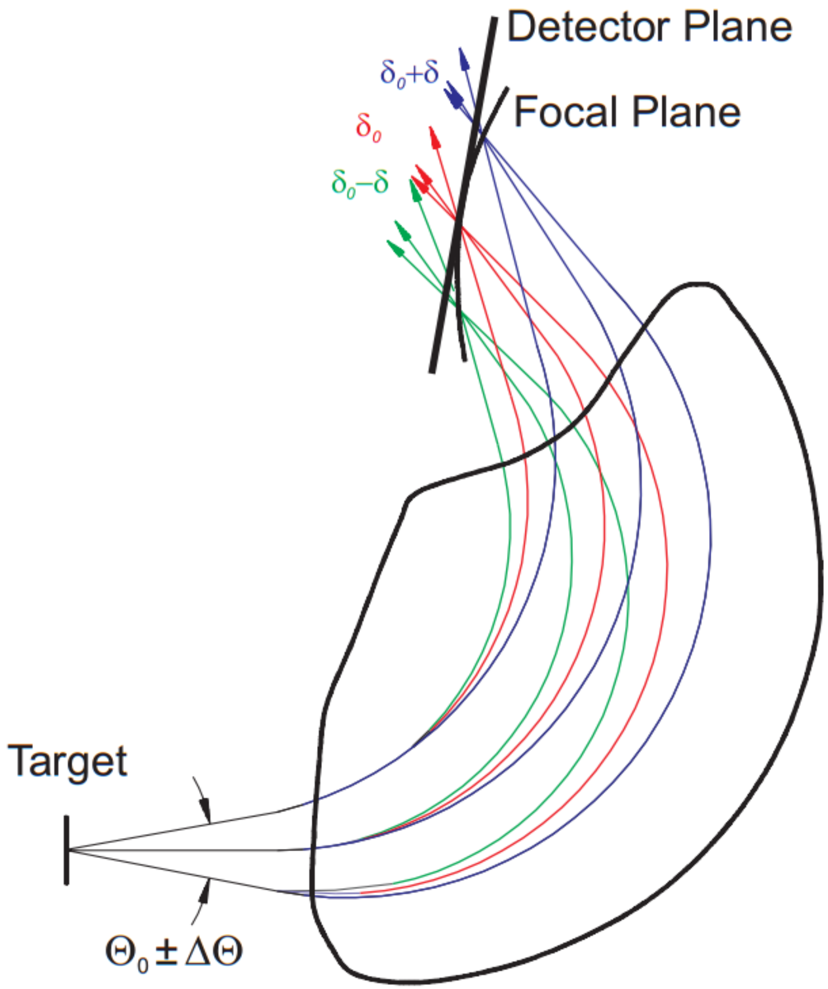


- Energy resolution is limited by
  → Beam energy resolution
  → Mean beam spot size

- Quadrupoles before scattering chamber for better focus?
  → Simulation needed

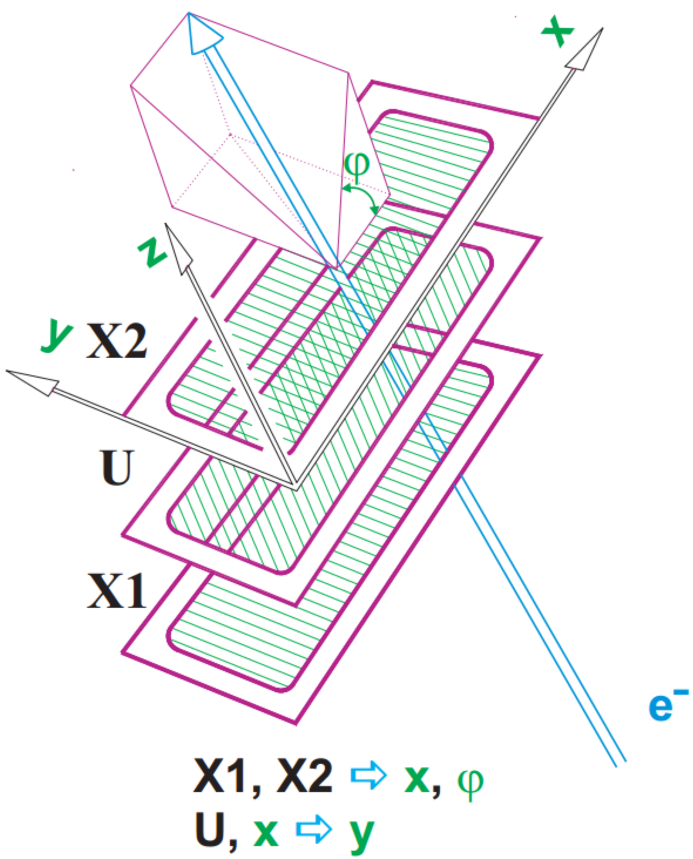
Large Acceptance Spectrometer



Y. Kalmykov, LINAC Palaver Talk, TU Darmstadt, (2003), mod.

- Different energies result into different positions on the focal plane
- Dipole design criteria:
  $(x|\theta) = 0 \quad (y|\phi) = 0$
- The focal plane is curved, the detector not!
  → electron track reconstruction needed
- Recoil correction needed

Electron Track Reconstruction



- 6 coordinates for a line fit needed:
  → 2z defined by the detector position
  → 1x from X1 MWDC
  → 1x from X2 MWDC
  → 1y from U MWDC
- One parameter is not determined
  → Use correlations in combination with a sieve slit calibration

Y. Kalmykov, LINAC Palaver Talk, TU Darmstadt, (2003), mod.

New Data Acquisition at QCLAM

Why a New Data Acquisition (DAQ) ?

- Reasons
  - In-house-made electronics (discontinued ICs → no repair)
  - Incomplete and fragmented documentation
  - Number of channels doubled due to the new MWDCs (896)
  - Slow data rate
  - Time resolution 1.33 ns
  - VAX-based readout computer (1980s technology)

Measurement Chain

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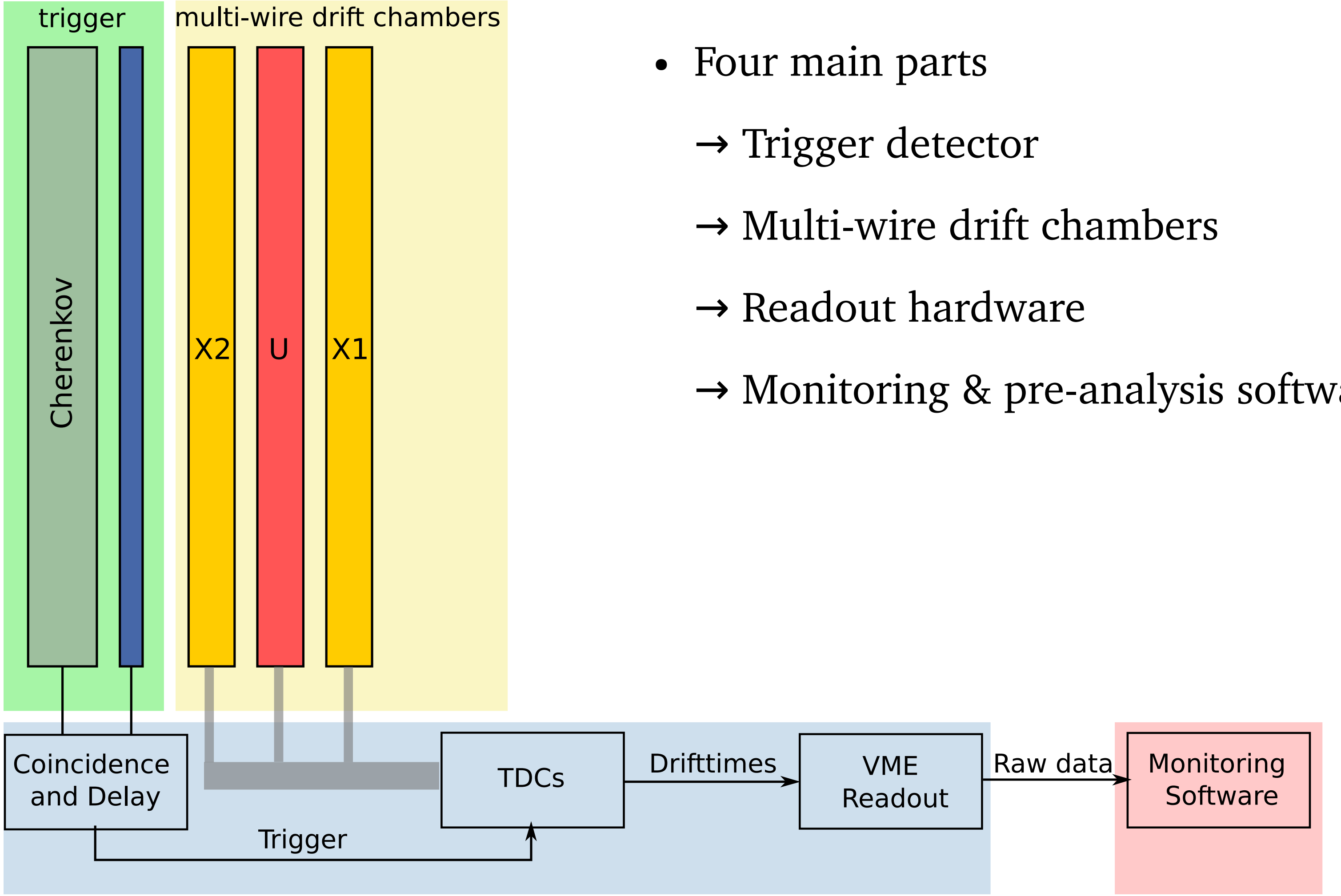
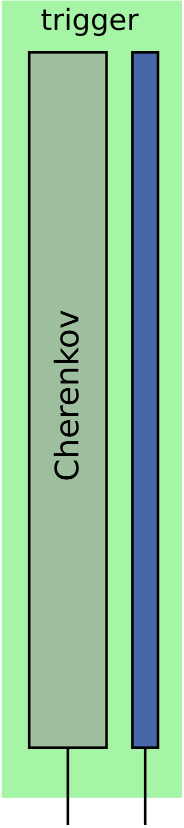


- Four main parts
  - → Trigger detector
  - → Multi-wire drift chambers
  - → Readout hardware
  - → Monitoring & pre-analysis software

Measurement Chain



- Four main parts

  → Trigger detector

MWDCs and Trigger Detectors Construction

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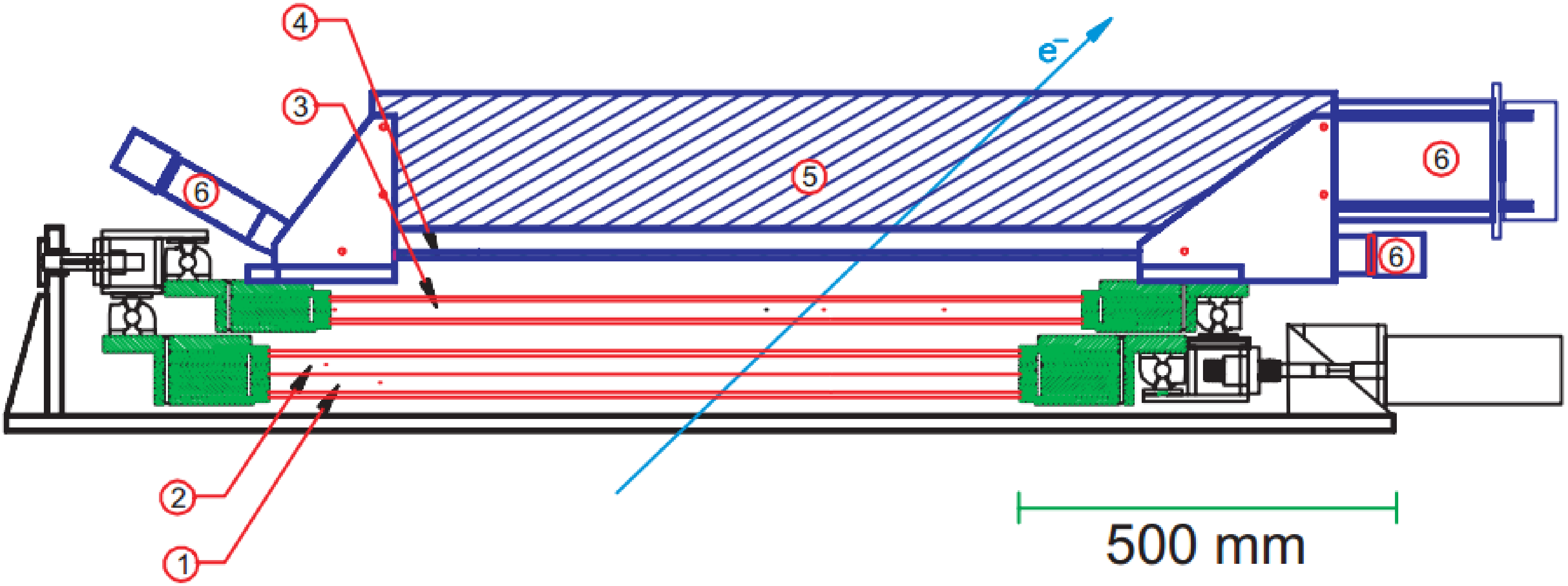

① VDC X1

② VDC U

③ VDC X2

④ Scintillator

⑤ Cherenkov detector

⑥ Photomultiplier

Y. Kalmykov, LINAC Palaver Talk, TU Darmstadt, (2003)

MWDCs and Trigger Detectors Construction

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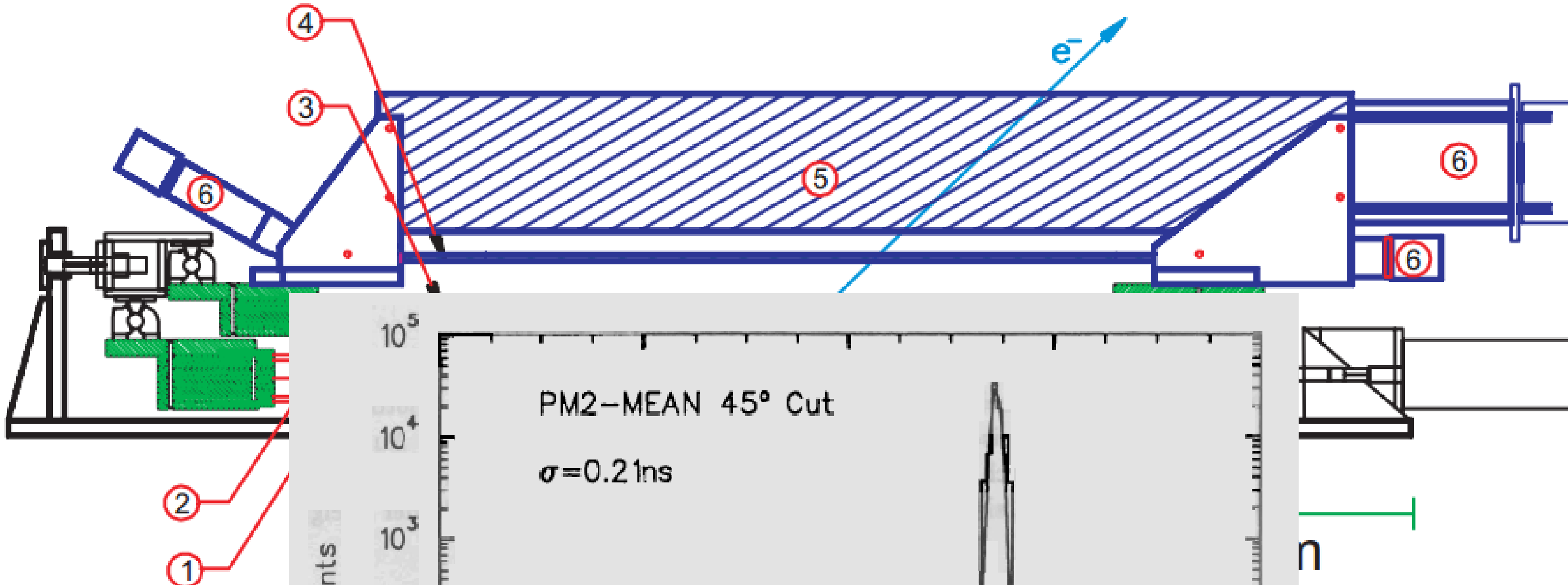
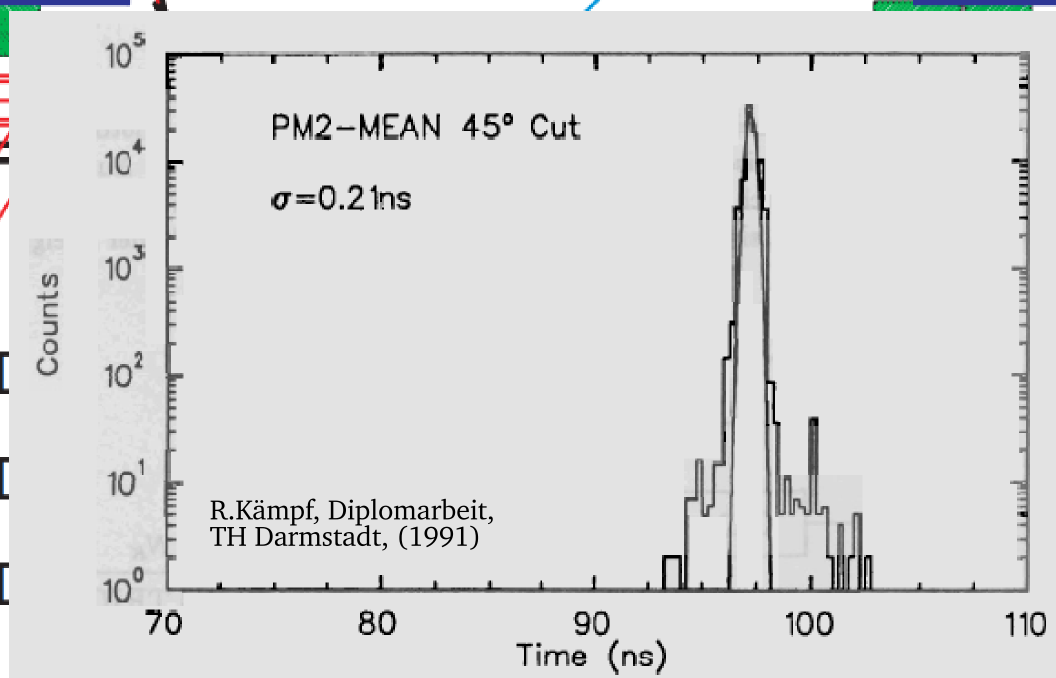




n

① VD

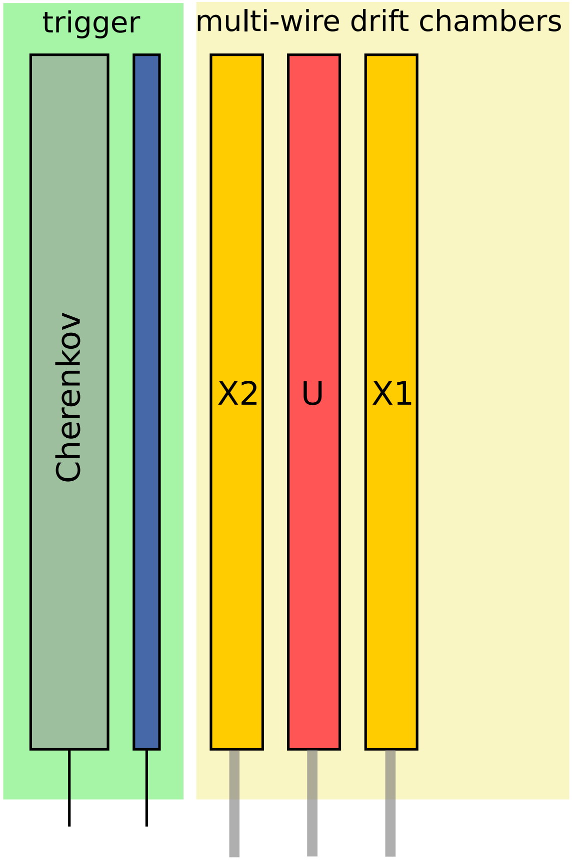
② VD … detector

③ VD … ier

Improvement of the Trigger Detector

- In the past problems with broken scintillator/light guide connection
- Remove light guides and attach PMTs directly to the scintillator
  → Smaller area, but no 3 % efficiency bottle neck from light guide
  → Unbowed connection → more stable
- New CFD with walk jitter < 50 ps
- Tests with silicon photomultipliers (Bsc. Thesis: M. Studlek)
  → Segmented scintillator for segmented readout?

Measurement Chain

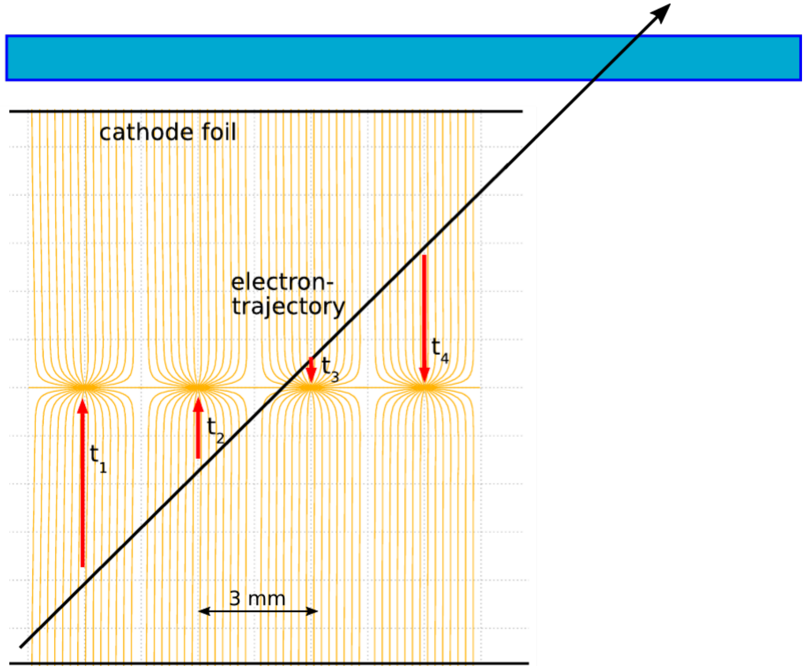


- Four main parts

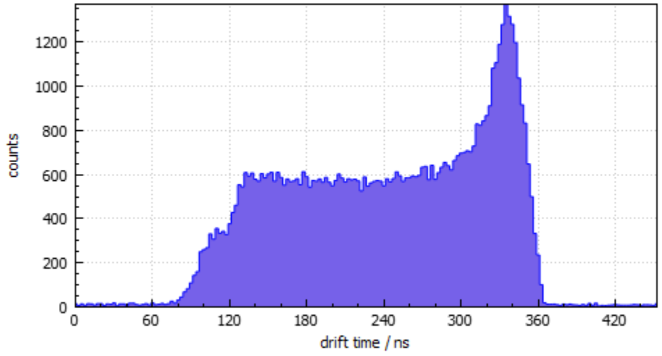
  → Trigger detector

  → Multi-wire drift chambers

Working Principle of a MWDC



- Counting gas ionization
- Charge cloud drifts to the anode wires ($v = 50\ \mu m/ns$)
- Scintillator defines the zero time (trigger to the TDC)
- Wire signals arrive after max. 300 ns



- To calculate the intersection point:
  - Calculate distances $Z_{wire}(t_n, \phi_0)$
  - Do linear regression → x_0

Measurement Chain

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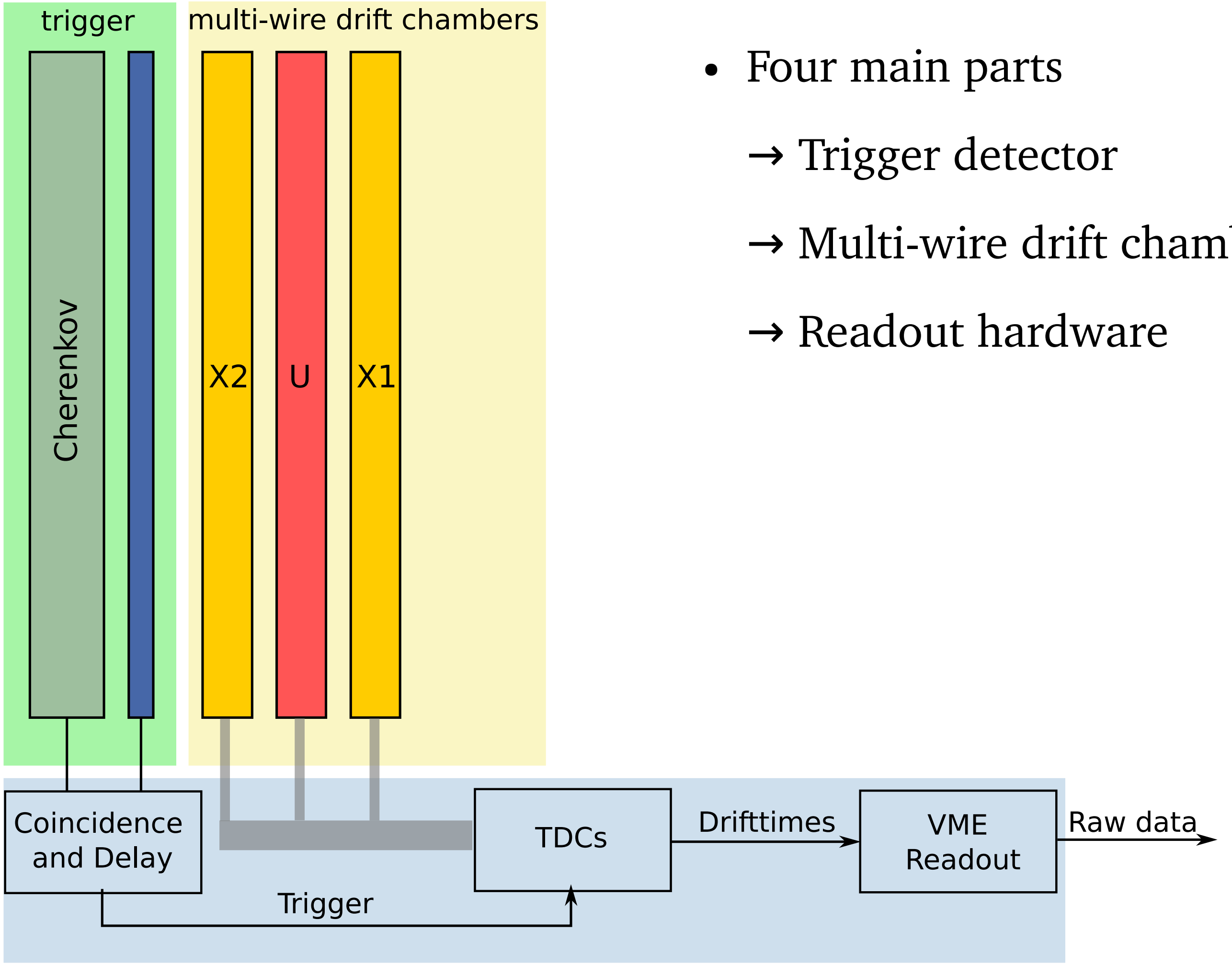

- Four main parts
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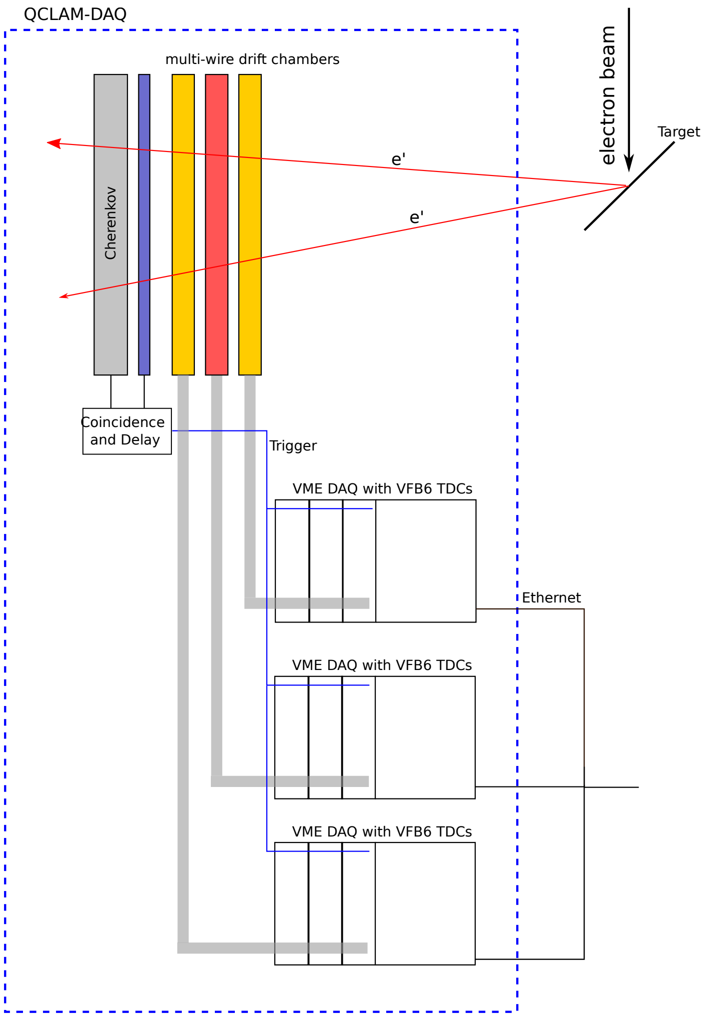
  - → Multi-wire drift chambers
  - → Readout hardware

(e,e‘)-DAQ Hardware Model



- Scintillator and Cherenkov signals are in coincidence
- Time measurement by VLB6 TDCs (rms 30 ps)
- 3 VME crates and 2 NIM crates of modules
- Several thousand lines of C code for hardware programming
- Event rate limited by VME single transfer mode: ~ 4.5 MB/s @ 15000 event/s
- Event synchronization between crates done by software

  → Extension of the TDC Firmware for event timestamps needed. Hardware programming in VHDL and Verilog language.

(e,e'x)-DAQ Extension

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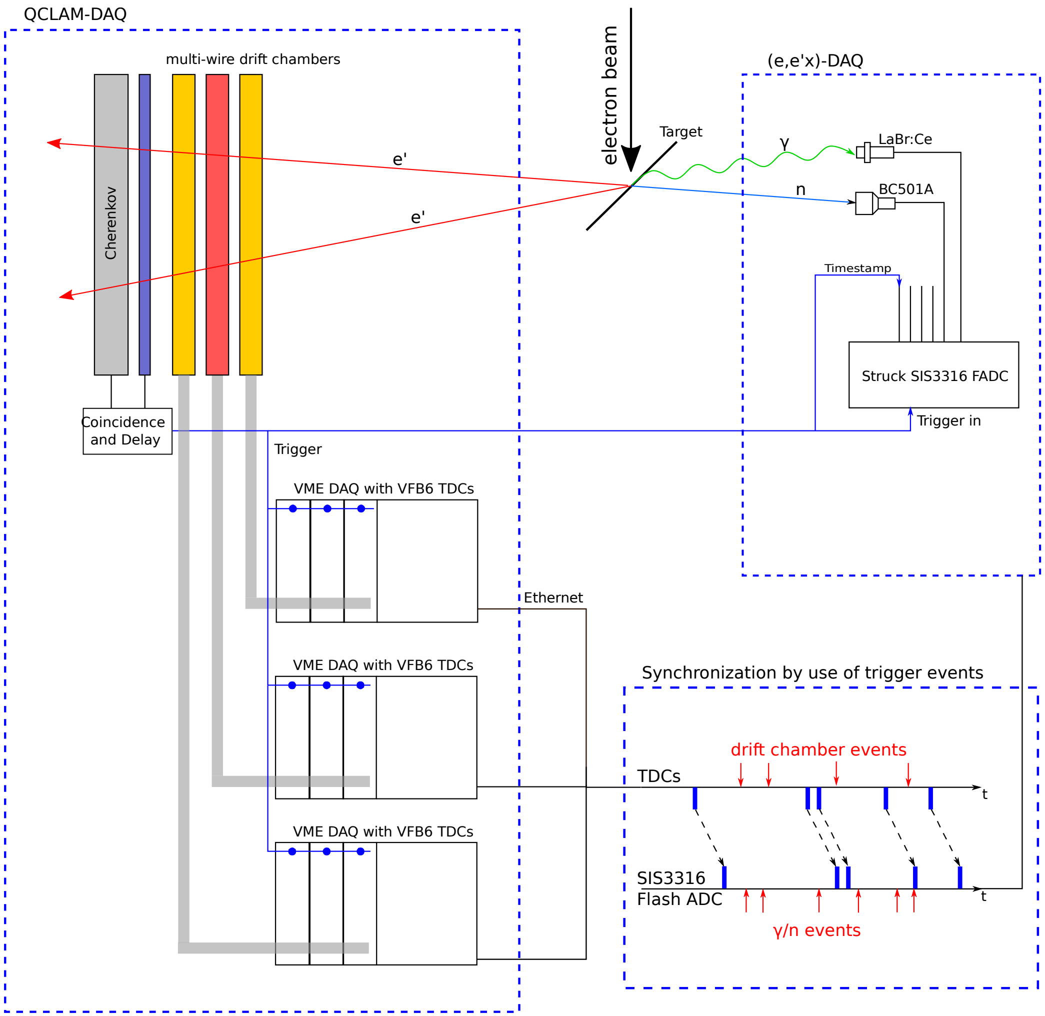
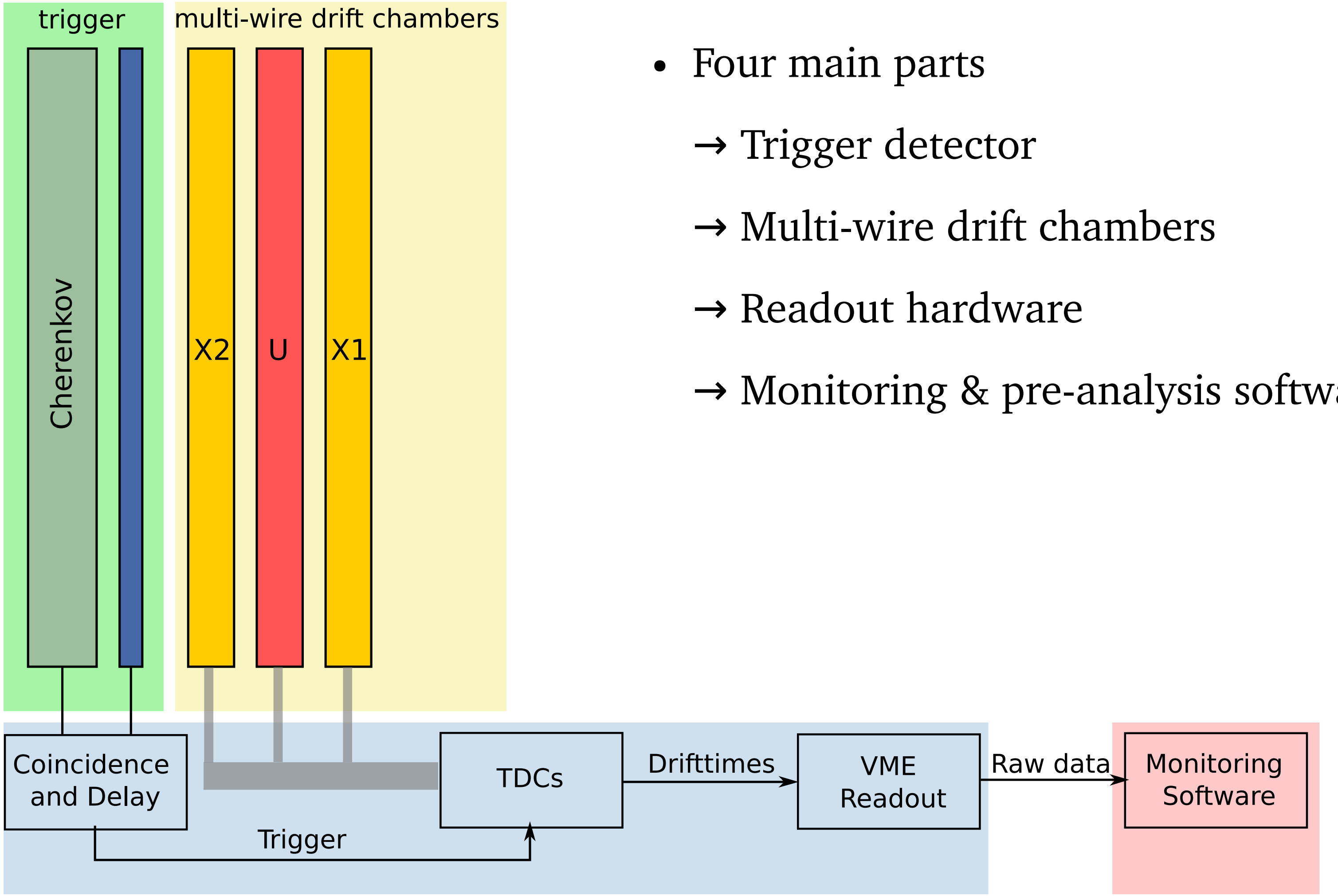


- (e,e')-DAQ is independent from the (e,e'x)-DAQ
- Scintillator trigger is the only (one way) cable connection
- Event building by software
- No changes on the (e,e')-DAQ needed for different experiments
- For more details:
  → Next talk by T. Klaus

Measurement Chain



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(e,e')-DAQ Software

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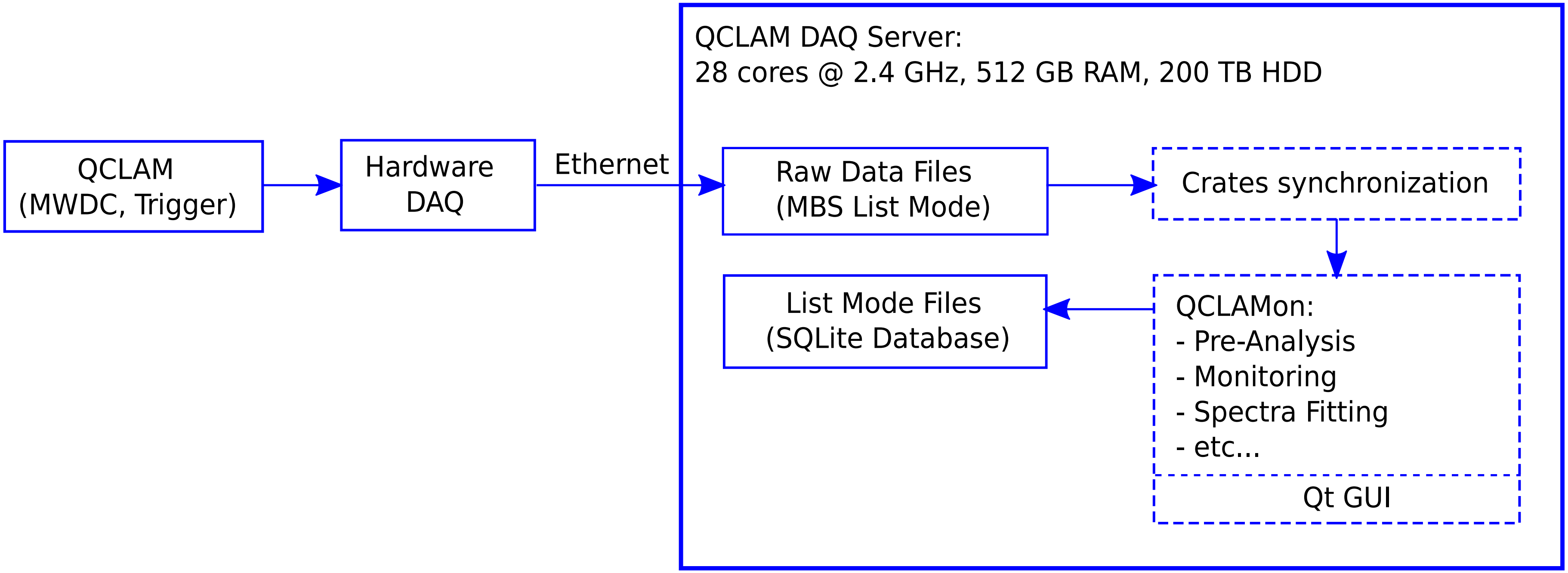
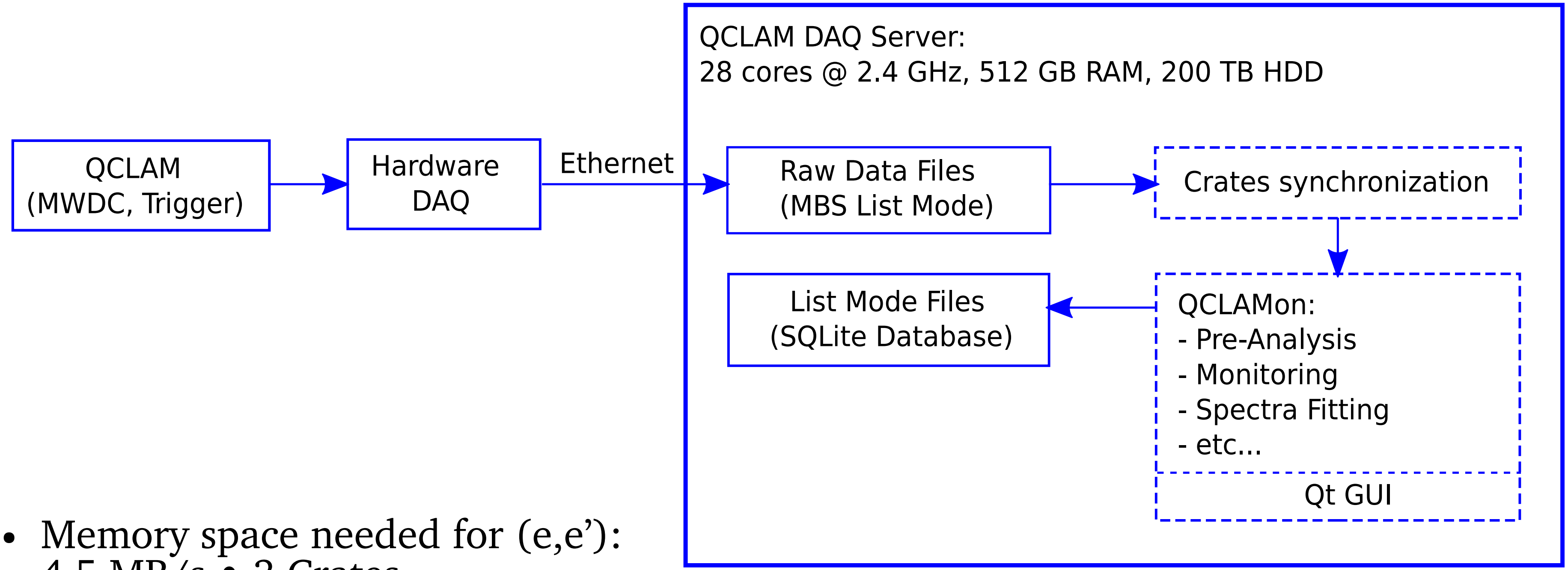


(e,e')-DAQ Software



- Memory space needed for (e,e'):
  4.5 MB/s • 3 Crates =
  - 1 hour: ~50 GB
  - 1 week: ~8 TB
  - CRC 1245 campaigns: ~200 TB
- For (e,e'γ) @ (15 det., 15 kHz):
  ~5 TB per week

New QCLAM Monitoring Software: QClamon

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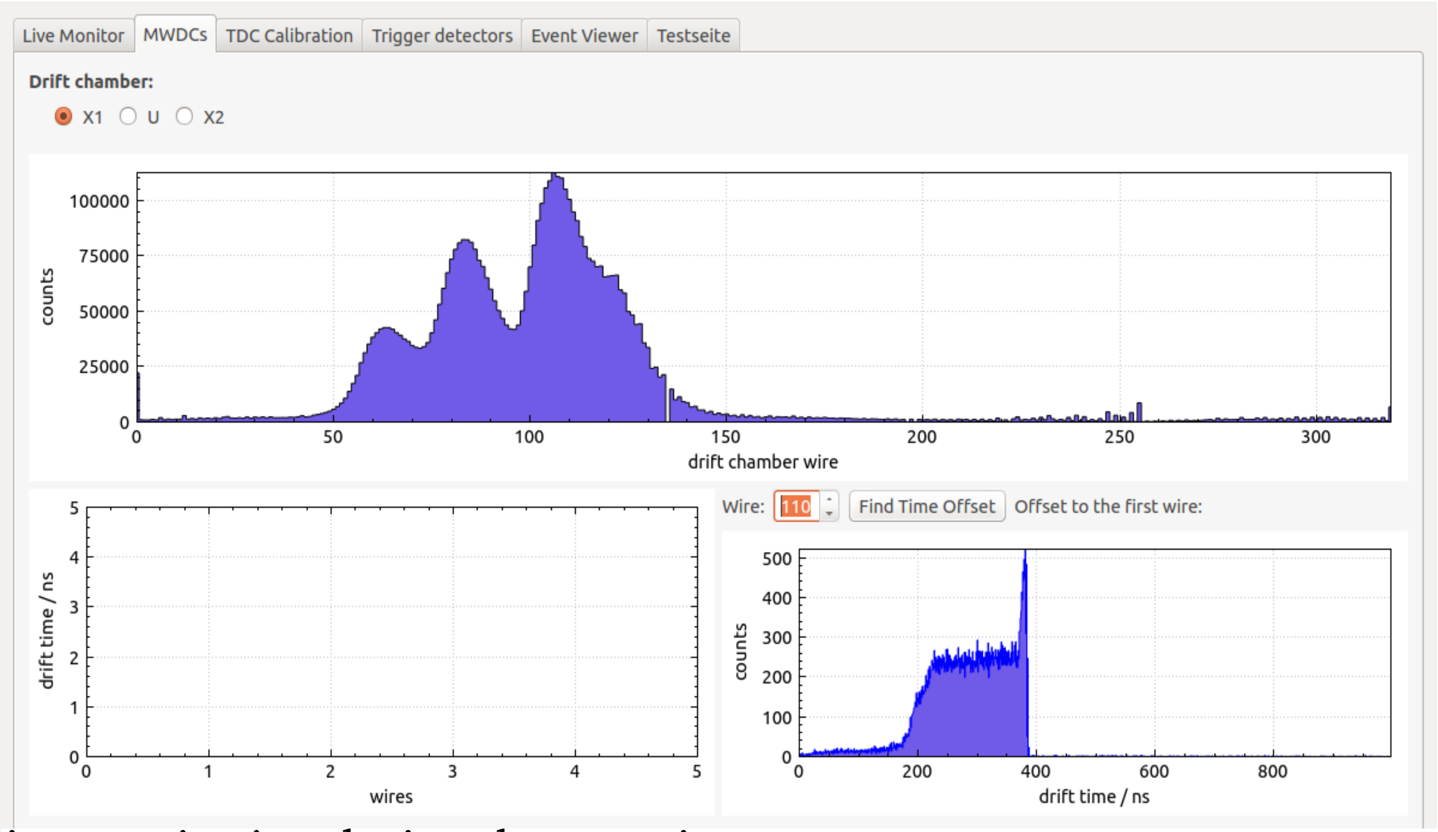

- On-line monitoring during the experiment
- Pre-analysis functionality
- Multi-core optimized for high trigger rate (>20 kHz)
- Works on Windows/Linux

Ongoing & Future Work

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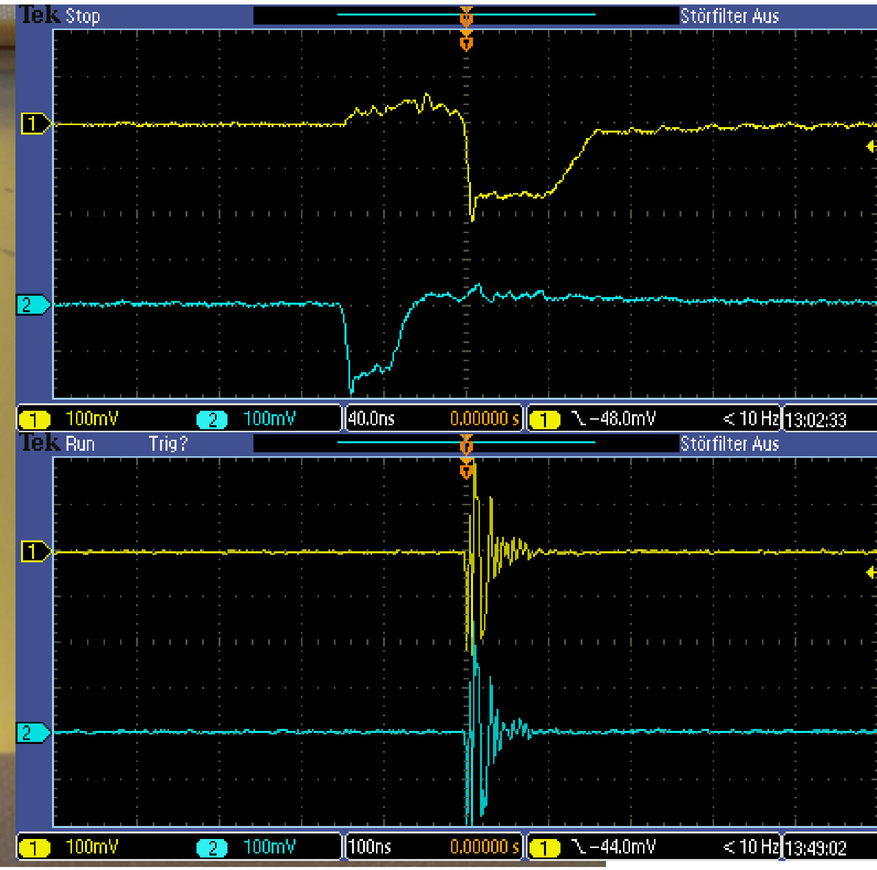
- New power supply for the pre-amplifiers at MWDCs installed
  → EPICS integration needed
- New power supply for dipole magnet installed
  → EPICS integration needed
- The entire power cabling at QCLAM was replaced
  → Also new ground potential cable to all hardware parts
- Improved scintillator construction
  → Time resolution measurements needed
- Hall sensor has to be installed
  → Bsc. Thesis ?
- New generation of drift chambers has to be developed
  → Ph.D. Thesis of A. D'Alessio?

Problems with (new) MWDCs



- Peeled off cathode foil (by sparks or humidity ?)
- 3rd generation MWDC (320 wires) not usable → use 2nd gen. of X1U-MWDC

Summary & Outlook

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- Lintott spectrometer is ready for operation

- QCLAM spectrometer
  → Preliminary DAQ successfully tested with Sr-90
  → Waiting for installation of a vacuum valve
     → Vacuum test → Drift chamber installation
  → Transfer the DAQ electronics from Lab 010 to QCLAM
  → Test with Sr-90

- Preliminary schedule
  → 11.10.2017 tests of the new DAQ at Lintott (3 days)
  → Measurements with high energy scraper (<2 weeks)
  → Ru-96, C-12 (A07), Xe-129/131 (B03) test experiments

  → QCLAM test maybe in November 2017

THE END

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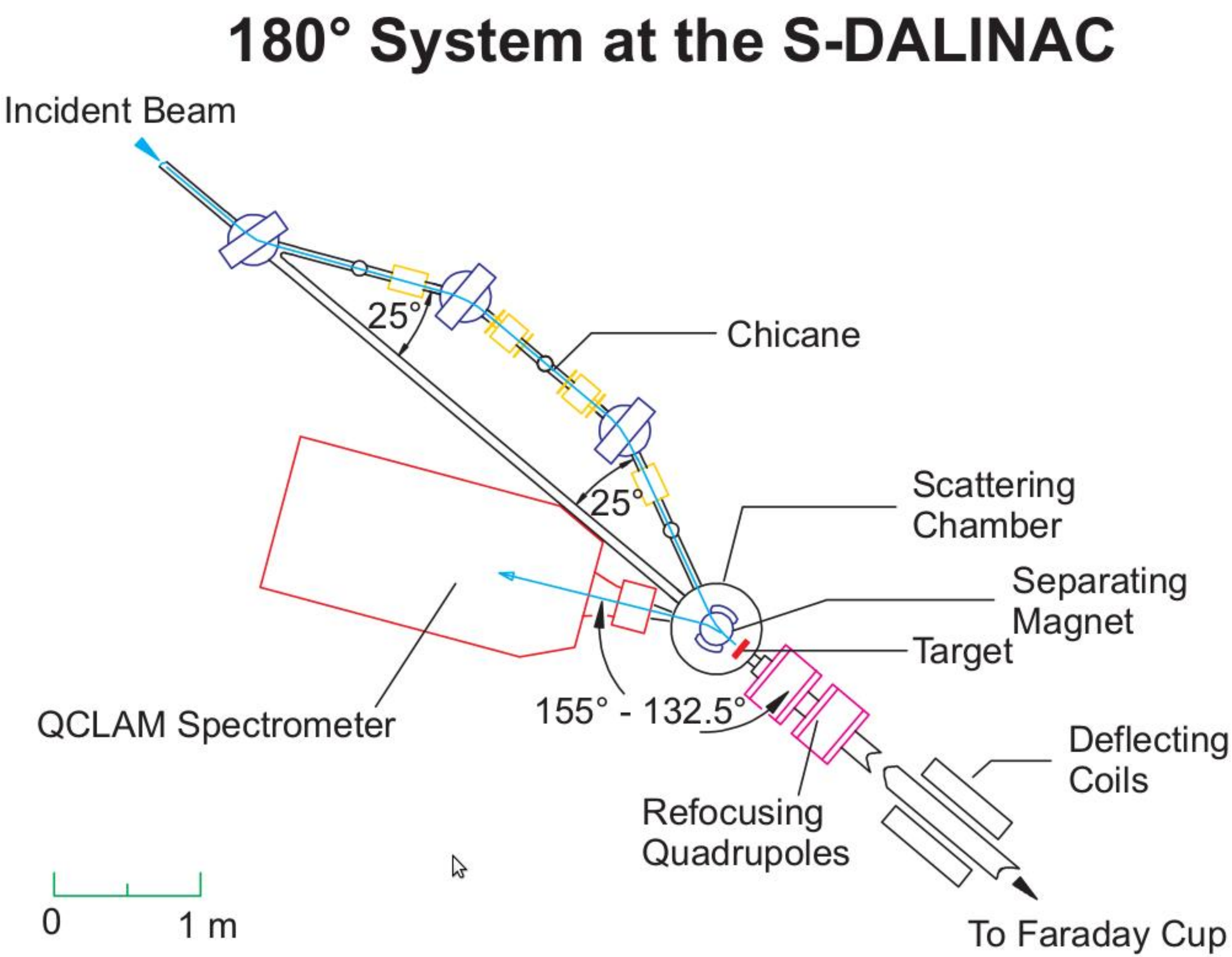
Thank you for your attention!

Questions?

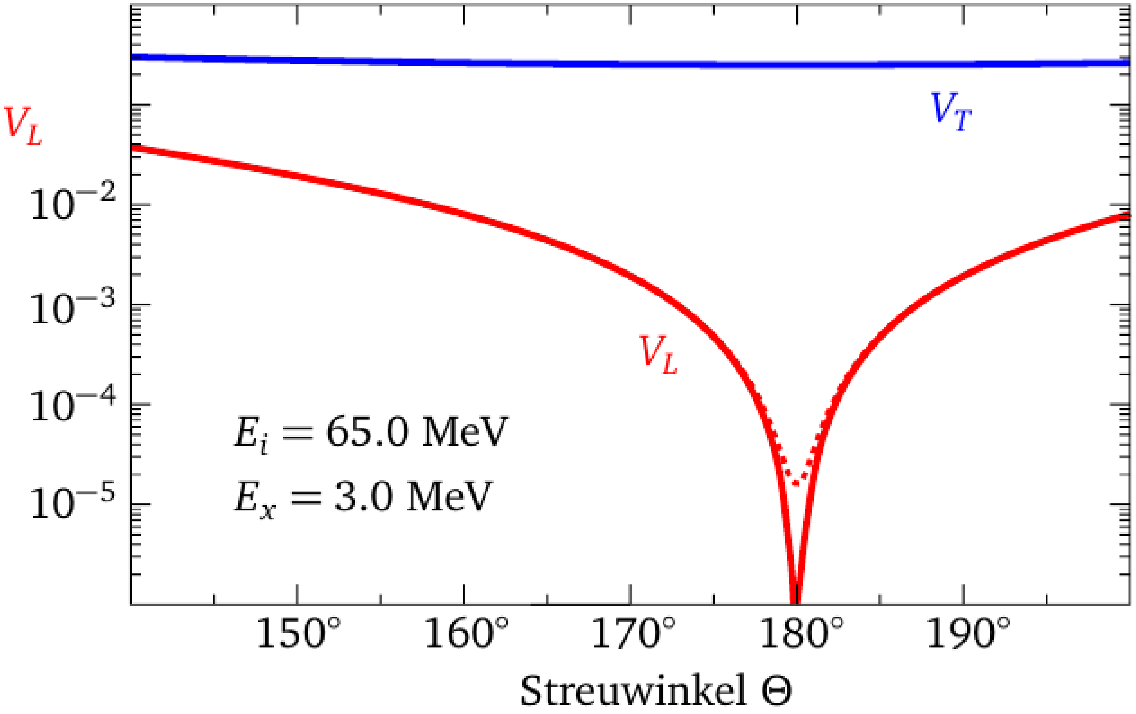

180° System at the S-DALINAC
Incident Beam
25°
Chicane
25°
Scattering
Chamber
Separating
Magnet
Target
QCLAM Spectrometer
155° - 132.5°
Deflecting
Coils
Refocusing
Quadrupoles
0
1 m
To Faraday Cup

$$\left(\frac{d\Omega}{d\sigma}\right) = \left(\frac{d\Omega}{d\sigma}\right)_T \cdot V_T + \left(\frac{d\Omega}{d\sigma}\right)_L \cdot V_L$$

$$V_L = \frac{1+\cos\theta}{2(y-\cos\theta)^2}$$

$$V_T = \frac{2y+1-\cos\theta}{4(y-\cos\theta)(1-\cos\theta)}$$

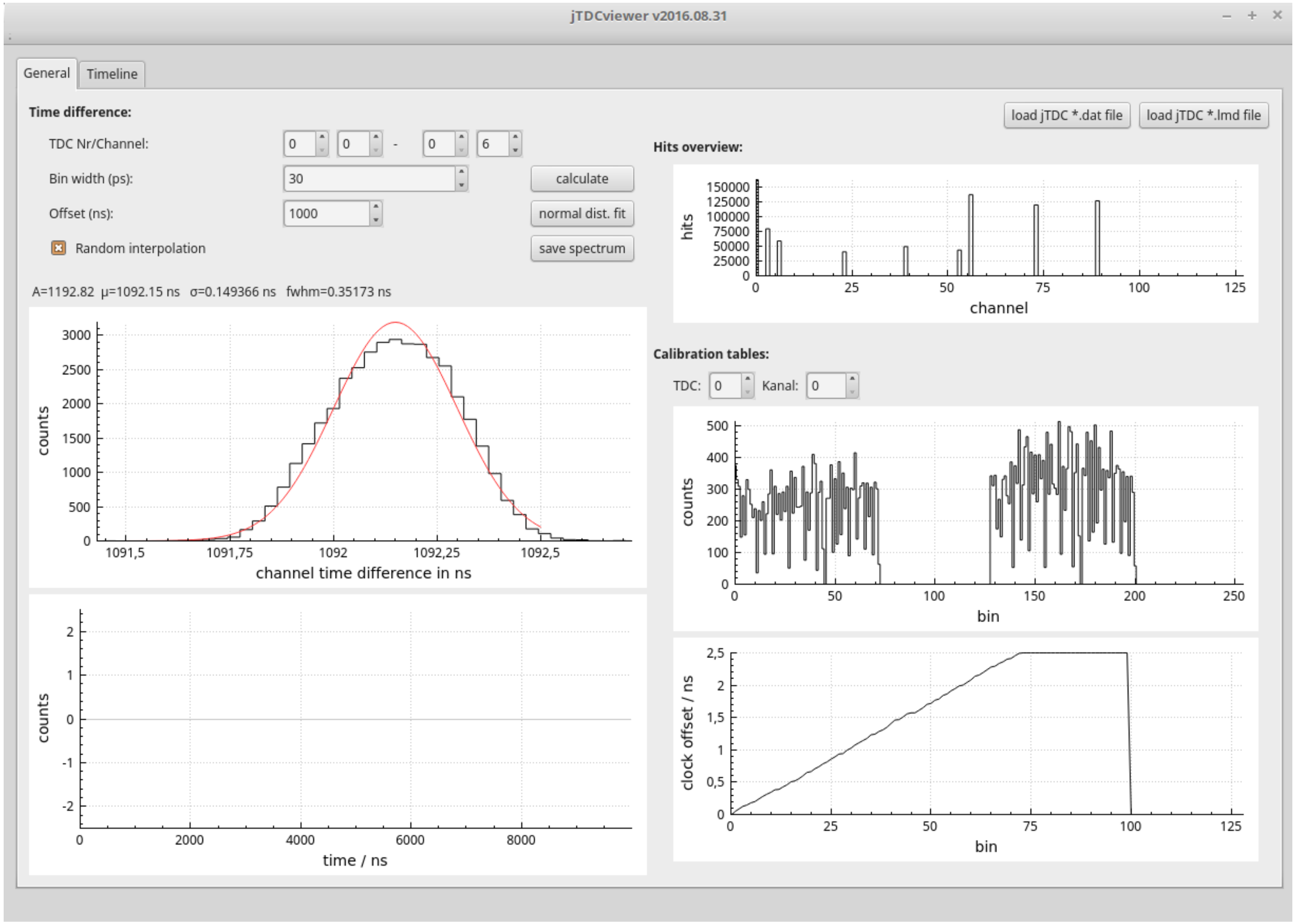
$$y = 1 + \frac{E_x^2}{2E_i(E_i-E_x)}$$



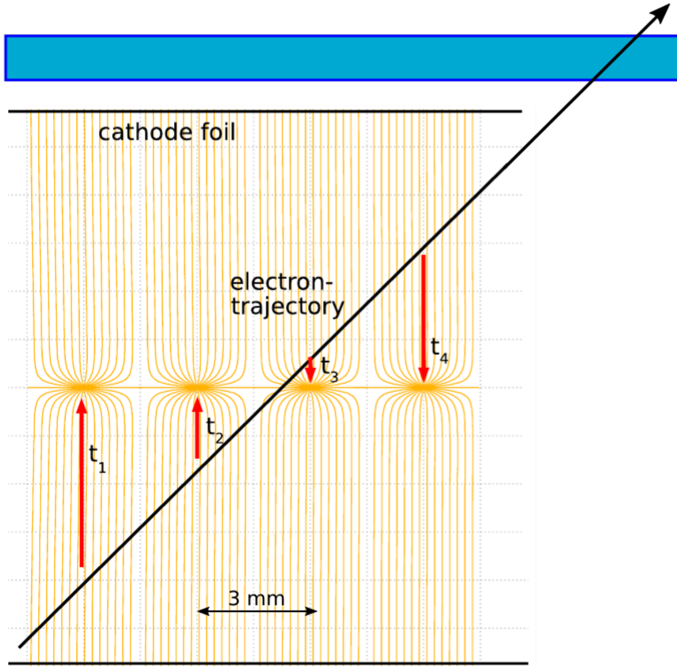
- V_T/V_L ist maximal für $\Theta = 180°$

Kremer,C.: DPG Mainz (2012)

JTDCviewer – jTDC data monitoring application



Working Principle of a MWDC



- Counting gas ionization
- Charge cloud drifts to the anode wires (v=50 μm/ns)

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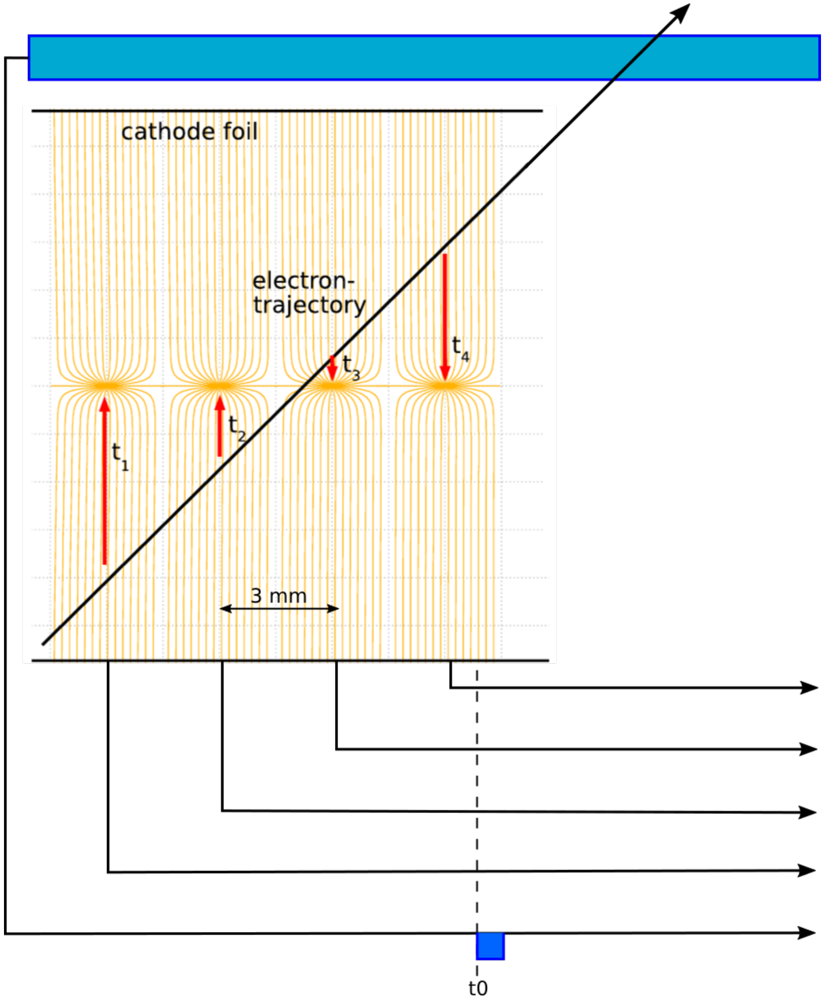

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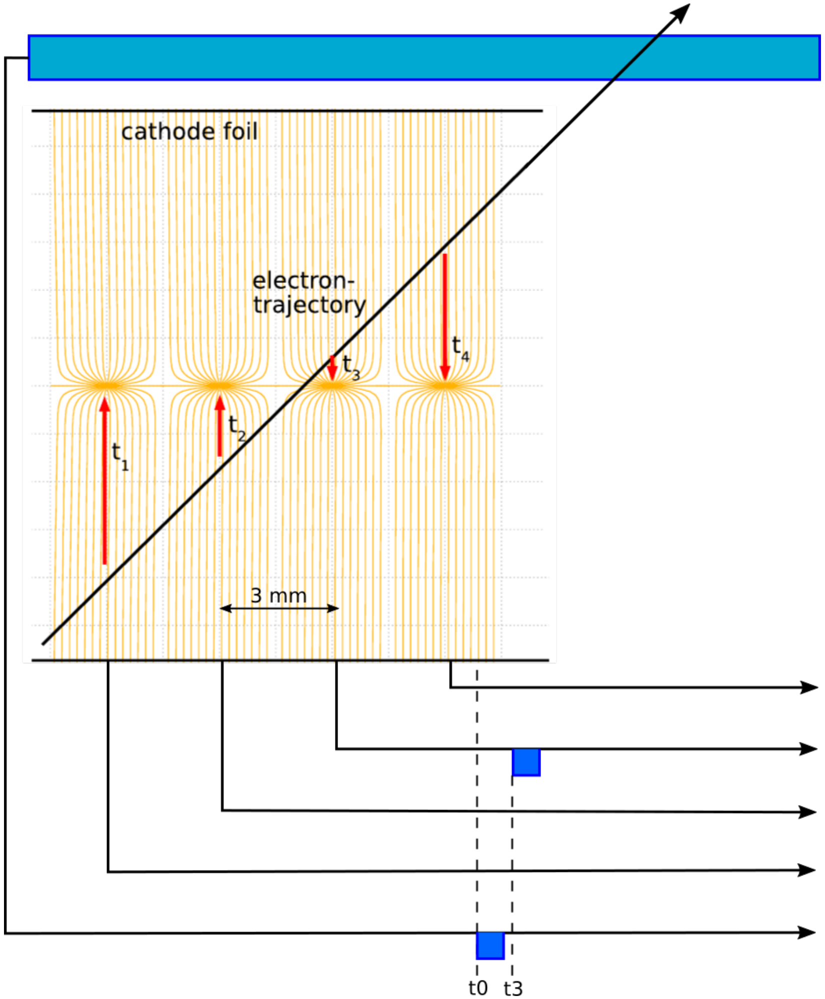

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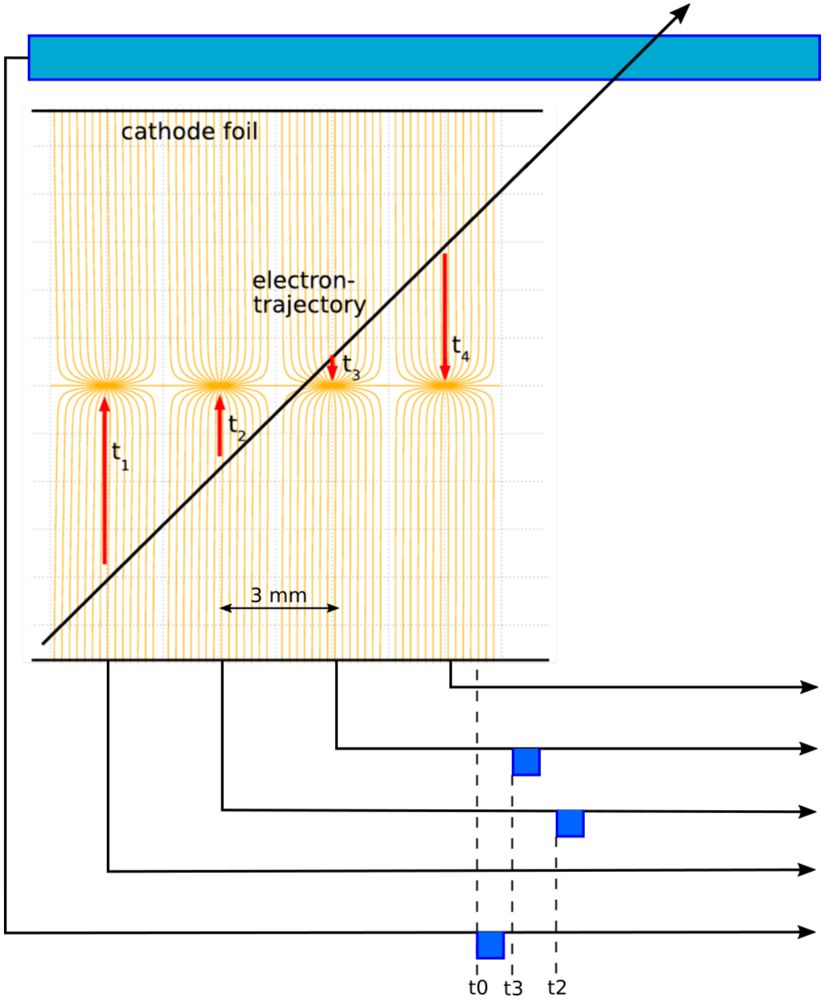

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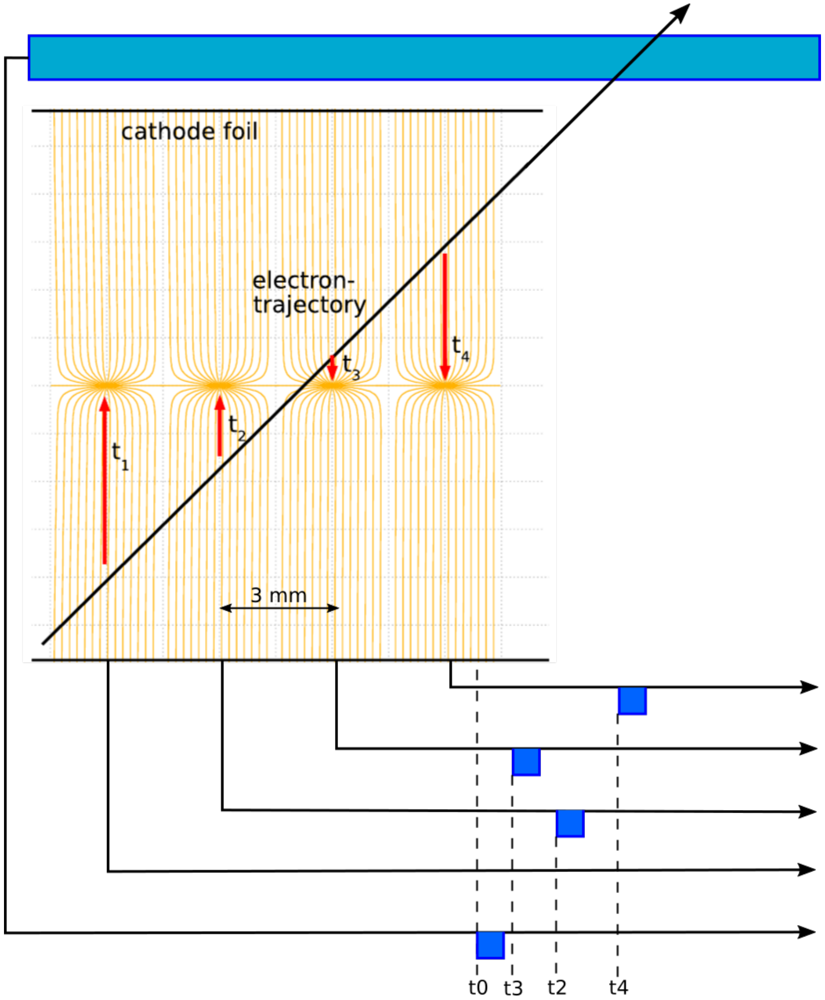

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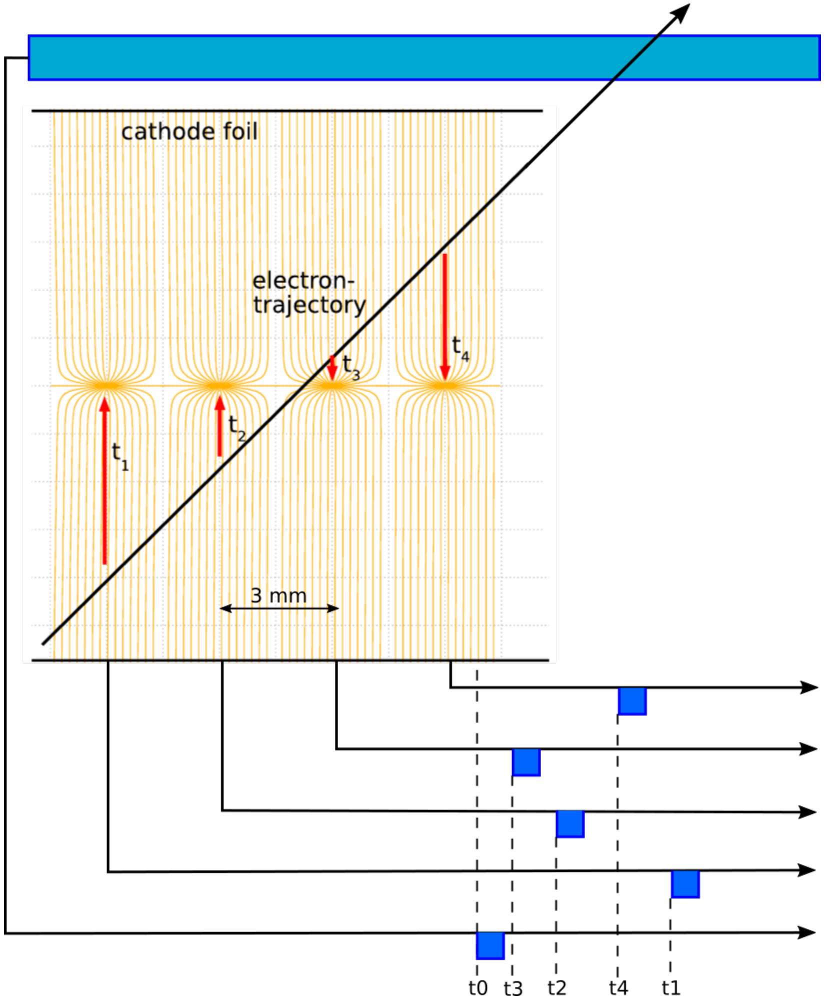
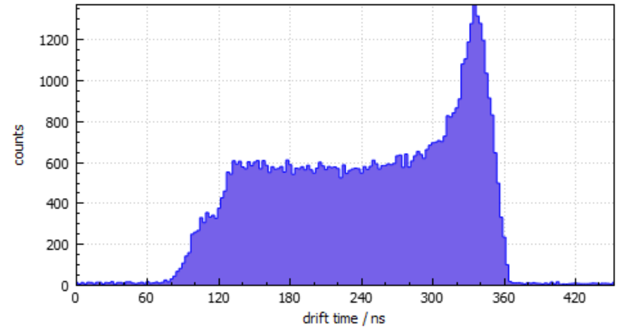
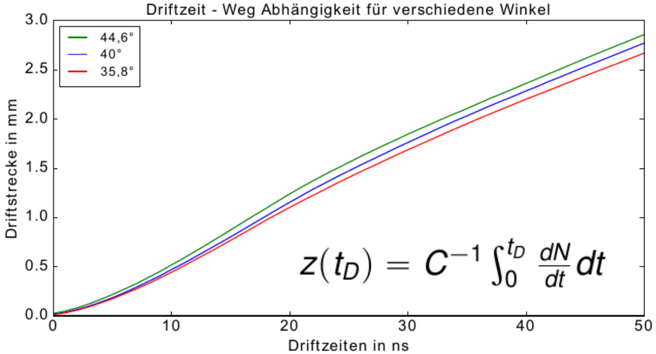
Working Principle of a MWDC



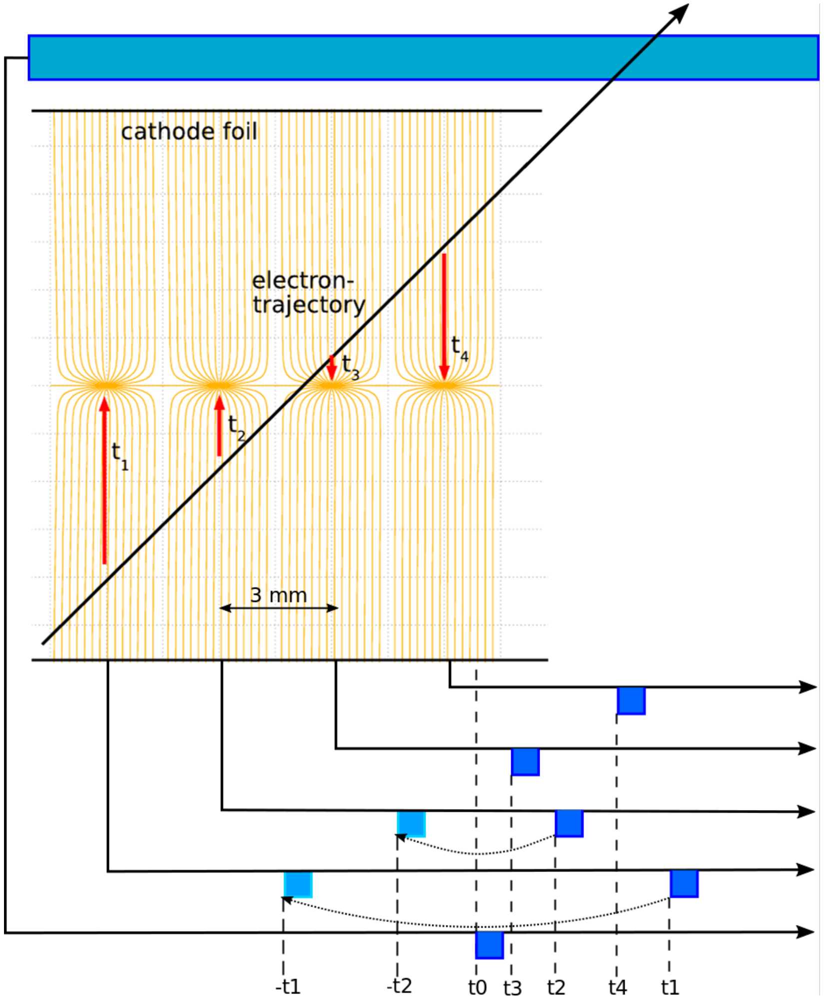
- Counting gas ionization
- Charge cloud drifts to the anode wires ($v = 50\ \mu m/ns$)
- Scintillator defines the zero time (trigger to the TDC)
- Wire signals arrive after max. 300 ns





A. D'Alessio, Master Thesis, TU Darmstadt, (2016)

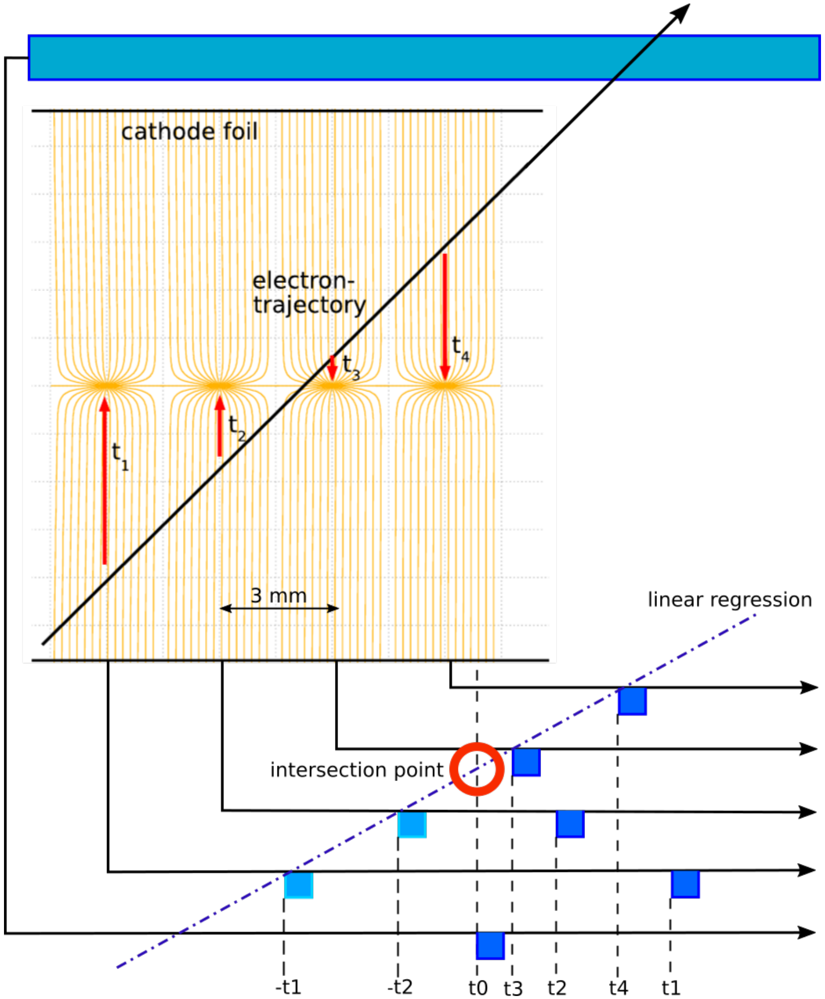
Working Principle of a MWDC



- Counting gas ionization
- Charge cloud drifts to the anode wires (v=50 μm/ns)
- Scintillator defines the zero time (trigger to the TDC)
- Wire signals arrive after max. 300 ns

- To calculate the intersection point:
  - Calculate the center of signals
  - Mirror on-half of the signals times with negative sign

Working Principle of a MWDC

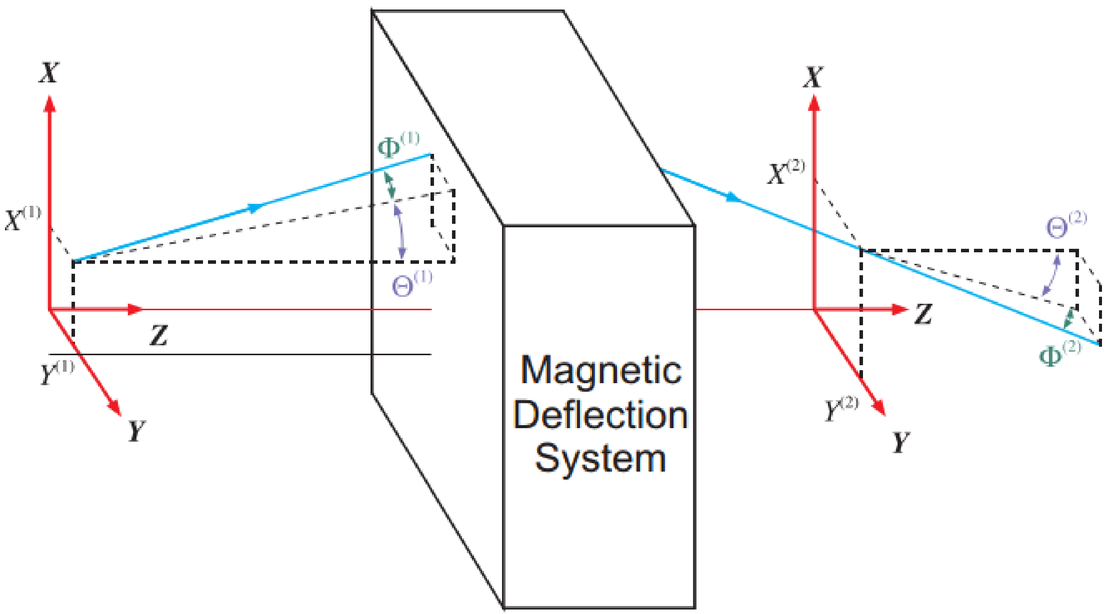


- Counting gas ionization
- Charge cloud drifts to the anode wires ($v=50\ \mu m/ns$)
- Scintillator defines the zero time (trigger to the TDC)
- Wire signals arrive after max. 300 ns

- To calculate the intersection point:
  - Calculate the center of signals
  - Mirror on-half of the signals times with negative sign
  - Calculate distances $Z_{wire}(t_n,\phi_0)$
  - Do linear regression → x_0

Example of Pre-Analysis in QClamon

Analysis Example: Sieve Slit Measurement Particle Transport



$x_2=(x/x)x_1+(x/\Theta)\Theta_1+(x/\delta)\delta+$

~~$+(x/x_2)x_1^2+(x/x\Theta)x_1\Theta_1+(x/\Theta^2)\Theta_1^2+(x/x\delta)x_1\delta+(x/\Theta\delta)\Theta_1\delta+$~~

~~$+(x/\delta^2)\delta^2+(x/y^2)y^2+(x/y\Phi)y_1\Phi_1+(x/\Phi^2)\Phi_1^2+$~~

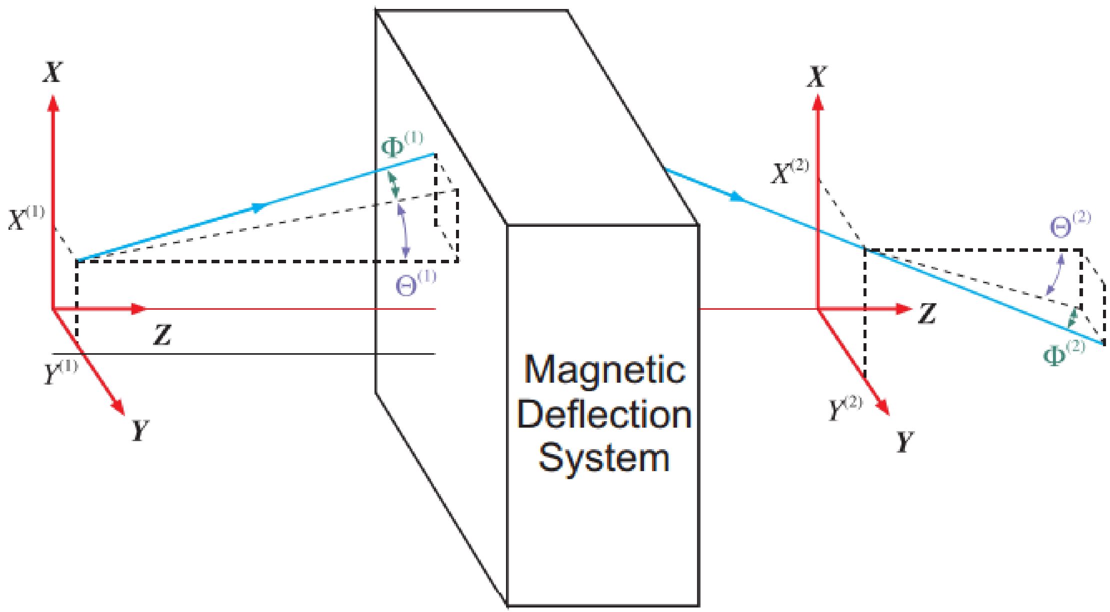
~~+higher order terms~~

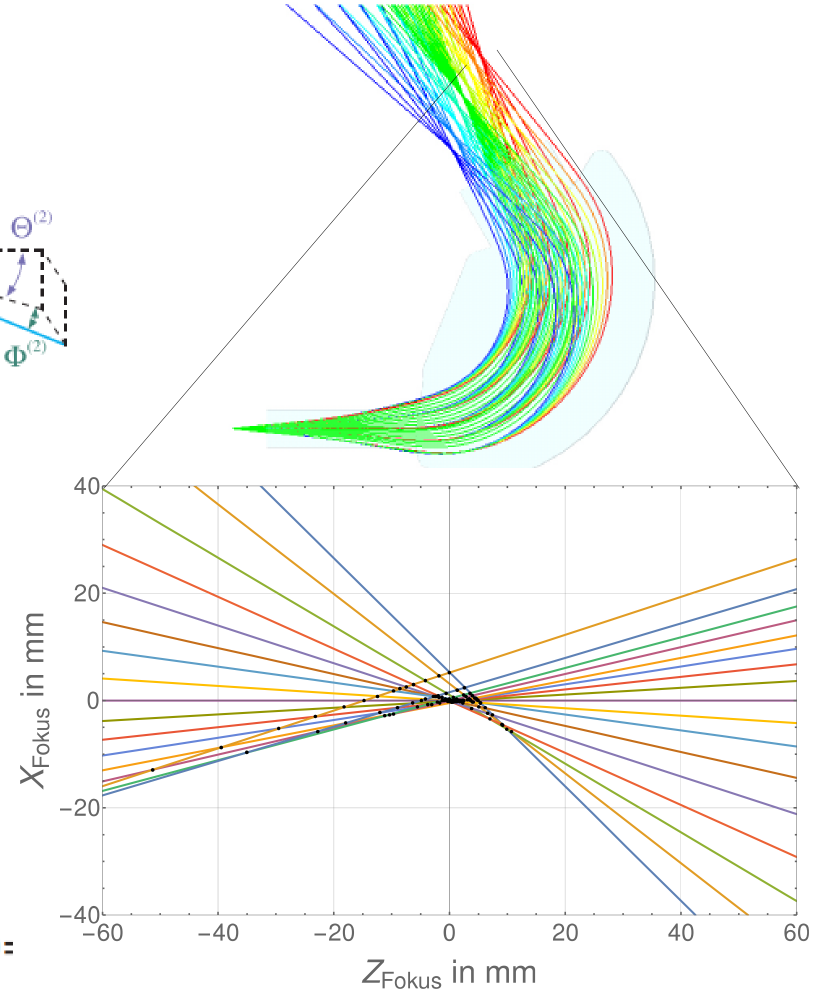
Ideal Spectrometer

(x/x) - magnification (x/δ) - dispersion $(x/\Theta)=0$, $(y/\Phi)=0$ - focus

Y. Kalmykov, LINAC Palaver Talk, TU Darmstadt, (2003), mod.

Analysis Example: Sieve Slit Measurement Particle Transport





$$x_2=(x/x)x_1+(x/\Theta)\Theta_1+(x/\delta)\delta+$$

$$+(x/x_2)x_1^2+(x/x\Theta)x_1\Theta_1+(x/\Theta^2)\Theta_1^2+(x/x\delta)x_1\delta+(x/\Theta\delta)\Theta_1\delta+$$

$$+(x/\delta^2)\delta^2+(x/y^2)y^2+(x/y\Phi)y_1\Phi_1+(x/\Phi^2)\Phi_1^2+$$

+*higher order terms*

(x/x) - magnification (x/δ) - dispersion $(x/\Theta)=0, (y/\Phi)=$

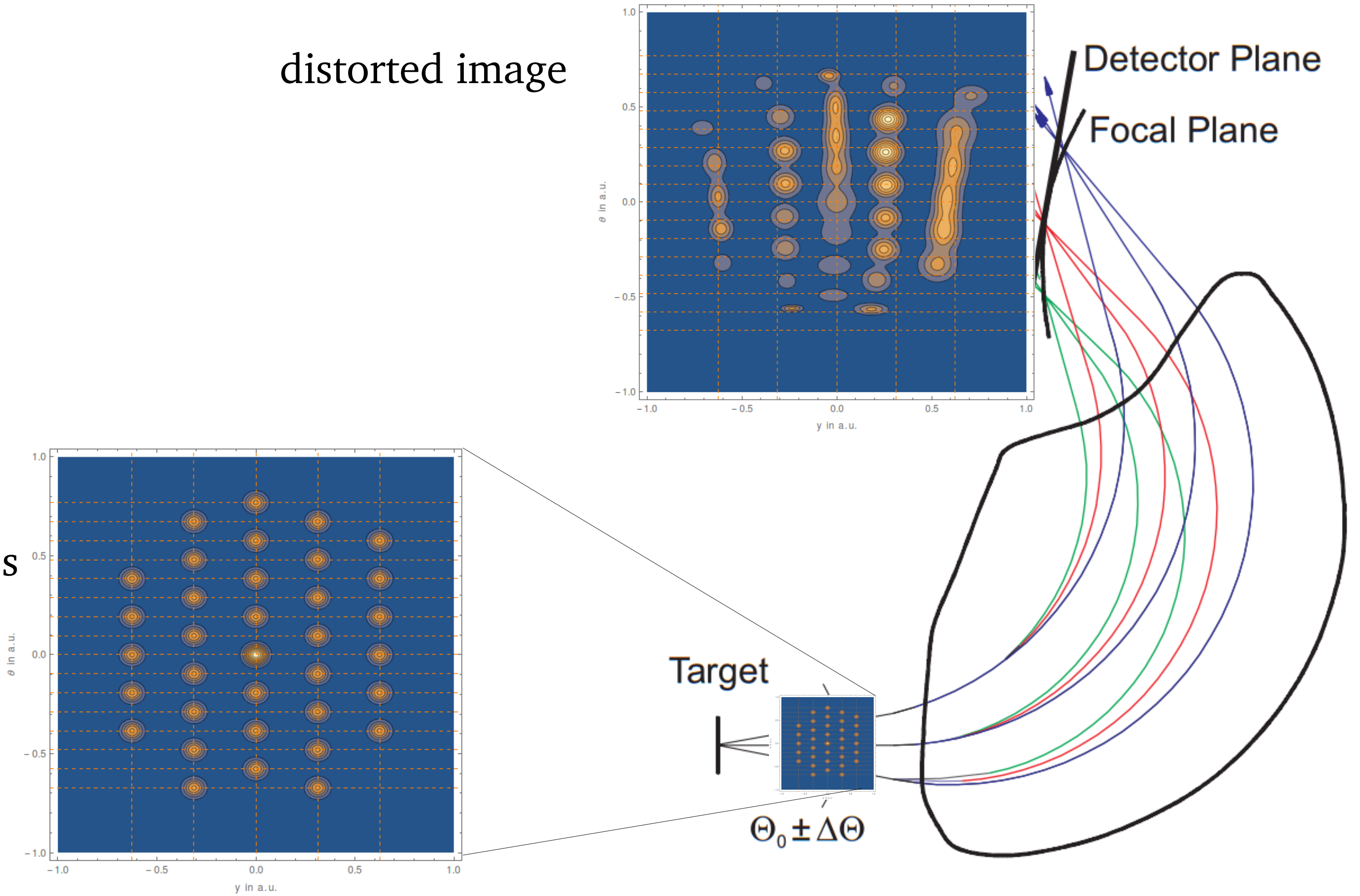
Y. Kalmykov, LINAC Palaver Talk, TU Darmstadt, (2003), mod.

G. Steinhilber, Master Thesis, TU Darmstadt, (2016)

Analysis Example: Sieve Slit Measurement

distorted image

2 cm of brass



Analysis Example: Sieve Slit Correction

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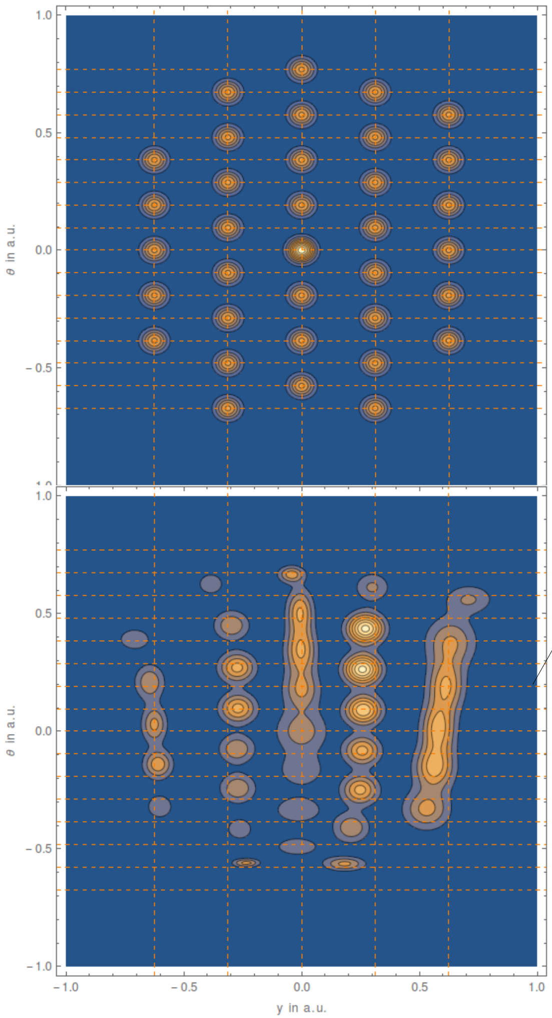
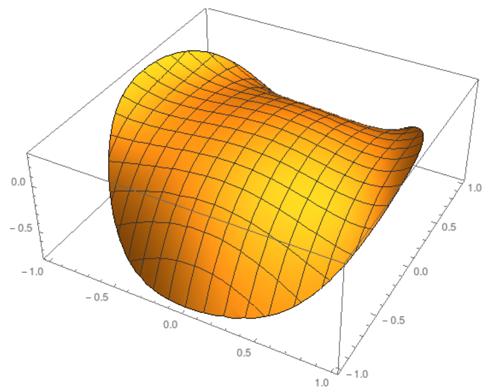
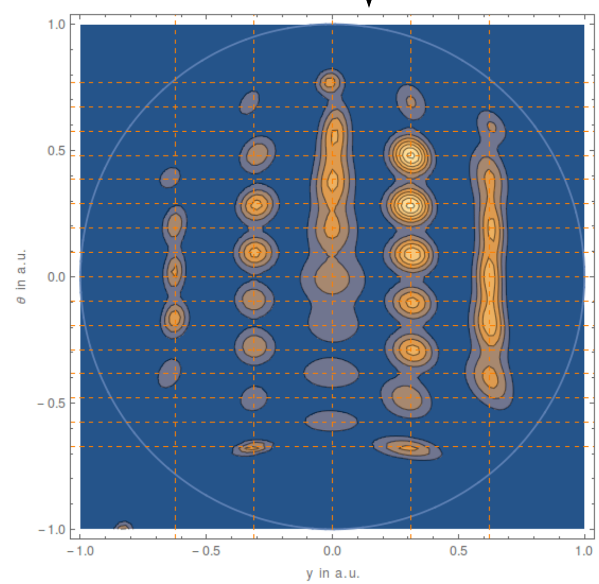


d/dθ
d/dy

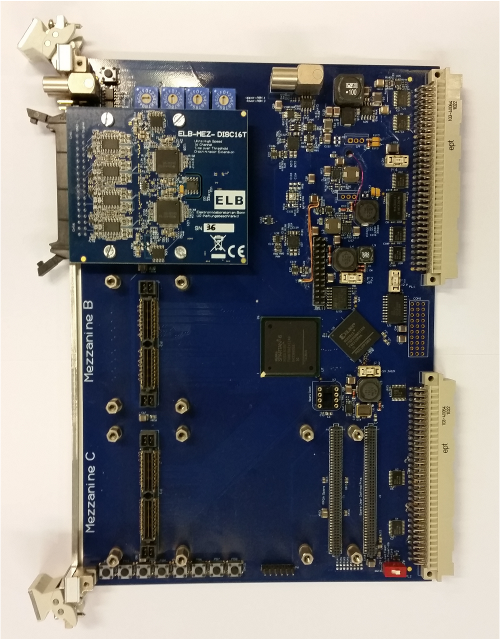




Uses derivation of a sum
of Zernike polynomials
(orthogonal on the unit disk)

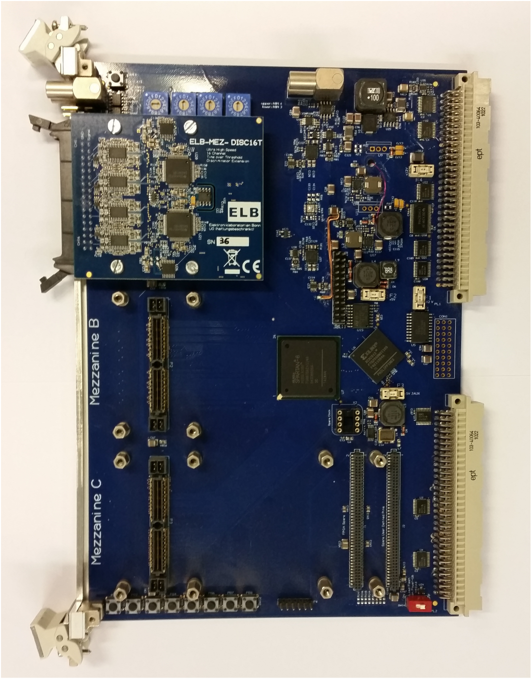
New DAQ Hardware

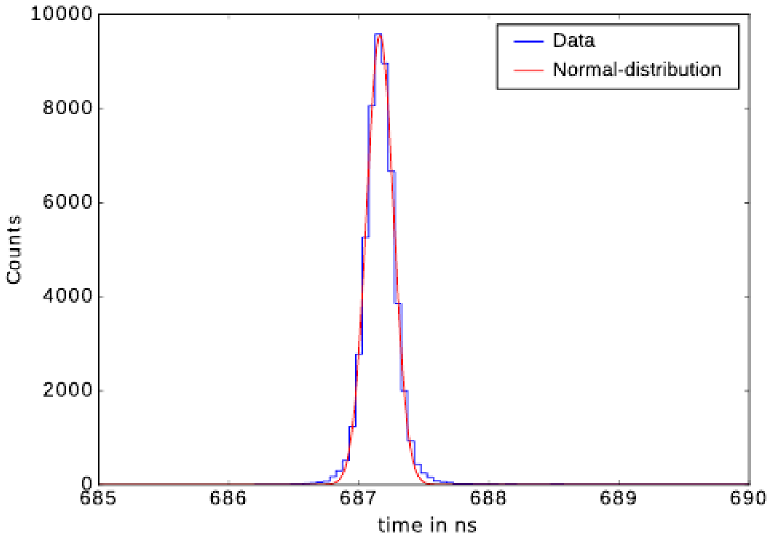
- VME standard based commercial available modules
- TDC resolution < 100 ps FWHM
- High channel density (48 per module)
- Leading Edge Discriminators on the TDC board
- Expandable for (e,e'x)-experiments
- CFD for the scintillator with time walk jitter < 50 ps



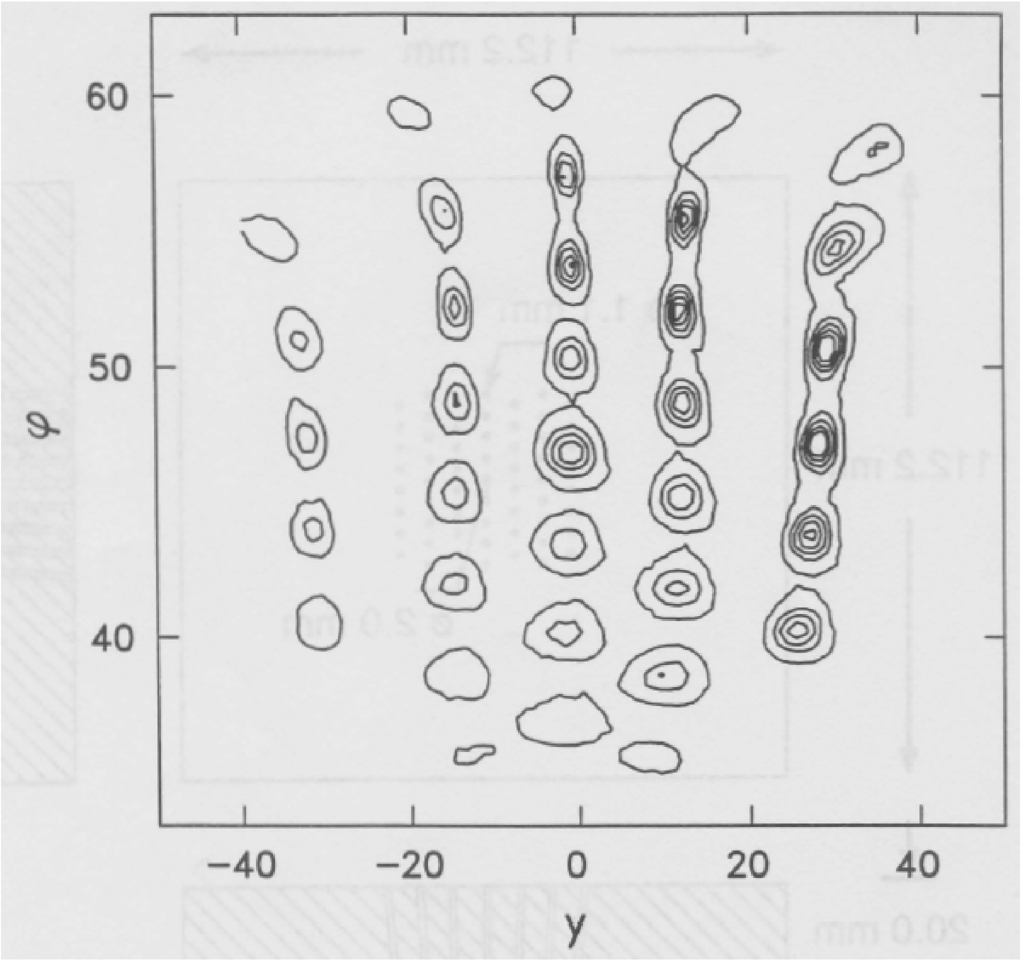
Main Harware Part:
Time to Digital Converter

- 56x ELB VFB6 VME TDC
- FWHM=100 ps time resolution (channel to channel and channel to trigger)
- 3x16 channels per board
- Each channel has a leading and falling edge discriminator (time-over-threshold)
- Open source FPGA source code



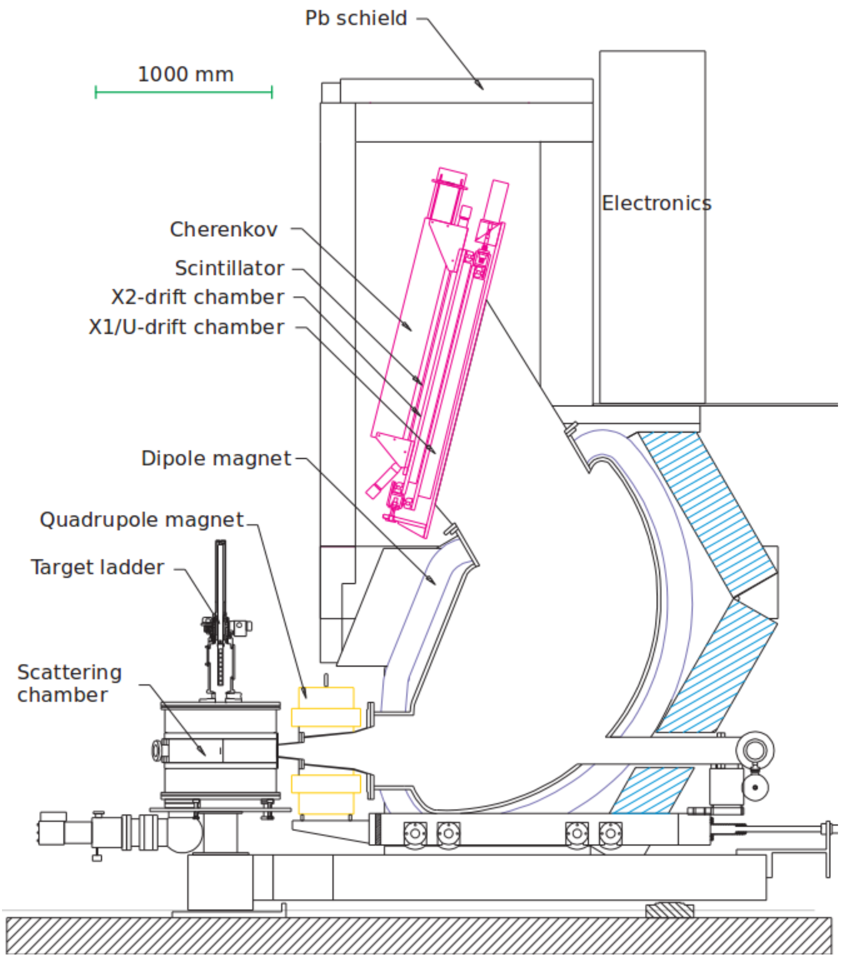


D'Alessio, A.: Master Thesis TU Darmstadt (2016), modified



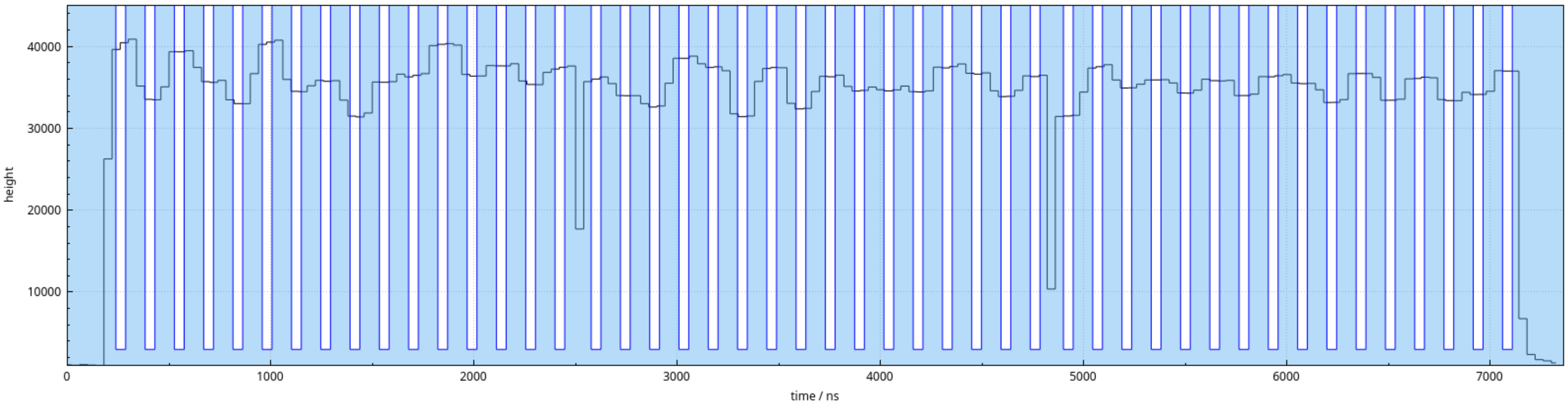
60
50
40
φ
−40
−20
0
20
40
y

QCLAM Characteristics

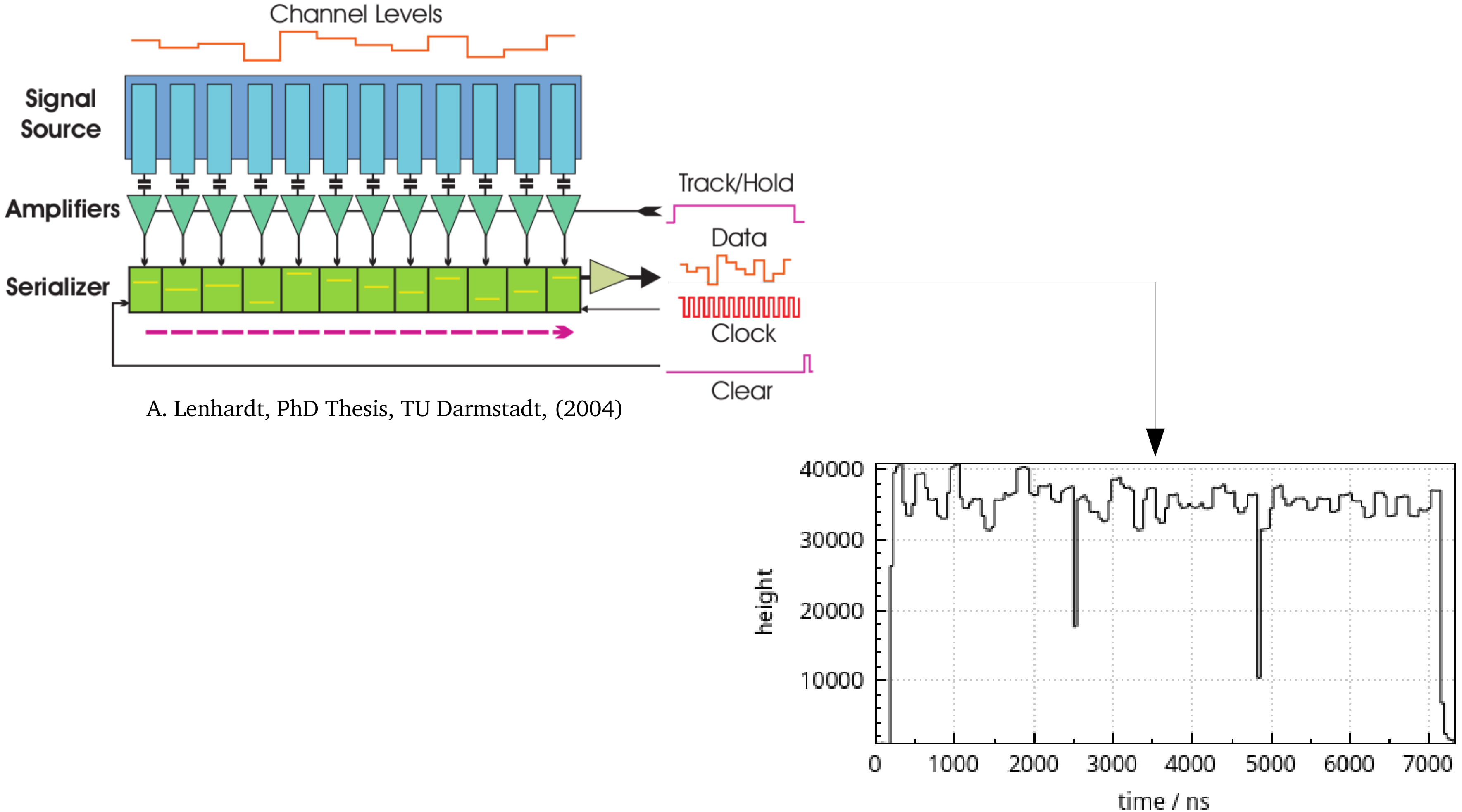


Y. Kalmykov, LINAC Palaver Talk, TU Darmstadt, (2003)

Lintott samples



Working Principle of the GASSIPLEX Chip



A. Lenhardt, PhD Thesis, TU Darmstadt, (2004)

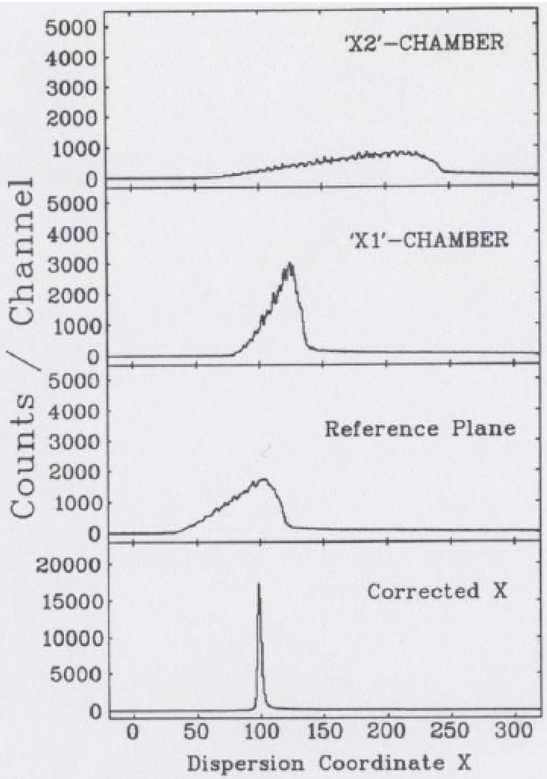
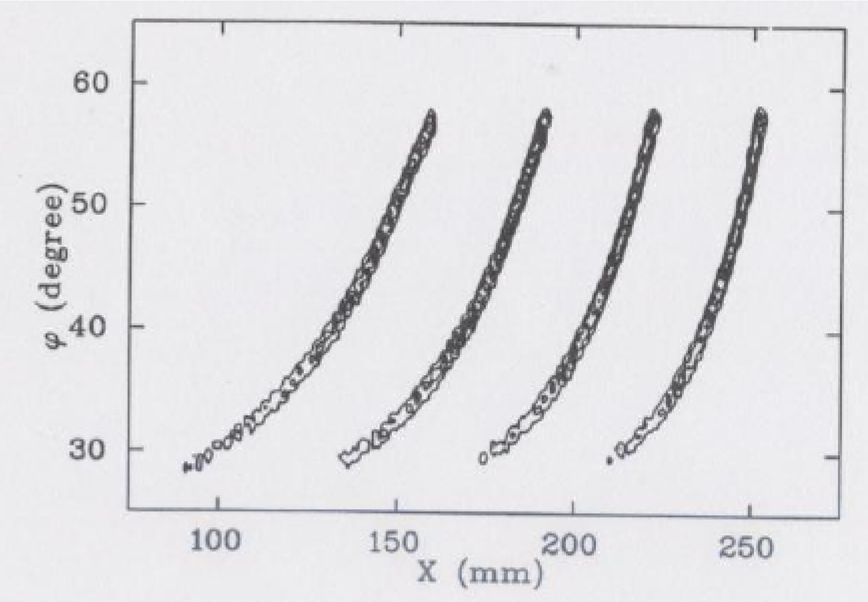


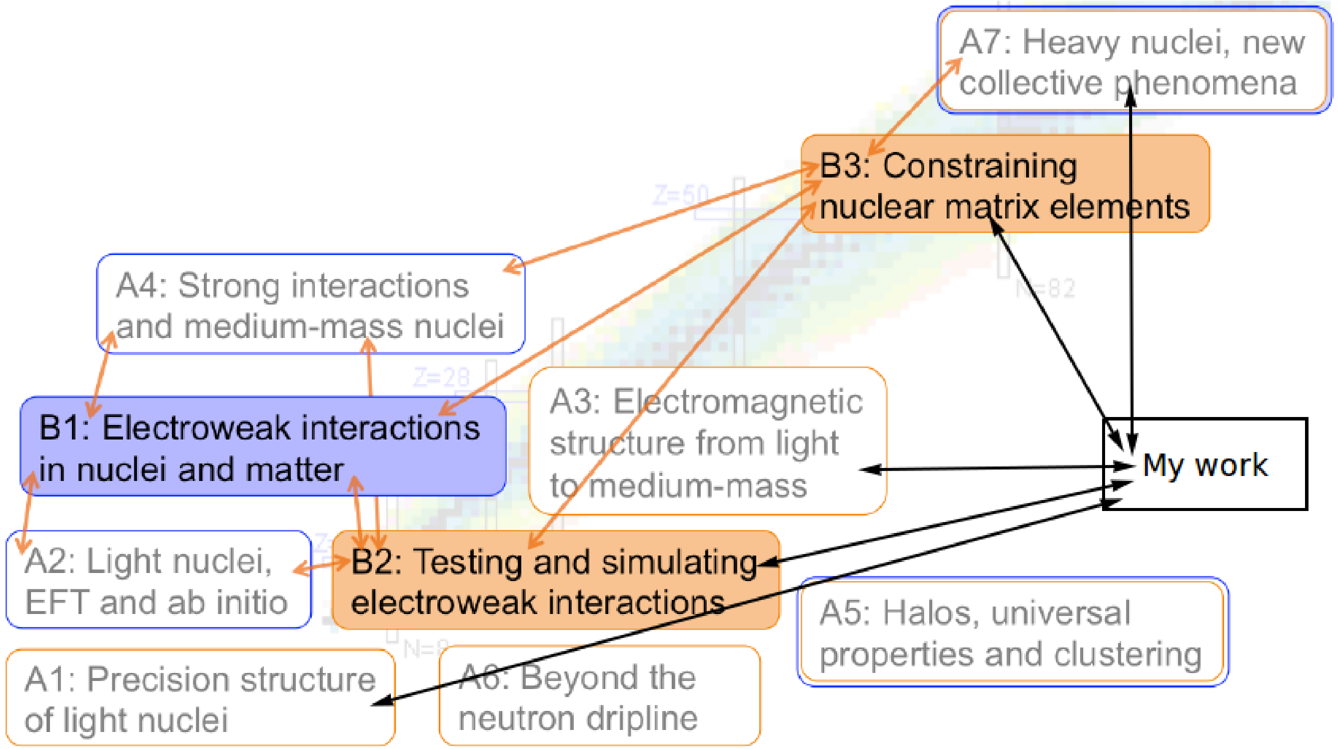
Abb. 6.4: Ermittlung der Dispersionskoordinate X. Die oberen drei Spektren sind Ortspektren von elastisch gestreuten Elektronen in den Nachweisebenen X2, X1 und der Detektor–Referenzebene. Das vierte Spektrum ist das Ergebnis des beschriebenen Verfahrens zur Entkopplung des Ortes x vom Dispersionswinkel.



K. D. Hummel, Dissertation, TU Darmstadt, (1992)

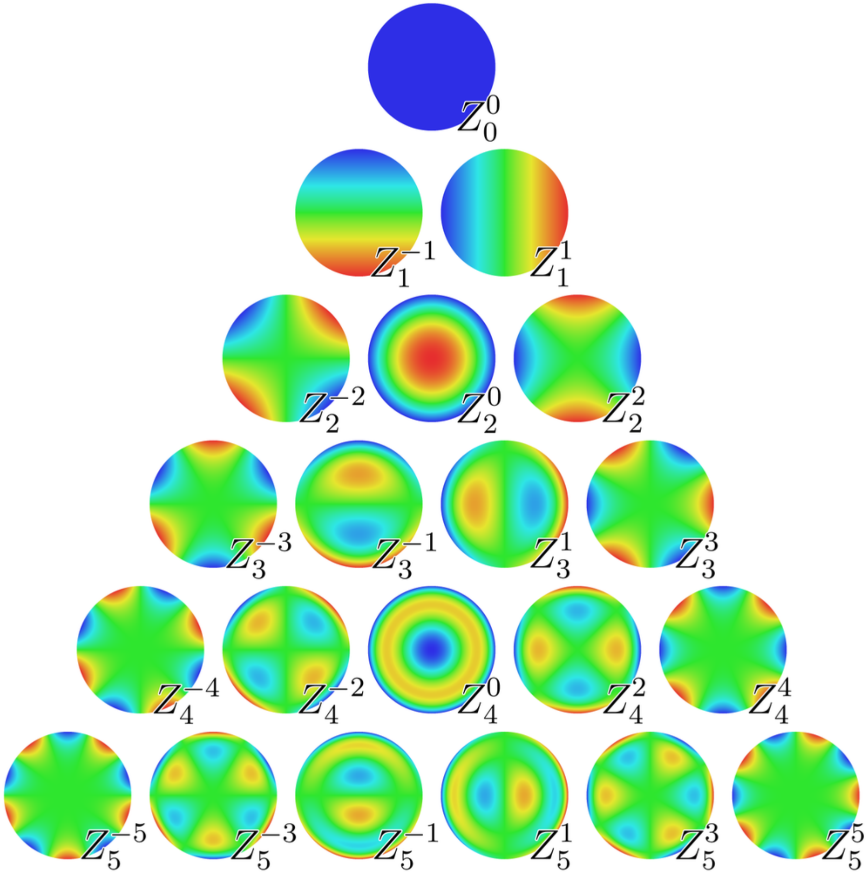
Projects B01 - B03
Connections and Synergies

The availability of high-quality electron beams in conjunction with the high-resolution **LINTOTT** spectrograph and the large-acceptance **QCLAM** spectrograph is unique to this facility at the TU Darmstadt. They will be used in projects **A01**, **A03**, **B02**, and **B03** for measuring elastic and excitation cross sections, and in **A07** for measuring γ-ray transitions from electroexcited nuclear states.



CRC 1245 Proposal, mod.

Zernike polynomials



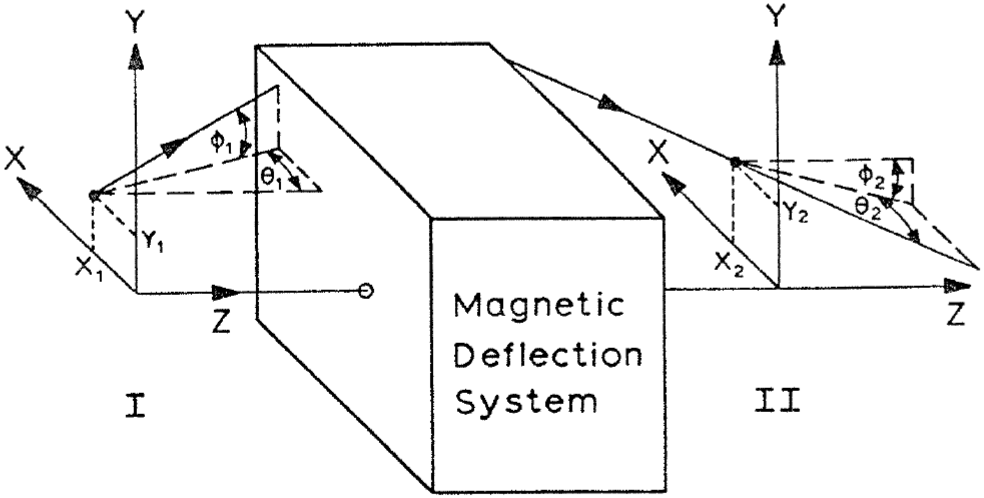


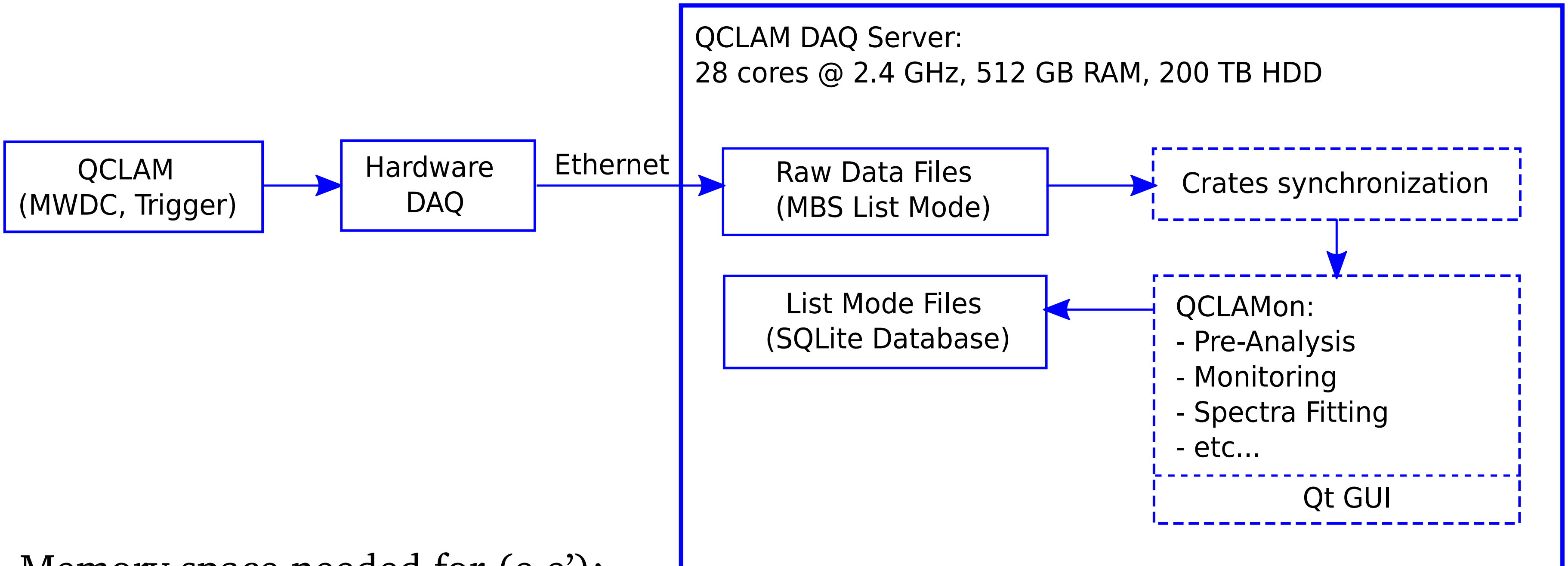
Abb. 2.2: Startkoordinatensystem I und Zielkoordinatensystem II eines magnetischen Ablenksystems.

$$X_i^{(2)} = \sum_{j=1}^{6} R_{ij} X_j^{(1)} \quad ,$$

$$R_{ij} = \begin{pmatrix} (X|X) & (X|\Theta) & 0 & 0 & 0 & (X|\delta) \\ (\Theta|X) & (\Theta|\Theta) & 0 & 0 & 0 & (\Theta|\delta) \\ 0 & 0 & (Y|Y) & (Y|\Phi) & 0 & 0 \\ 0 & 0 & (\Phi|Y) & (\Phi|\Phi) & 0 & 0 \\ (\ell|X) & (\ell|\Theta) & 0 & 0 & 1 & (\ell|\delta) \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

$$X_i^{(2)} = \sum_{j=1}^{6} R_{ij} X_j^{(1)} + \sum_{j=1}^{6} \sum_{k=j}^{6} T_{ijk} X_j^{(1)} X_k^{(1)} \quad .$$

(e,e')-DAQ Software



- Memory space needed for (e,e'):
  4.5 MB/s • 3 Crates =
  - 1 hour: ~50 GB
  - 1 week: ~8 TB
  - CRC 1245 campaigns: ~200 TB
- For (e,e'γ) @ (15 det., 15 kHz):
  ~5 TB per week

- Should we back up MBS raw data files or SQL list mode files?
  → same size
  → same information
  → no readout hardware knowledge needed
  → SQL is an ISO standard