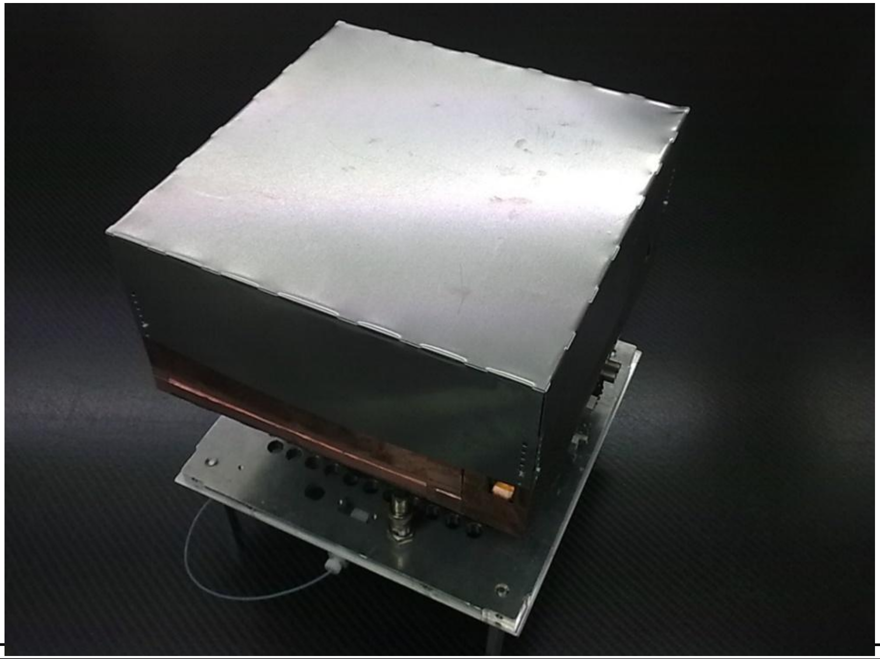
Neutron Detection with CASCADE



The synthesis of

GEMs and Solid State Converters

Bundesministerium für Bildung und Forschung

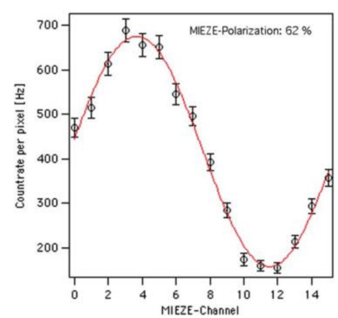
Markus Köhli

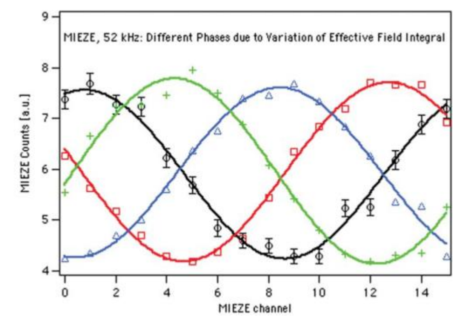
PI/ANP

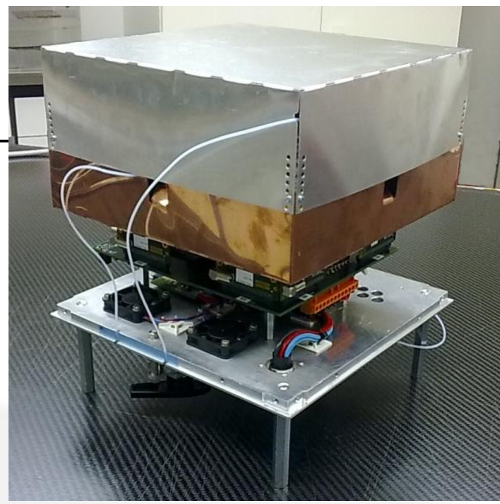
Universität Heidelberg

Contents

Conduct

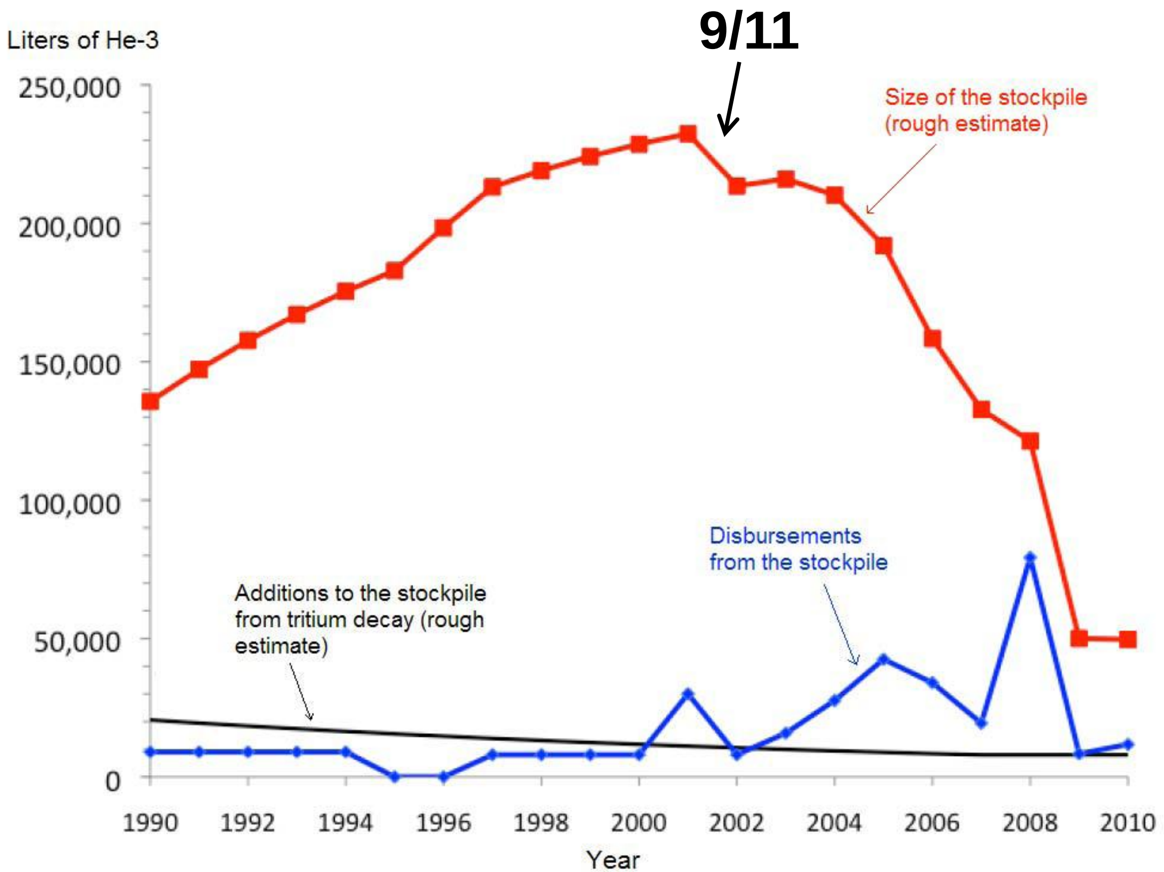






Construct

The Helium-3 crisis



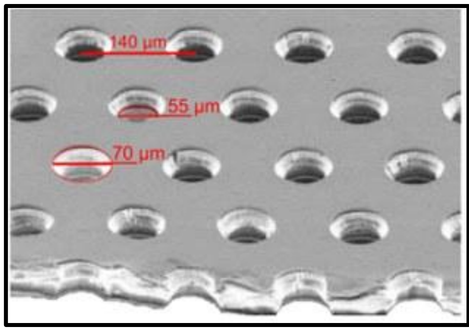
Costs:
2000-3000 €/L
…If you can get it

Size of the Helium-3 Stockpile, 1990-2010 [1]

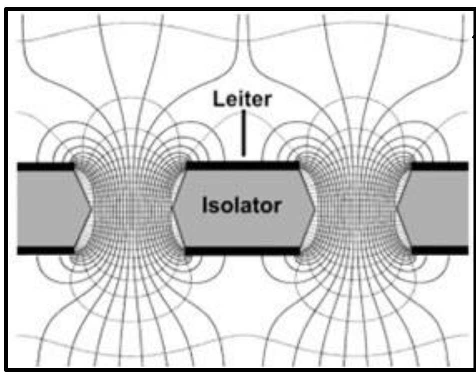
[1] AAAS, Overview of Helium-3 Supply and Demand

Basic concept

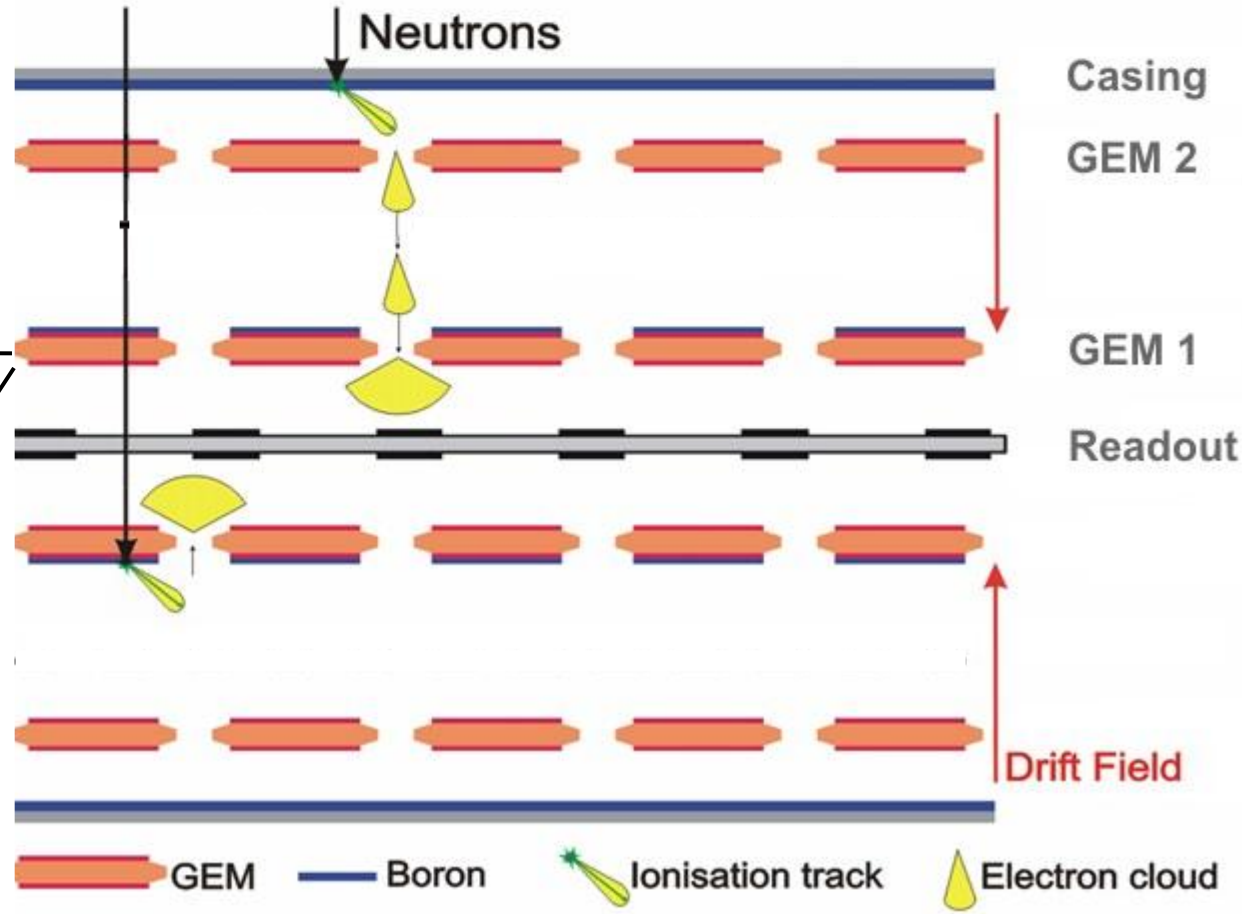
Cross section: active detection volume



[1]

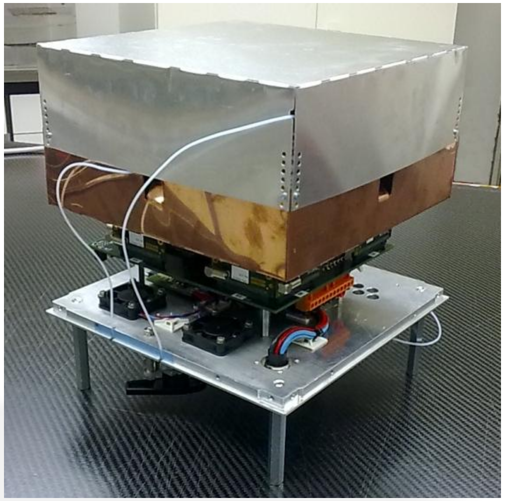


[1]



[1] Sauli, F. ; Sharma, A.: *Micropattern Gaseous Detectors*. In: Annual Review of Nuclear and Particle Science 49 (1999)

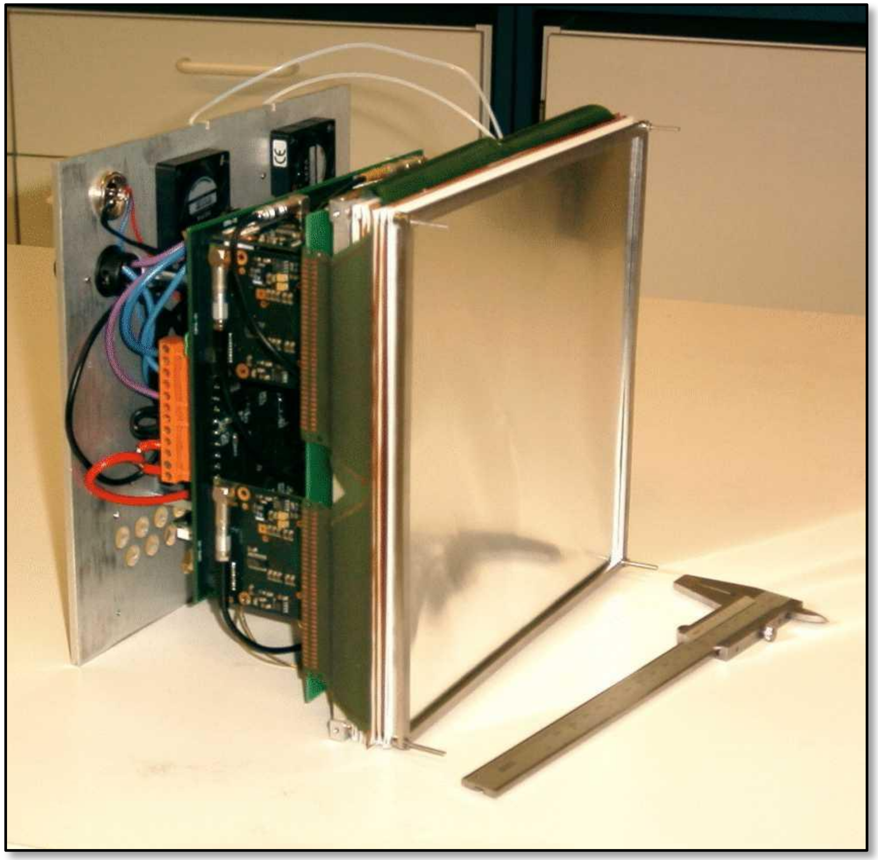
>_ About:



Construct

CASCADE – an overview

CASCADE detector without housing



200mm x 200mm

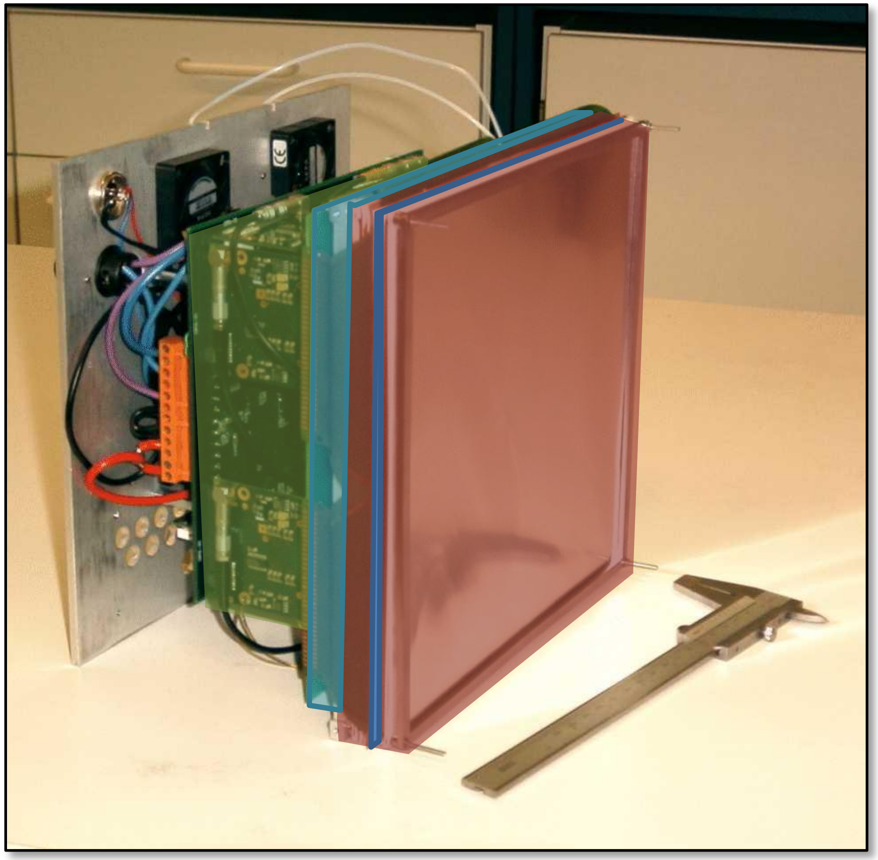
CASCADE – an overview

Active Detection Volume

Readout

Electronics

CASCADE detector without housing



CASCADE – an overview

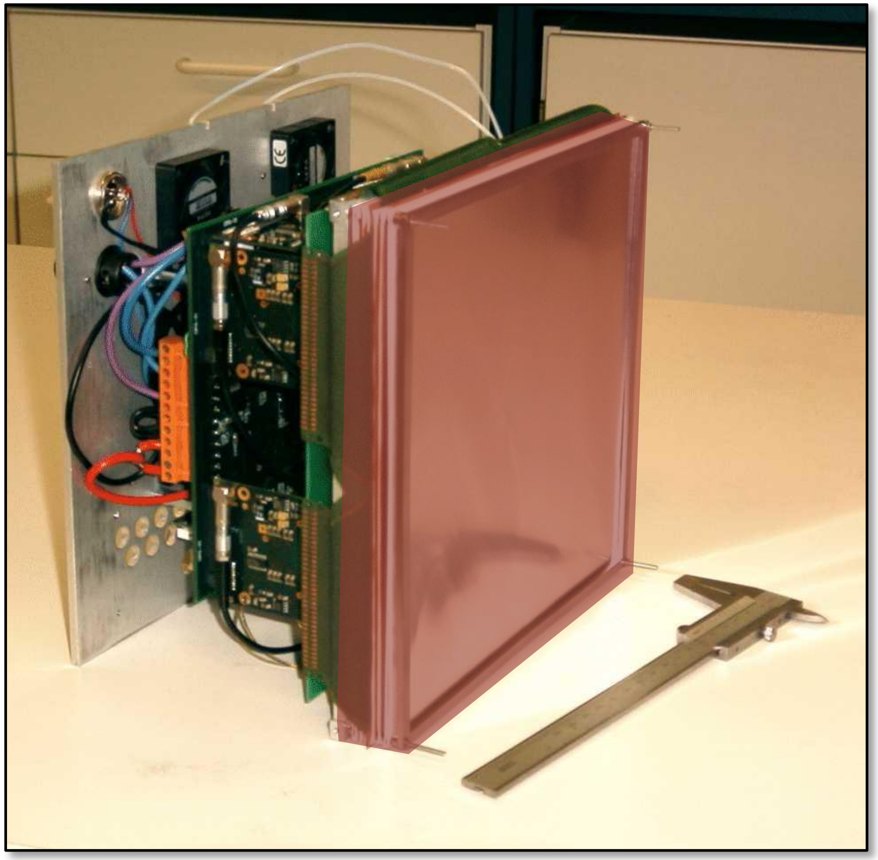
Active Detection Volume

- Neutron conversion in Boron-10

$^{10}B + n \rightarrow {}^{7}Li + \alpha + 2.79\ MeV$ (6%)
$\phantom{^{10}B + n \rightarrow} {}^{7}Li^{*} + \alpha + 2.31\ MeV$ (94%)

- Charge amplification with GEMs in standard gas

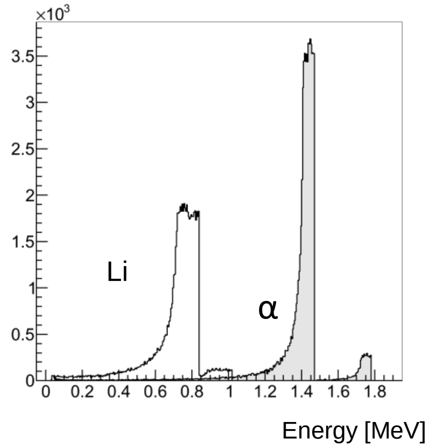
CASCADE detector without housing

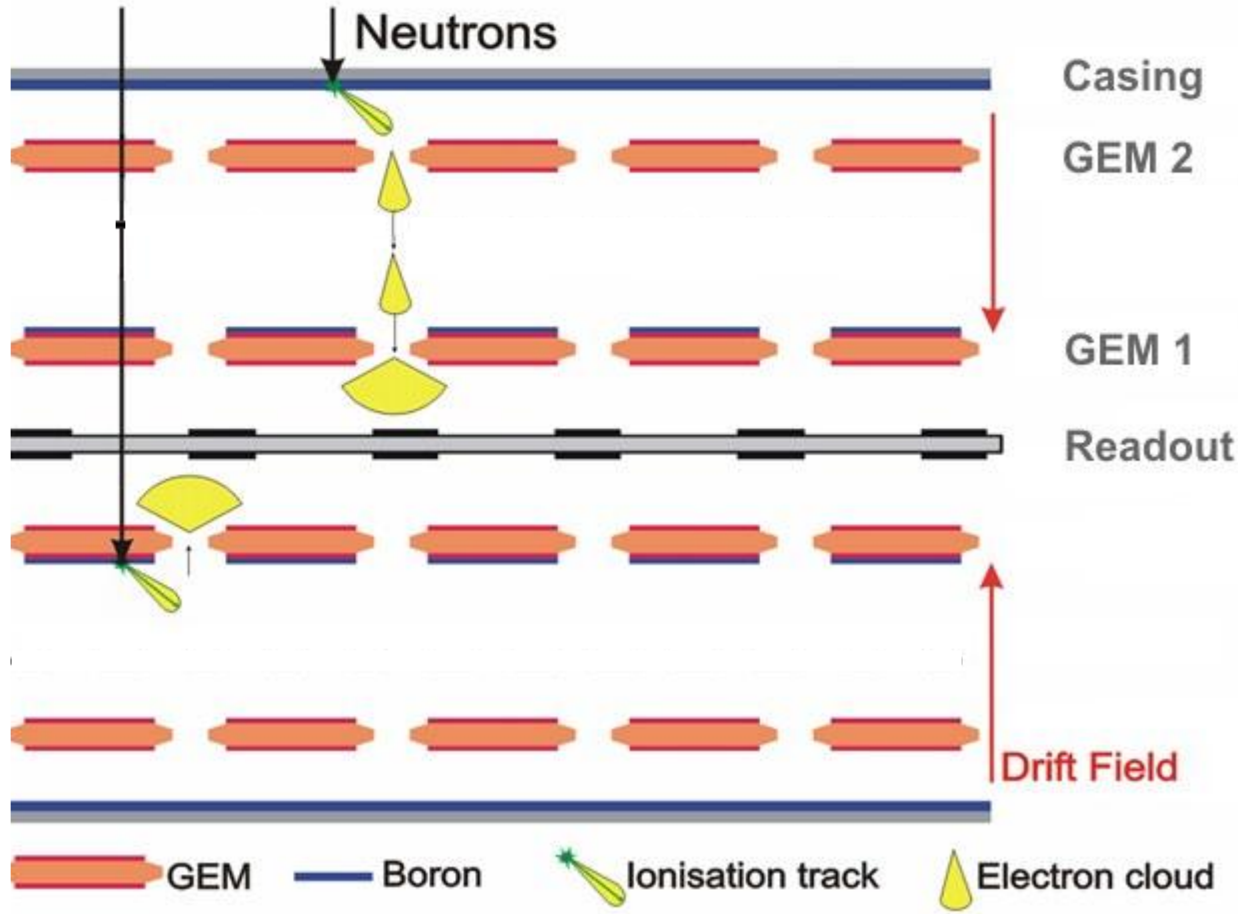


Howto: Neutron Detection

Cross section: active detection volume

Energy of the particles **(thin layer)**





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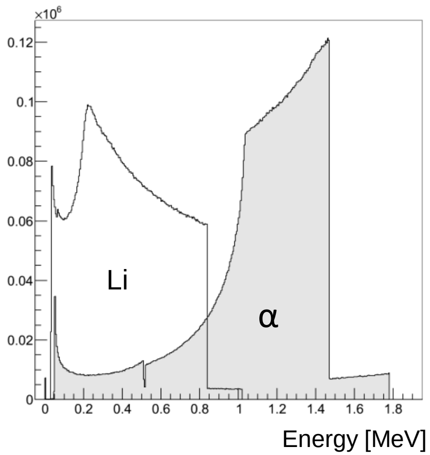
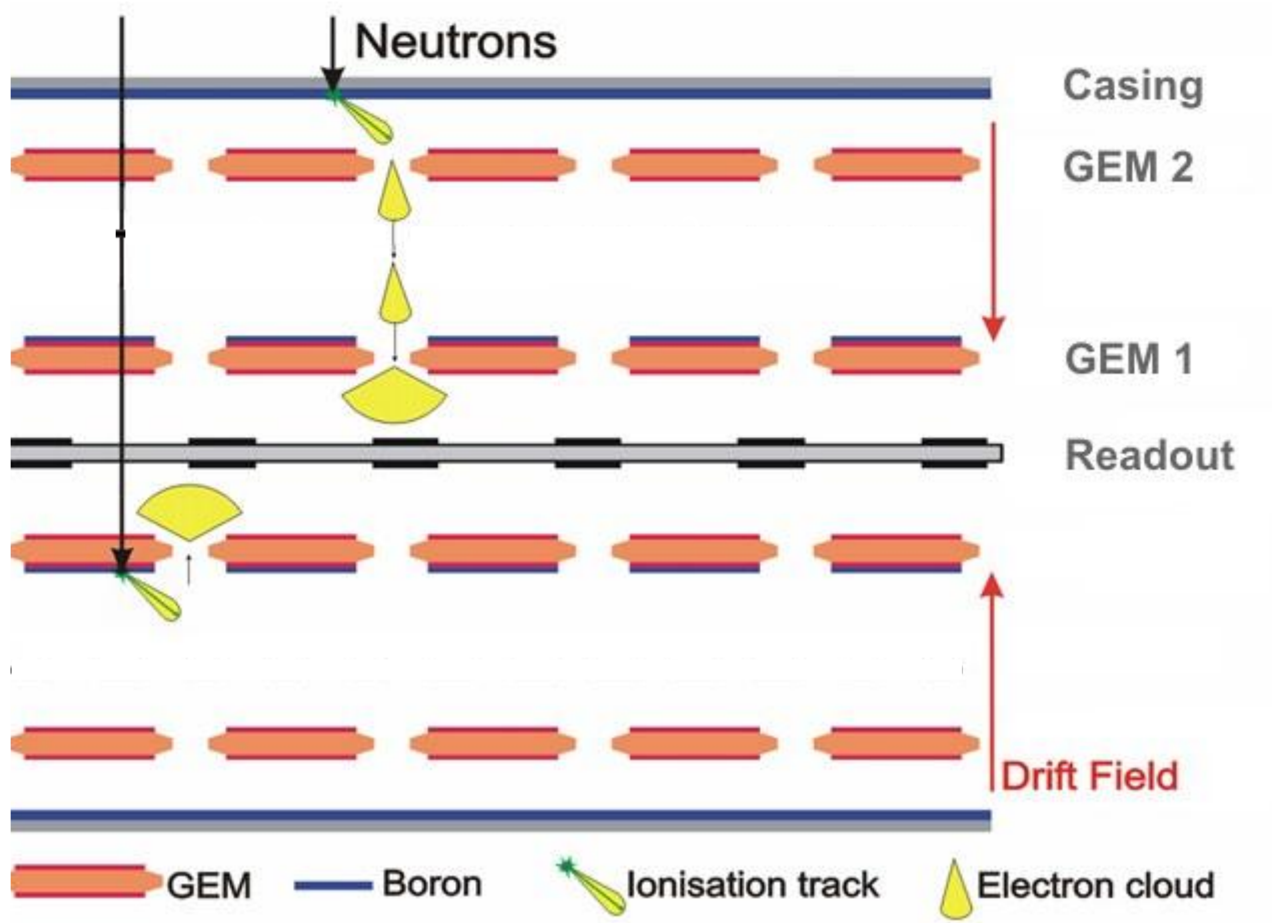
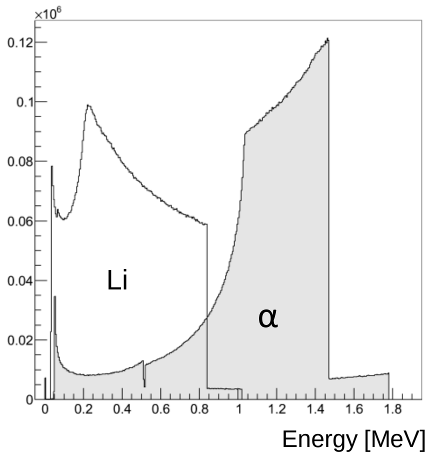




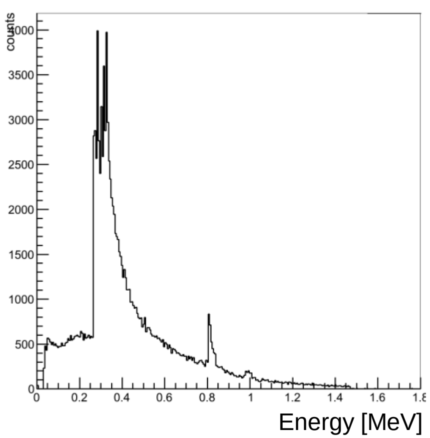
Howto: Neutron Detection

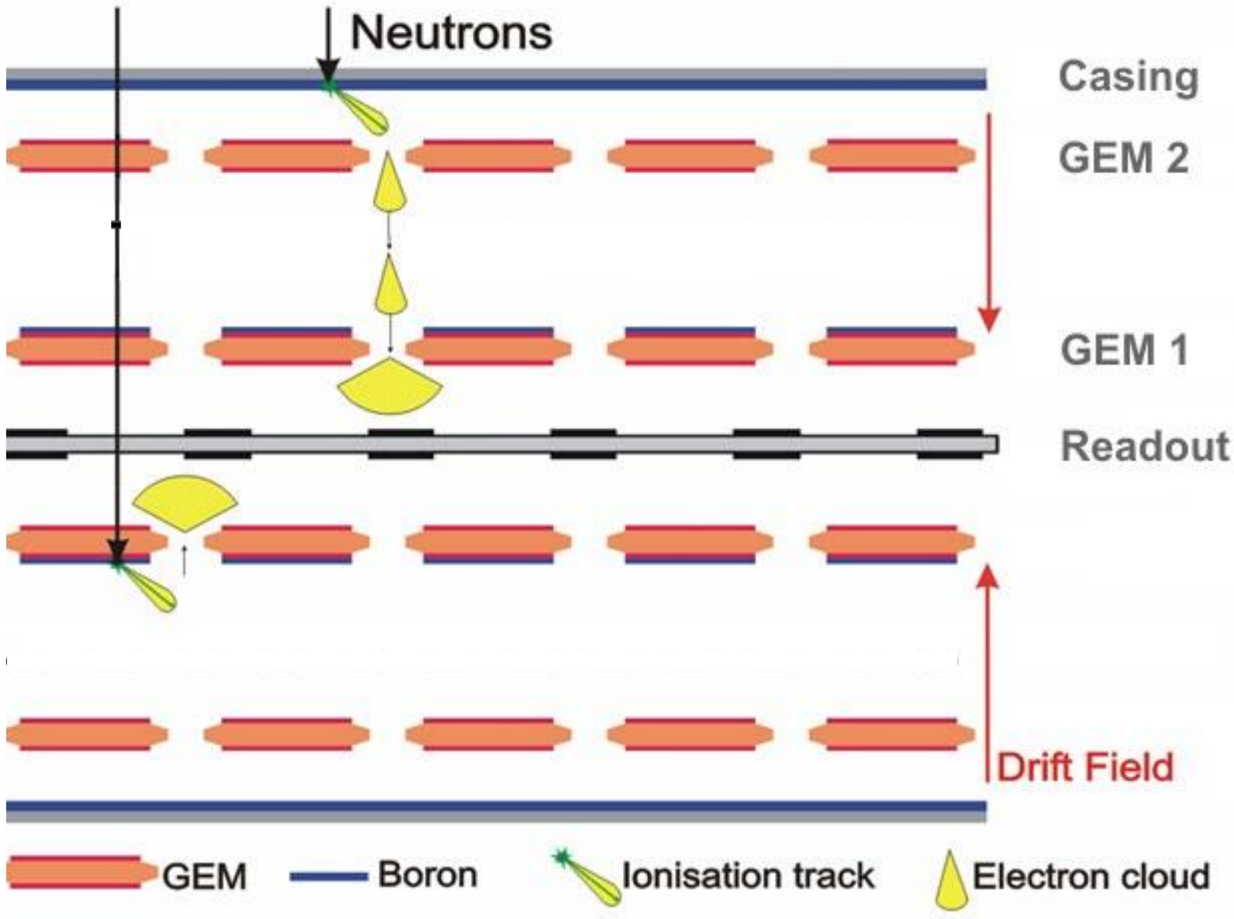
Cross section: active detection volume

Energy of the particles (thick layer)



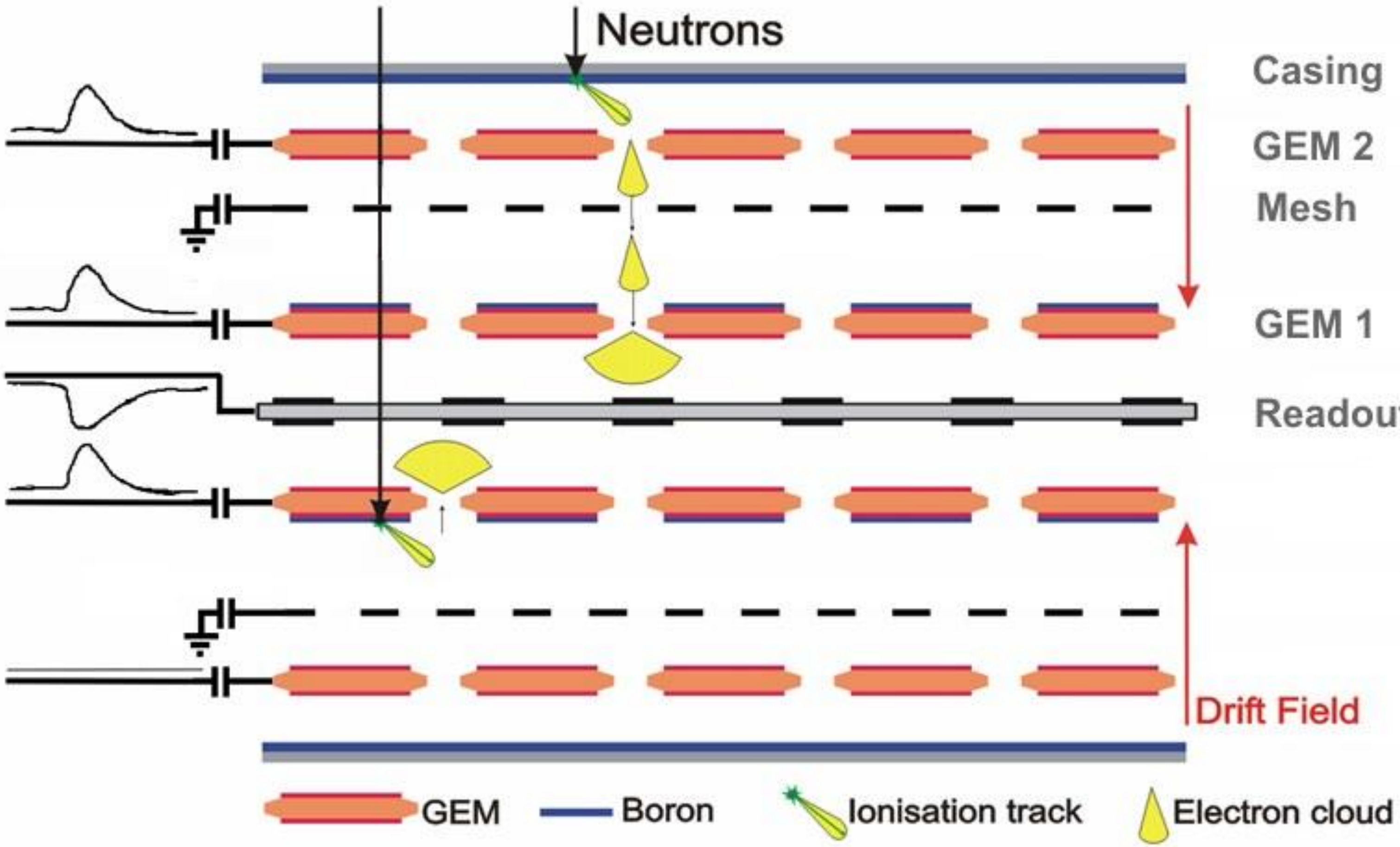
Deposited energy (in detector gas)





Howto: Neutron Detection

Cross section: active detection volume



CASCADE – an overview

Active Detection Volume

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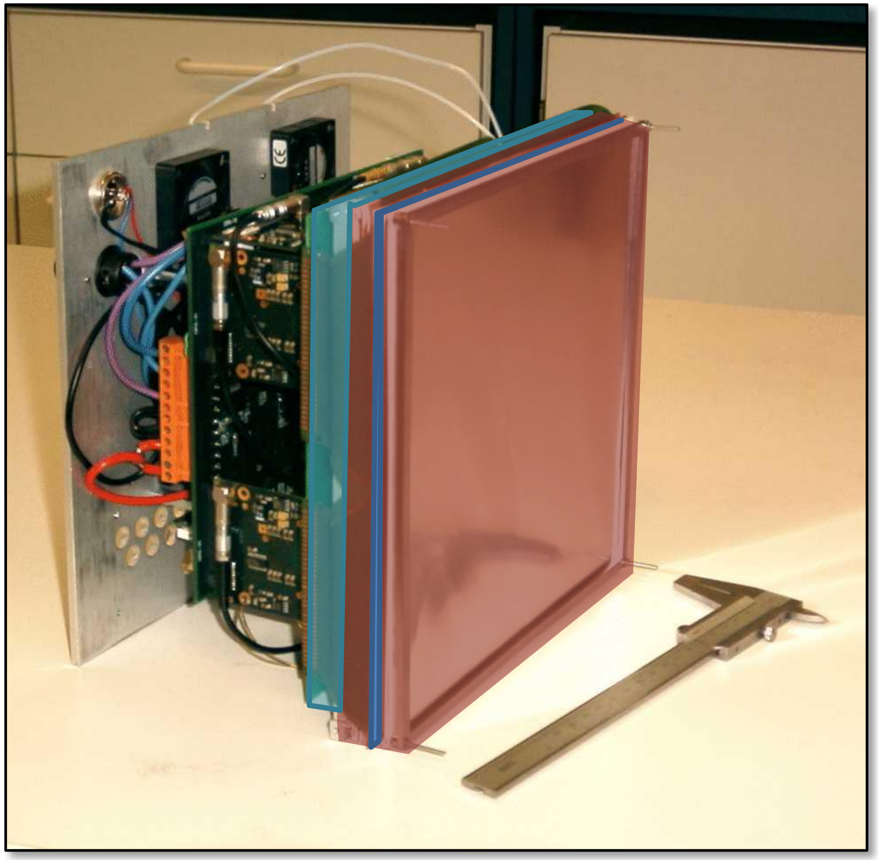
- Charge amplification with GEMs in standard gas

Readout

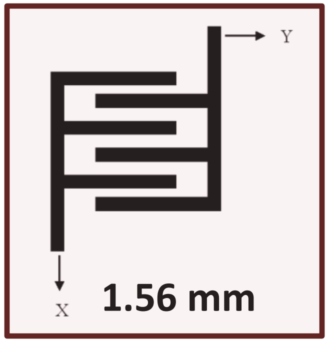
- readout stripes: 128 x | 128 y @ 1.56mm
- double sided

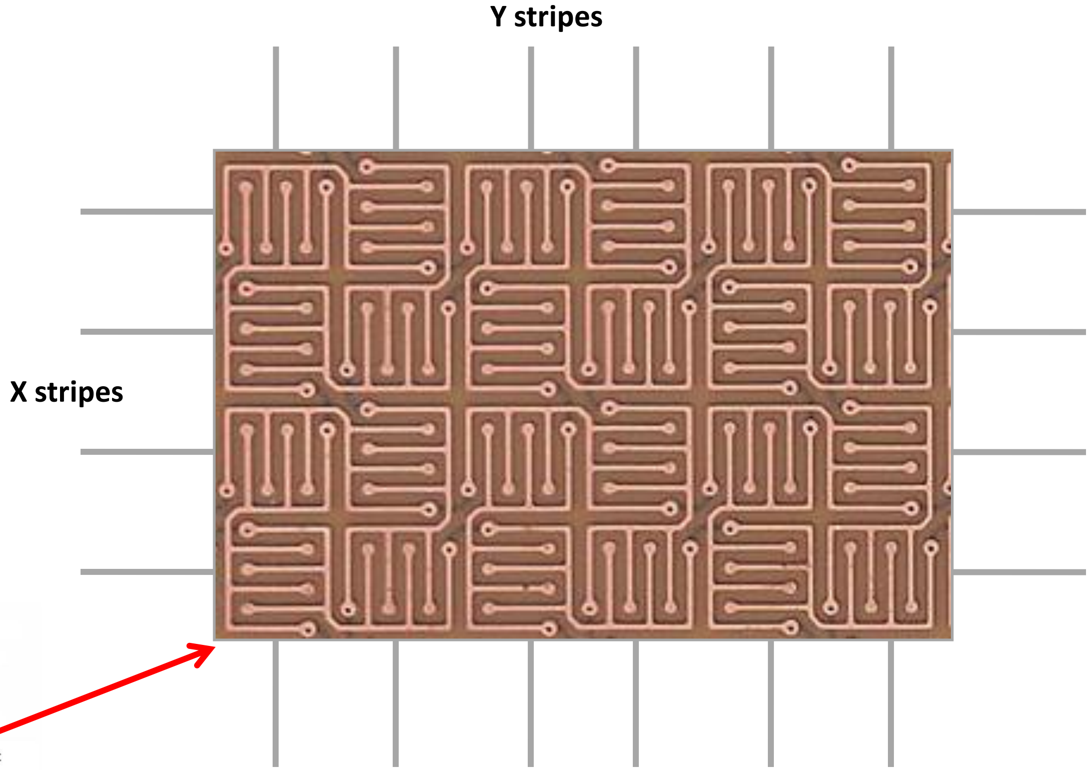
CASCADE detector without housing

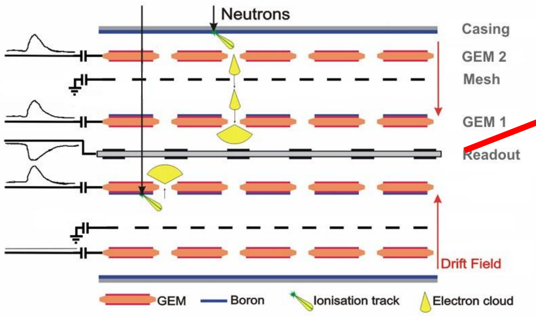


XY Readout

Unit Cell:







CASCADE – an overview

Active Detection Volume

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- Charge amplification with GEMs in standard gas

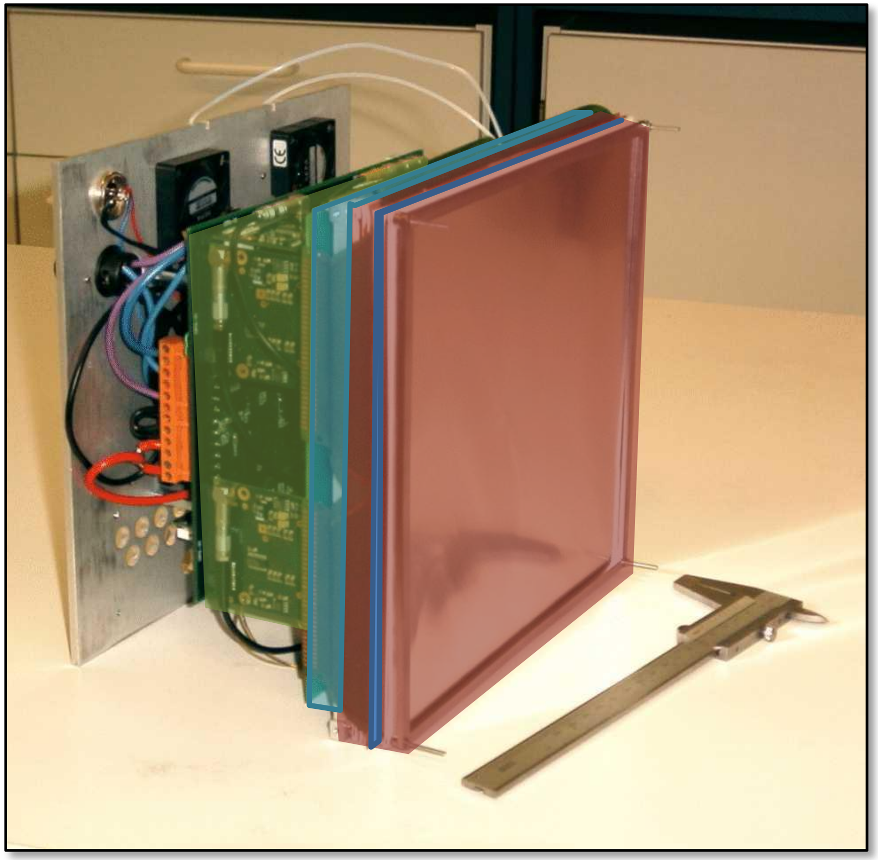
Readout

- readout stripes: 128 x | 128 y @ 1.56mm
- double sided

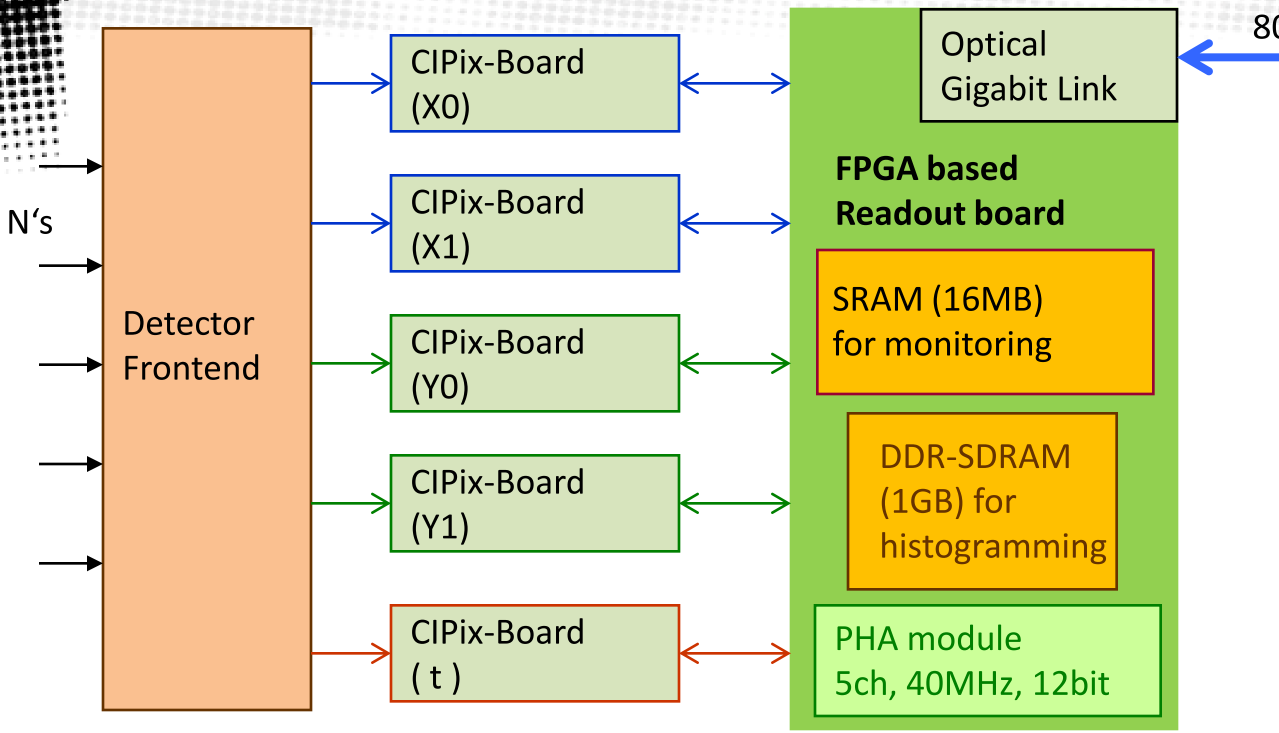
Electronics

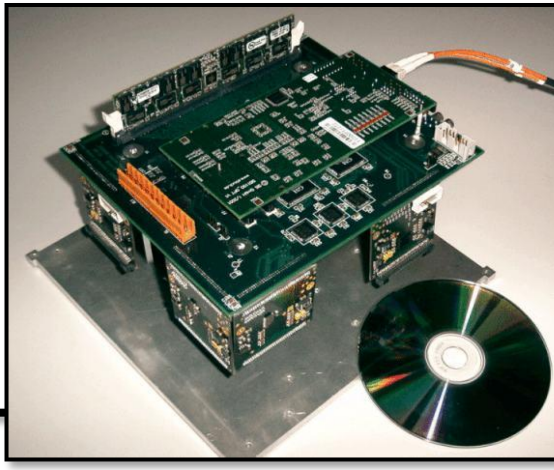
- A/D: CiPix –Chip (ASIC) with 10 MHz
- FPGA based data preprocessing
  - o histogram (on the fly)
- Optical GBit Interface

CASCADE detector without housing



Readout electronics





Specs:

- **4 CIPix ASICs reading 128x128 channels**
- **1 CIPix ASIC for TOF-resolution down to 100ns**

Next: Replaced by nXYter

- **FPGA (Virtex 2) based readout, control of CIPix, data-preprocessing and compression**

Next: Replaced by Spartan 6

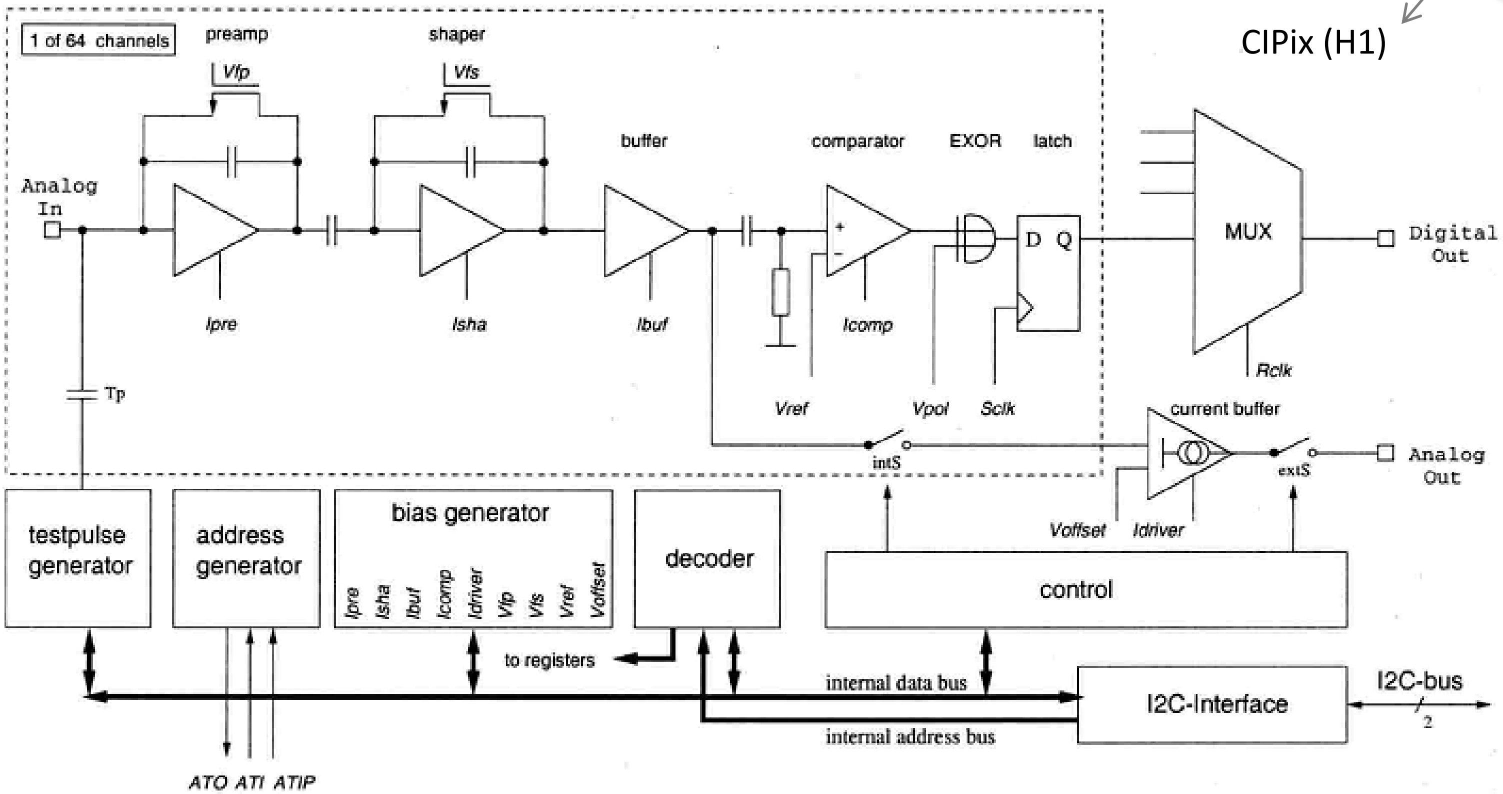
- **electrically decoupled from host computer**

The CIPIX ASIC

CIPix Schematic [1]

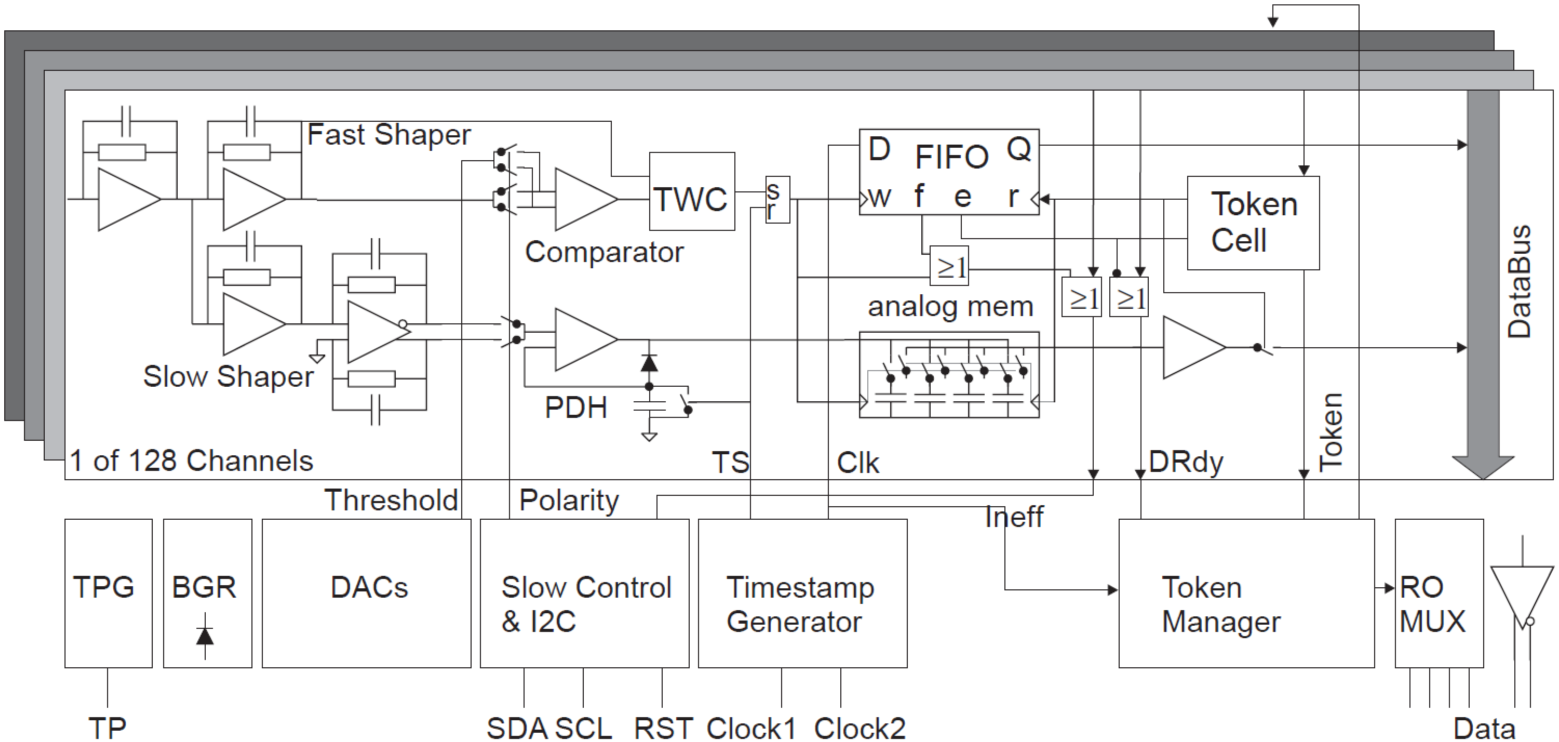
Timeline

- FElix chip (RD20, LHC) 1993
- HELIX 1.0
- HELIX 32 1998
- HELIX128-2.2 (HERA-B)
- HELIX128-3.0 (Zeus)
- BEETLE (LHCb)
- CIPix (H1)



The nXYter ASIC

nXYter Schematic



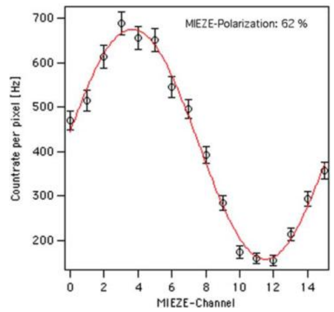
[1]

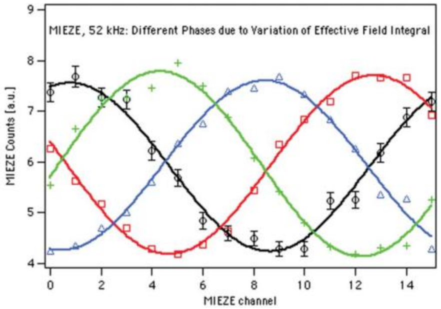
[1] The n-XYTER Reference Manual 1.50, 2009

>_ About:

Conduct

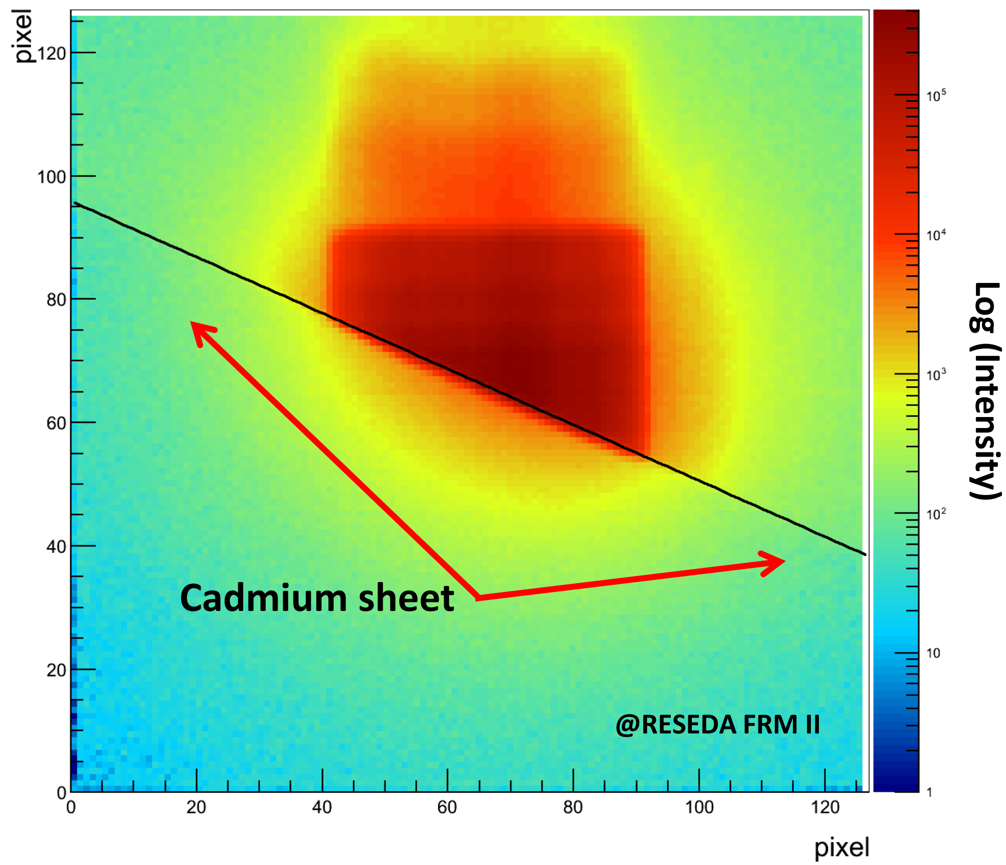
- 2D ‚imaging‘
- rate capability
- efficiency
- GEM gain
- Spin Echo





CASCADE – Imaging

Image of a thermal neutron beam (after guide)

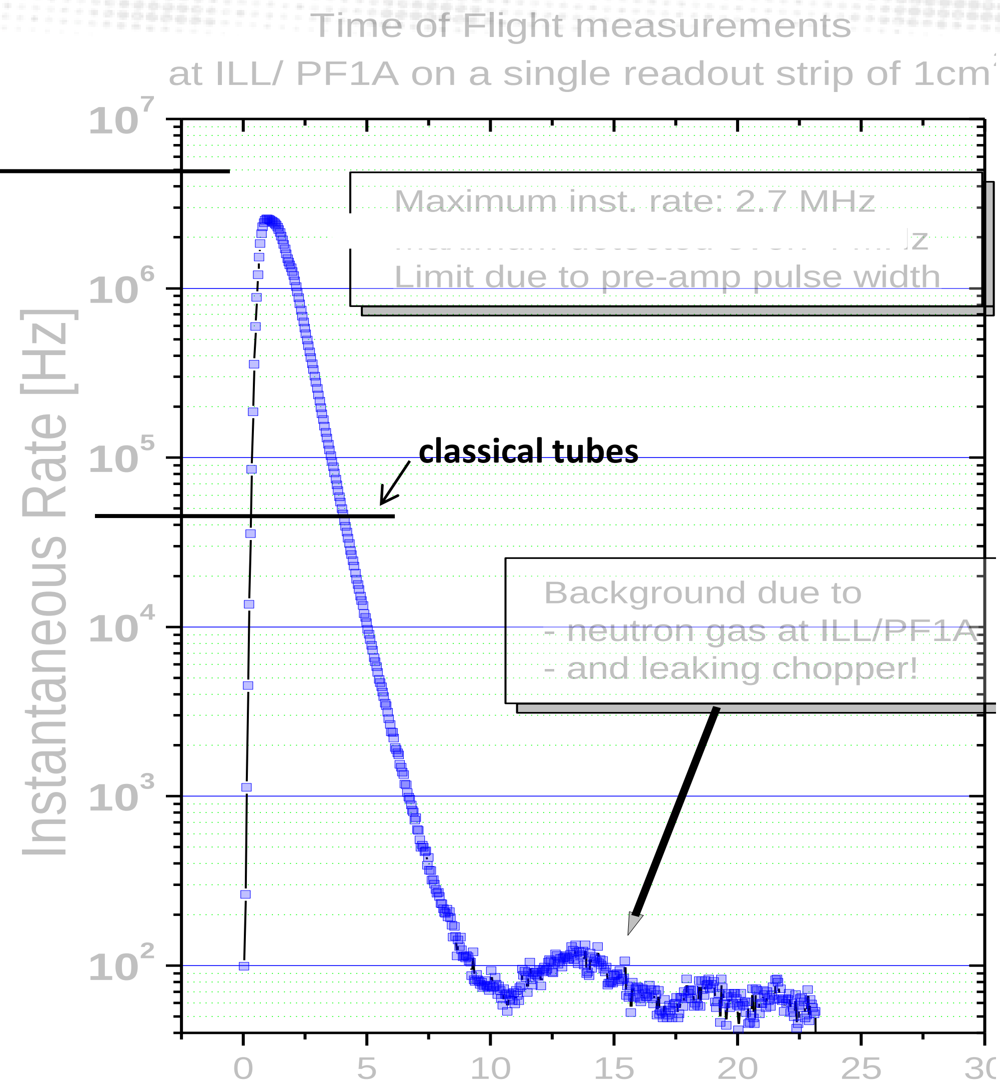


Spatial resolution: 2.4 mm

CASCADE – rate capability

Count rate

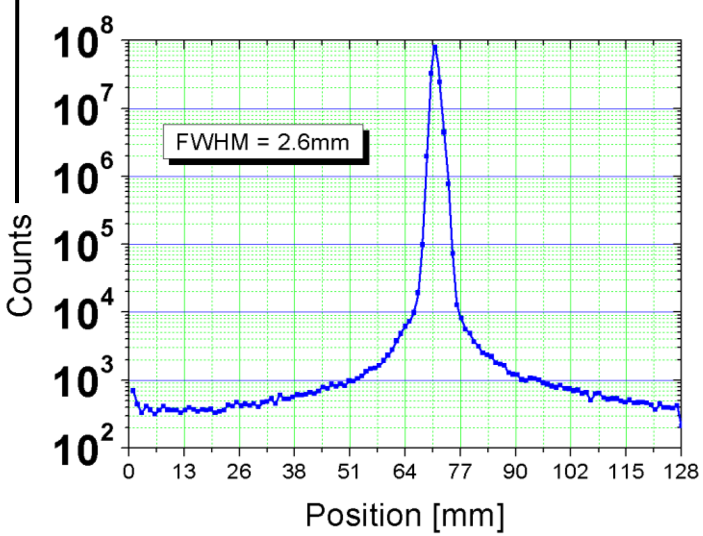
> 1 MHz



CASCADE – rate capability

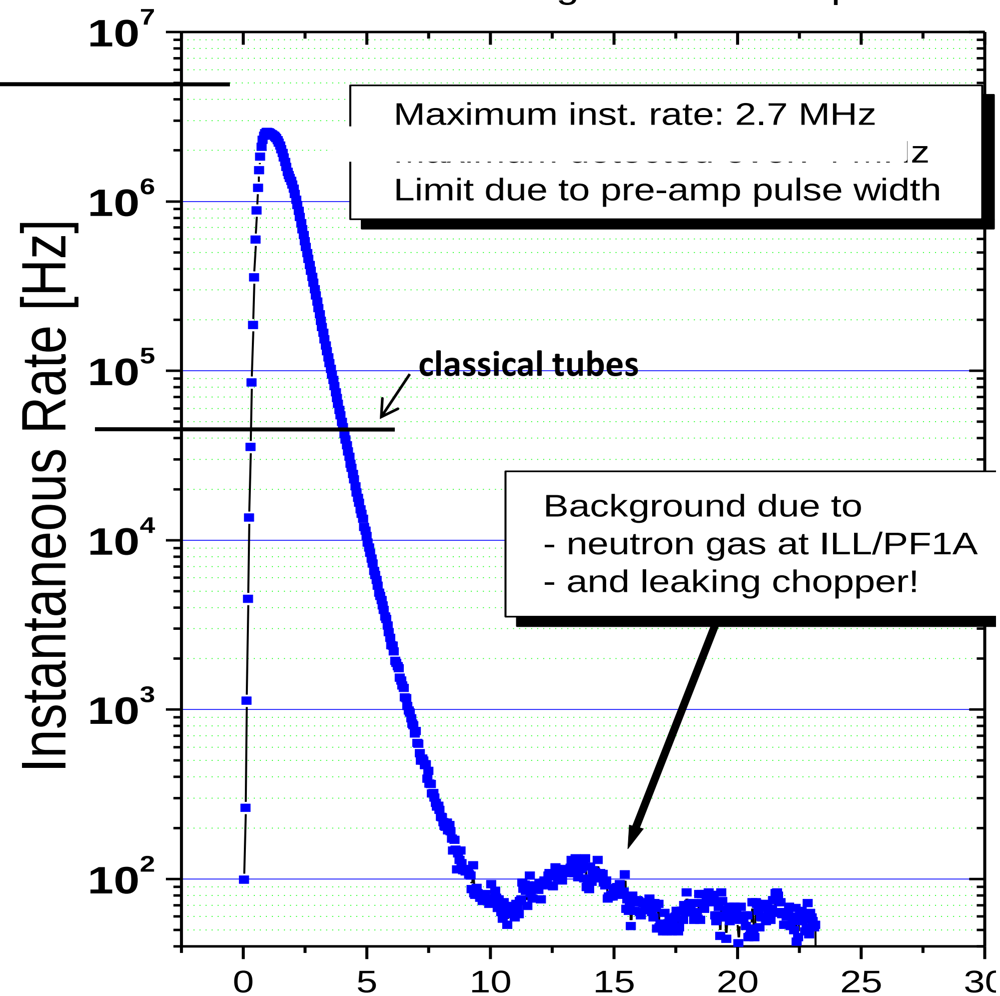
Count rate
> 1 MHz

Dynamic range
5 orders of magnitude

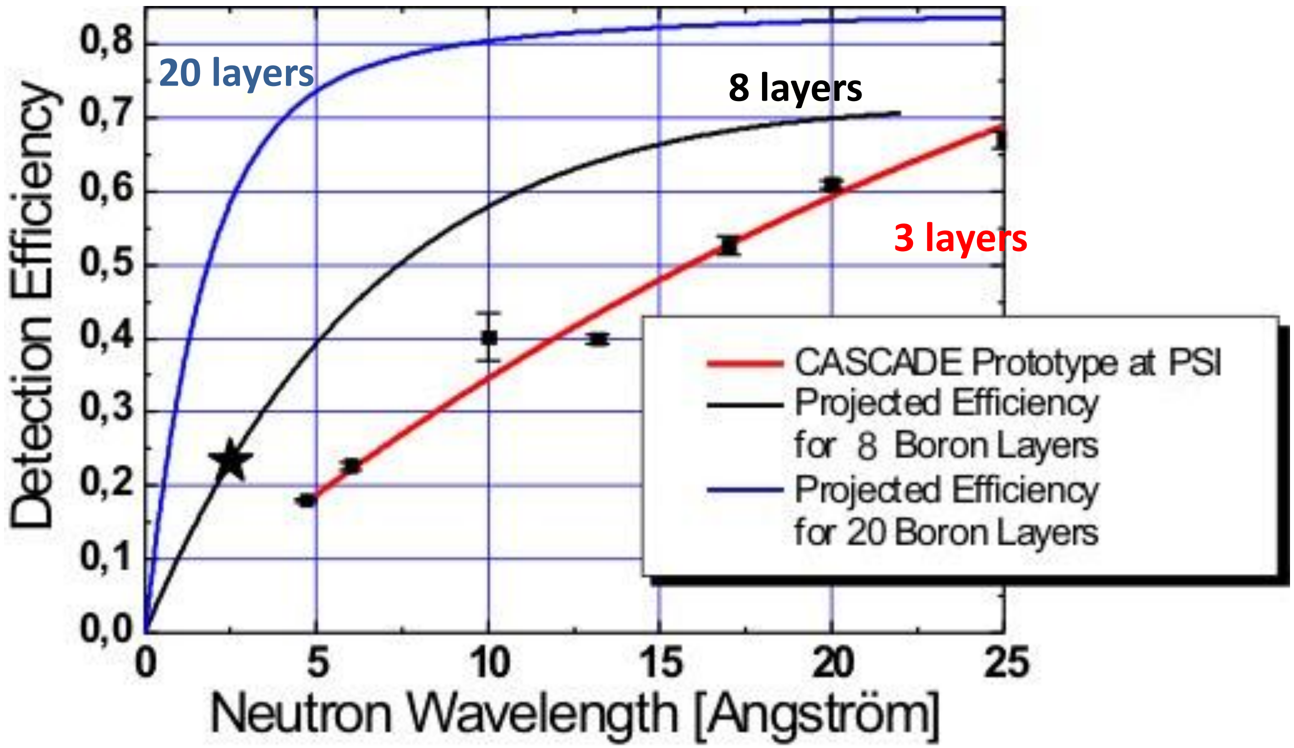


Point spread function of 0.57mm beam

Time of Flight measurements
at ILL/ PF1A on a single readout strip of 1cm²



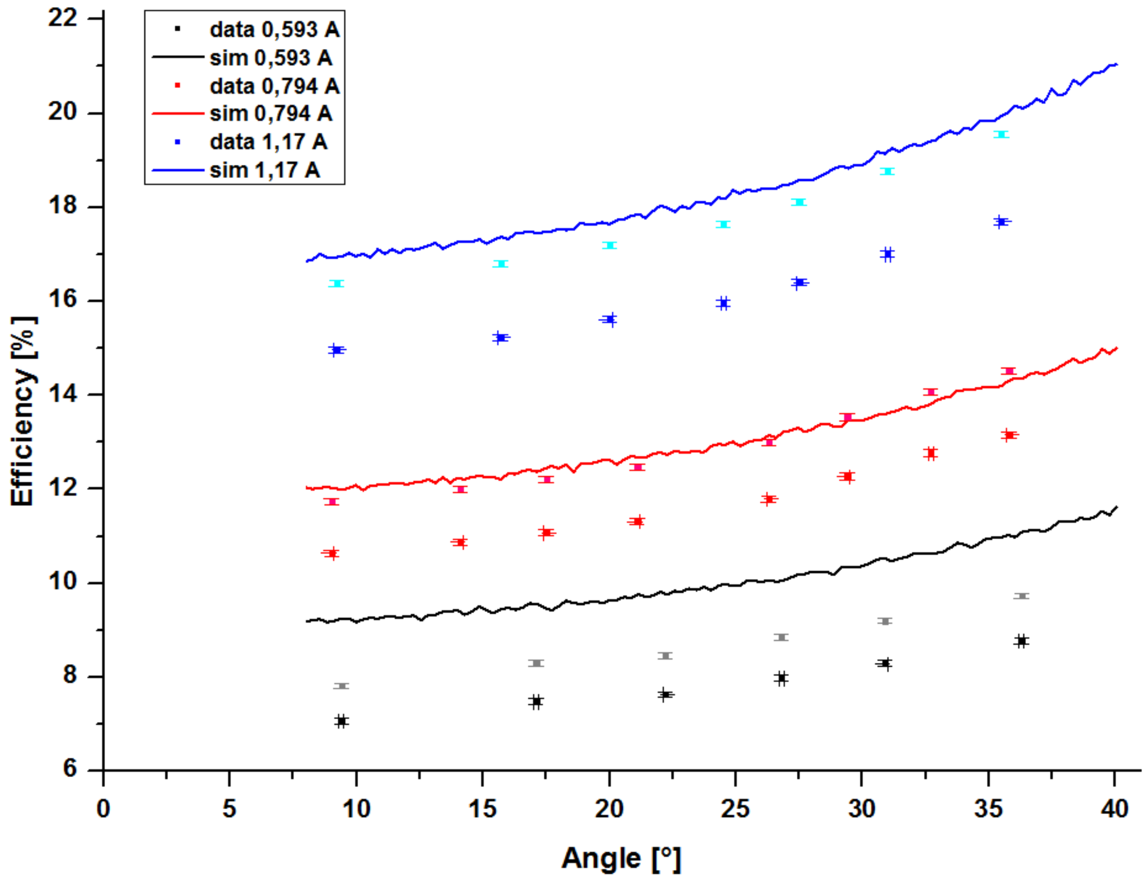
CASCADE – detection efficiency



CASCADE – detection efficiency

Efficiencies of the detector at different wavelenghts

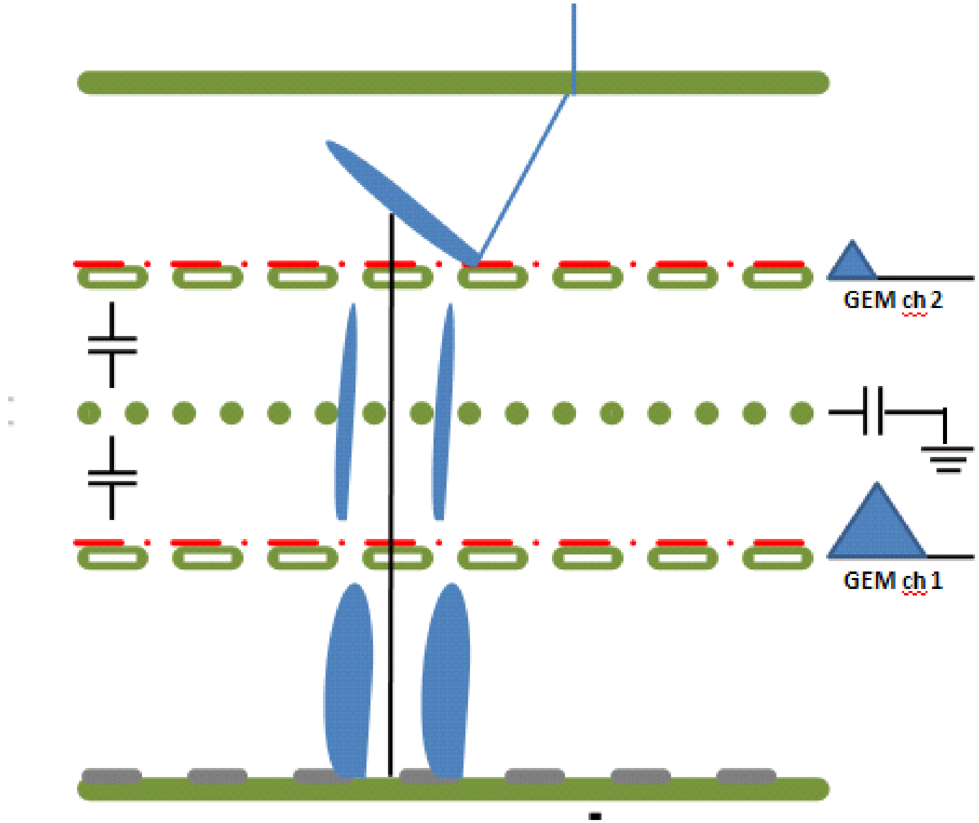
- Simulation
- Data
- T-GEM corrected data



Measurements at HEIDI, FRM II

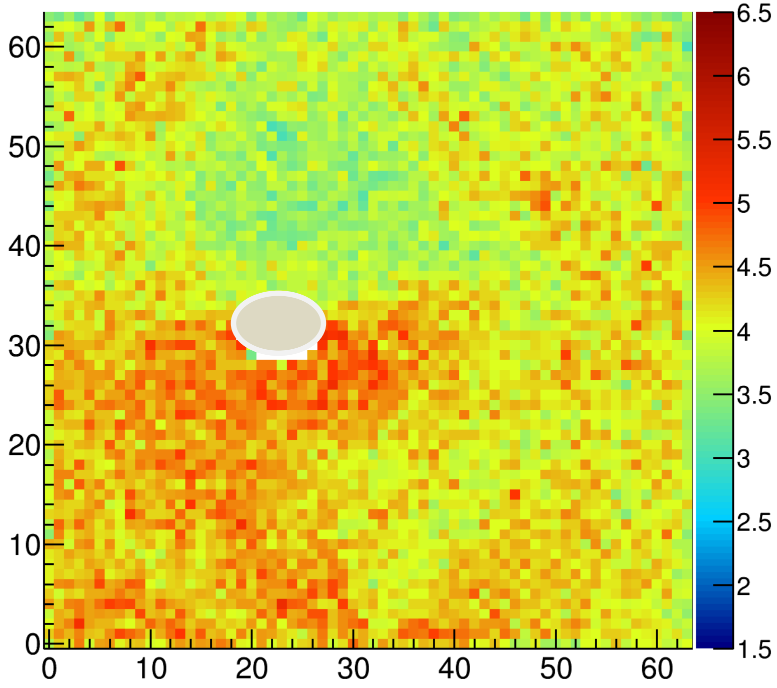
CASCADE – gain by layer

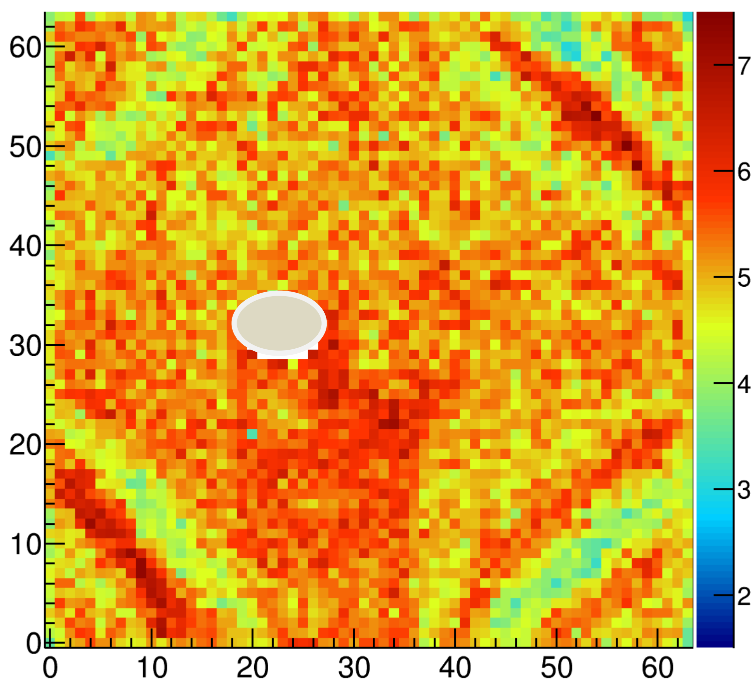
Mean local gas gain



CASCADE – gain by layer

Mean local gas gain





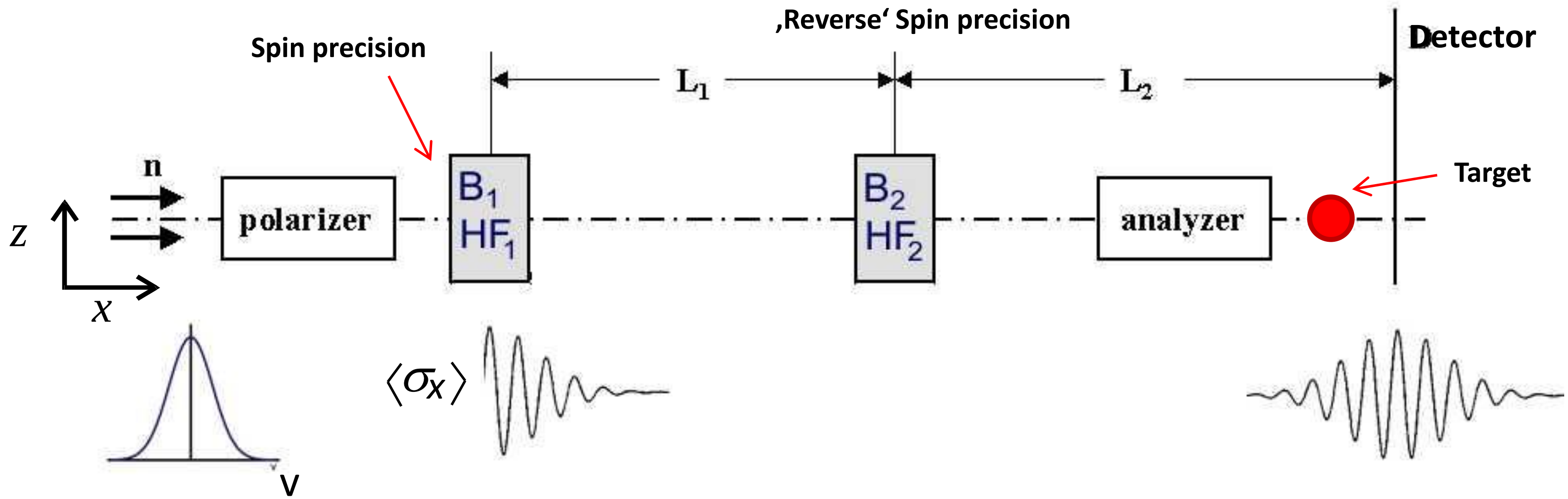
Spin Echo Spectroscopy

Application: **High resolution neutron scattering:**

Neutron Resonance Spin Echo Methods

Principle: **Use Neutron Spin as Obervable in Interference Time Of Flight Experiments**

e.g. Mach-Zehnder Interferometer in time



Schematic: MIEZE I setup

Time dependent scattering at sample causes loss in polarization

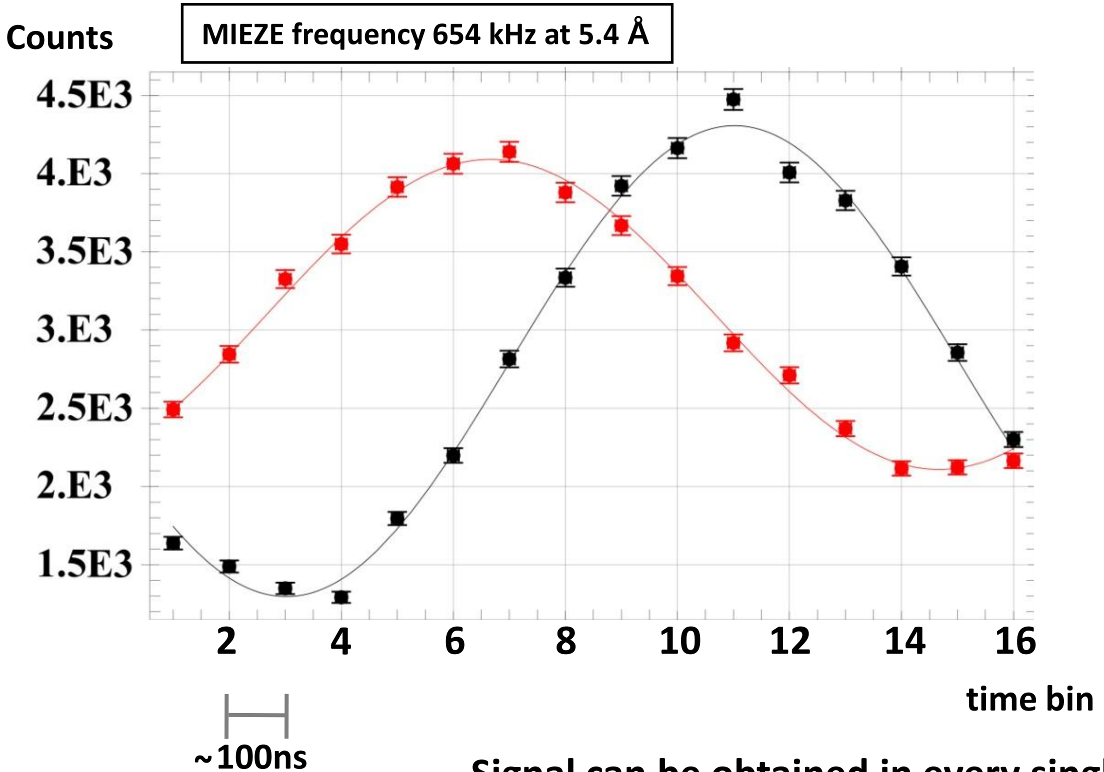
Polarization is proportional to Fourier Transform of Energy Transfer Spectrum

Example:

Frequency 654kHz,
λ_n= 5Å ,v = 800m/s;
Spin-Wavelength of signal: 1.2 mm

CASCADE – MIEZE

Polarization in two pixels:

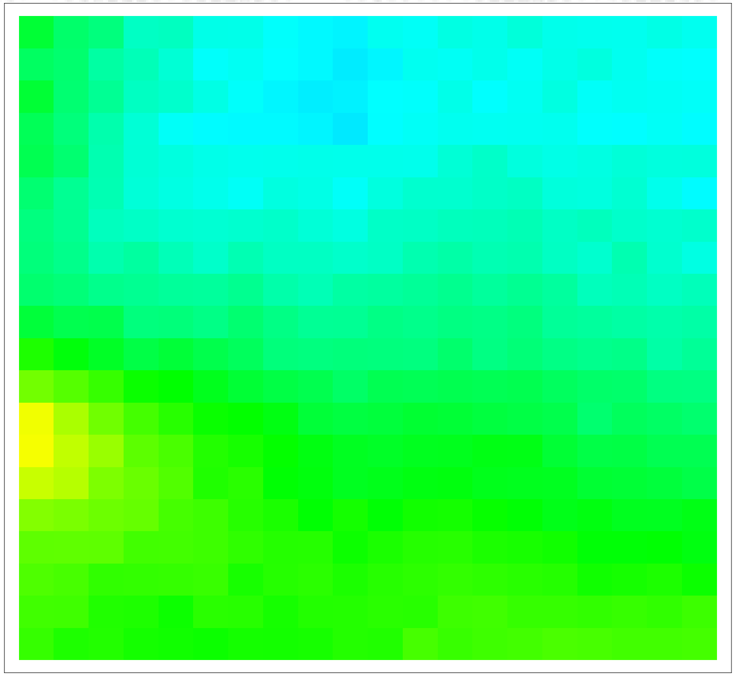


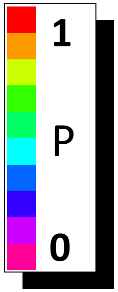
Signal can be obtained in every single pixel and layer

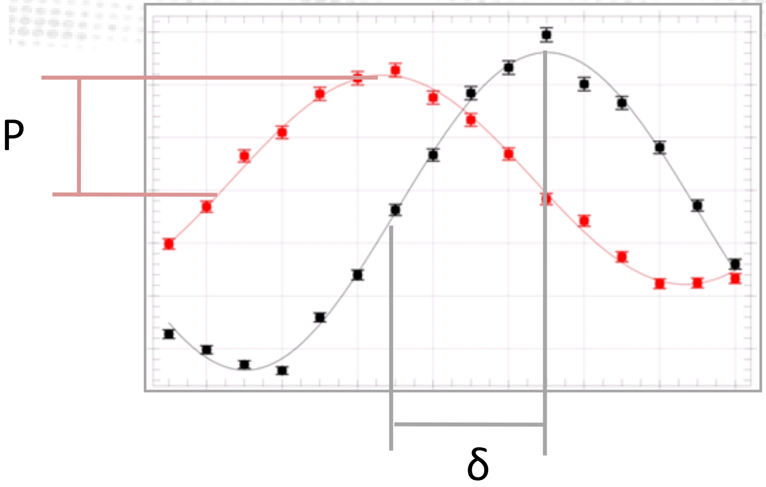
From: FRM II, Reseda

From: FRM II, Reseda

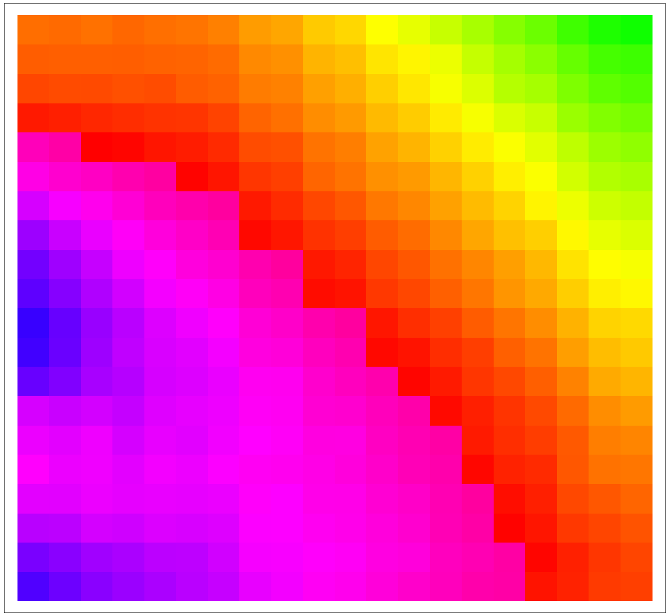
CASCADE – MIEZE

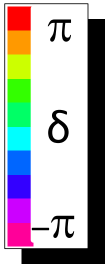






polarization map





phase front map

From: FRM II, Reseda

Summary

- The CASCADE detector offers an alternative to classical ^3He based systems with
  - spatial resolution (2.6 mm)
  - high count rate capability (up to 2 MHz)
  - high time of flight resolution

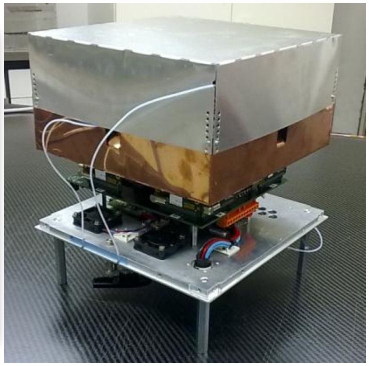
    ⟶ important for Spin Echo methods

- Efficiency depends on number of layers:

  2x3 layers in operation (…-50% eff. at 5.4 Angstroms)

Ongoing Improvements:

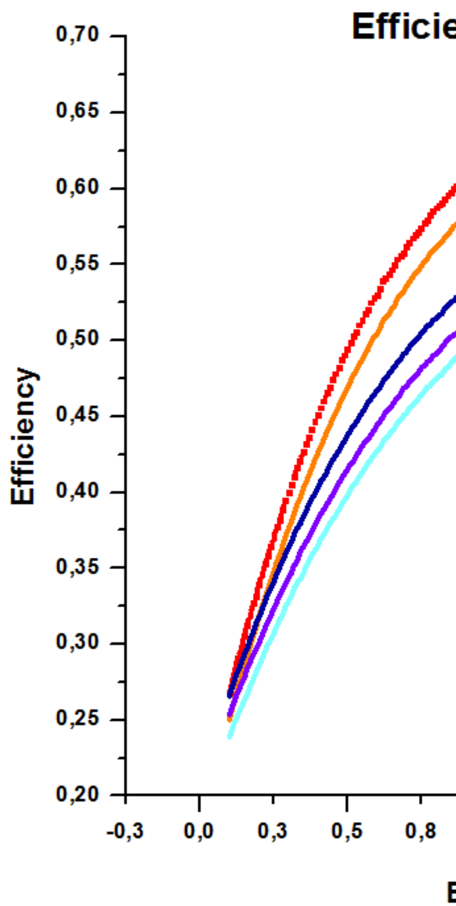
- redesign for better ASIC (CiPix → nXYter)
- more compact structures & improved field configuration
- scale up to 10 layers



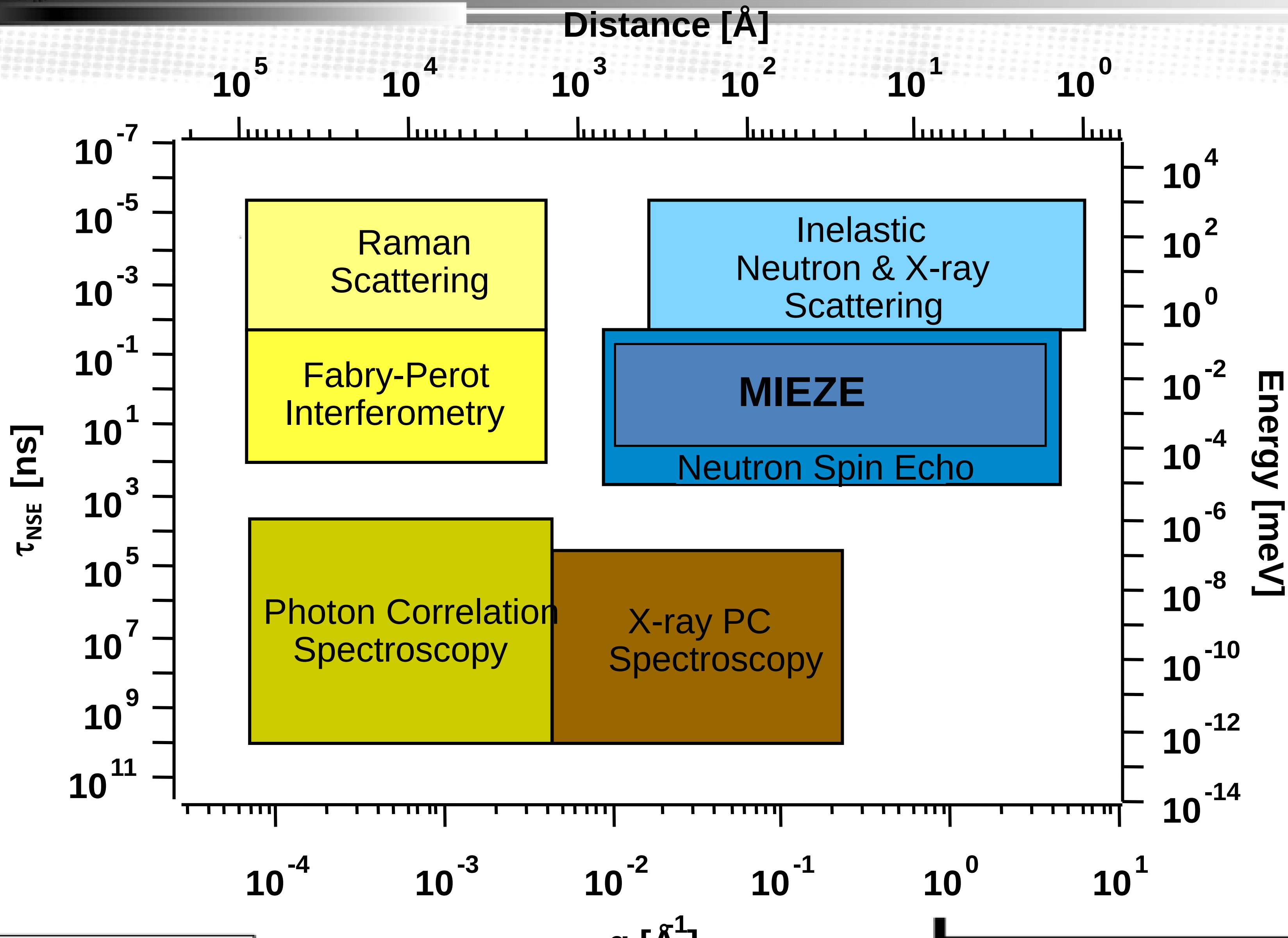
Backup Slides

CASCADE – detection efficiency

Efficiency and internal scattering



The Scattering Map



CASCADE – MIEZE