Technical Challenges to be matched for future nuclear physics experiments

H. Simon – GSI-Darmstadt

MENU

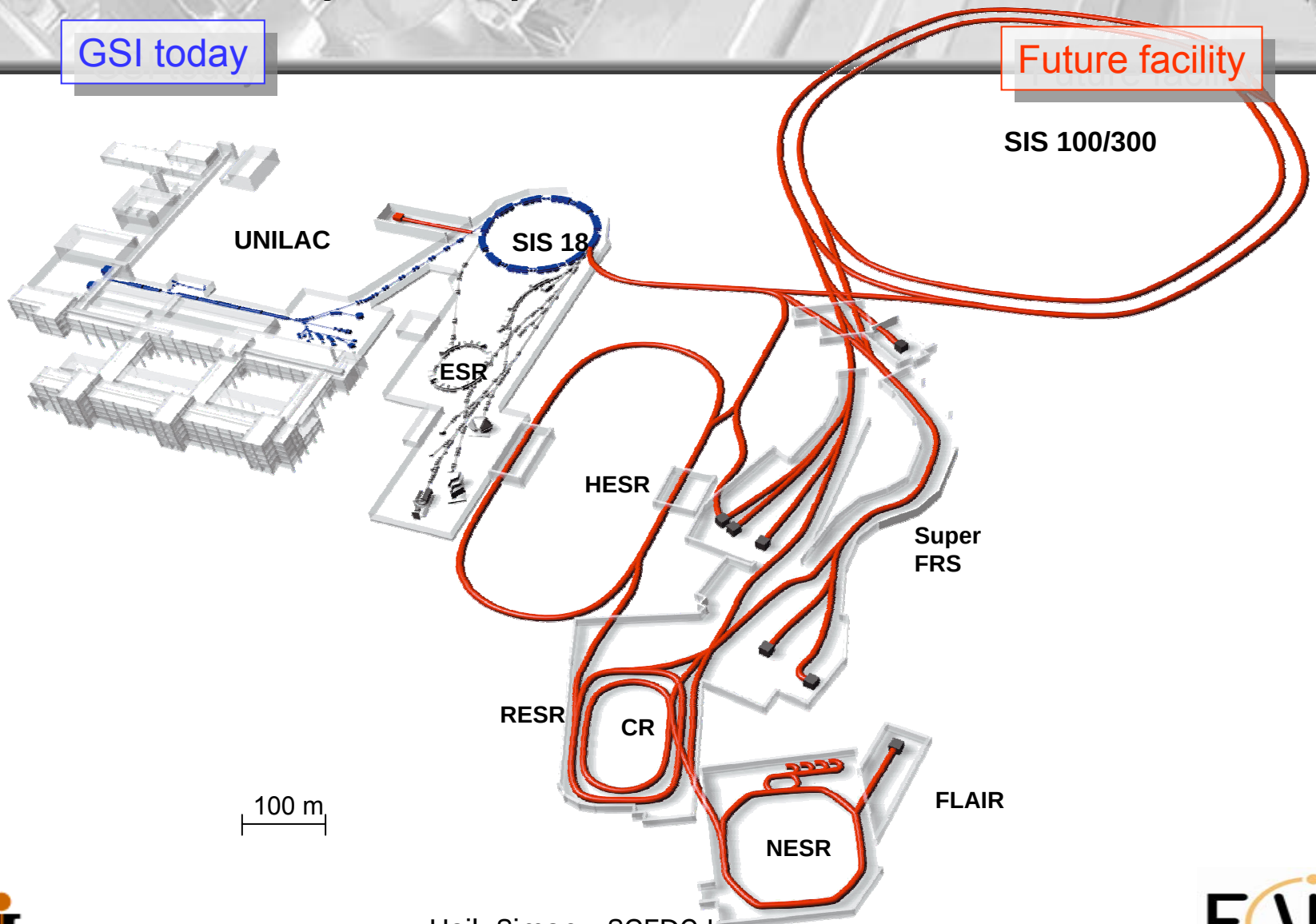
(i) the future → FAIR

(ii) experiments

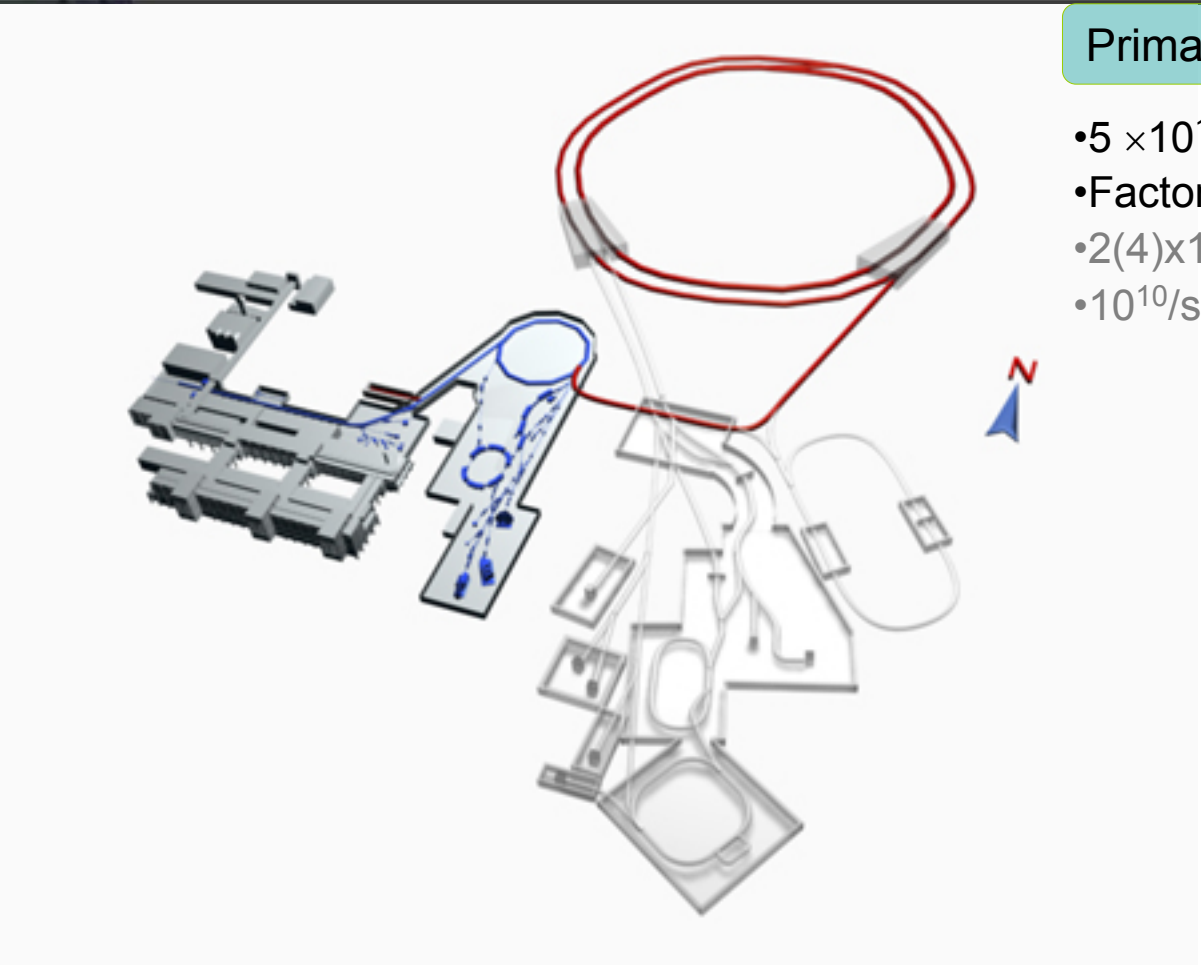
(iii) techniques

(iv) summary & evoked technologies

(i) FAIR - Facility for Antiproton and Ion Research



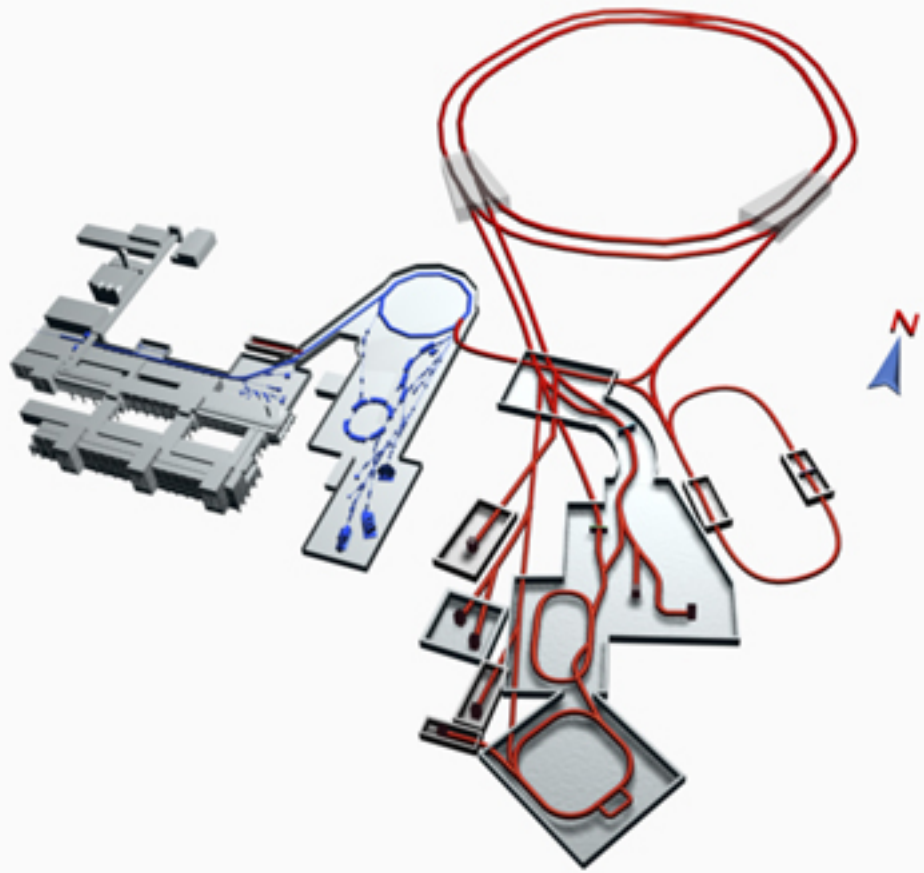
Parameters FAIR



Primary Beams

- 5×10^{11}/s; 1.5 GeV/u; $^{238}U^{28+}$
- Factor 100-1000 over present in intensity
- 2(4)x10^{13}/s 30 GeV protons
- 10^{10}/s $^{238}U^{73+}$ up to 25 (- 35) GeV/u

The FAIR facility



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Secondary Beams

- Broad range of radioactive beams up to 1.5 - 2 GeV/u; up to factor 10 000 in intensity over present
- Antiprotons 3 - 30 GeV

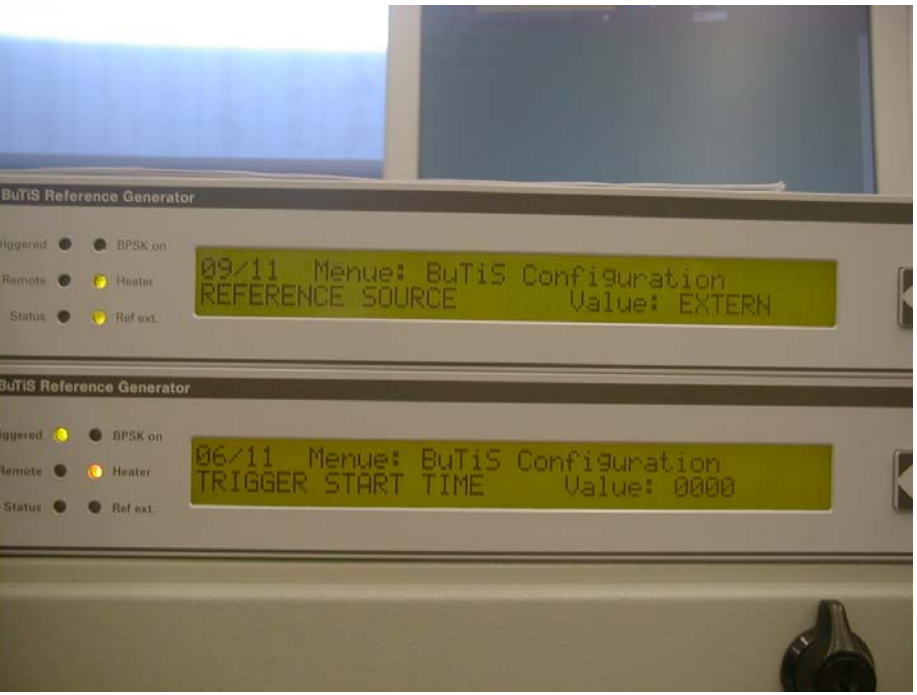
Storage and Cooler Rings

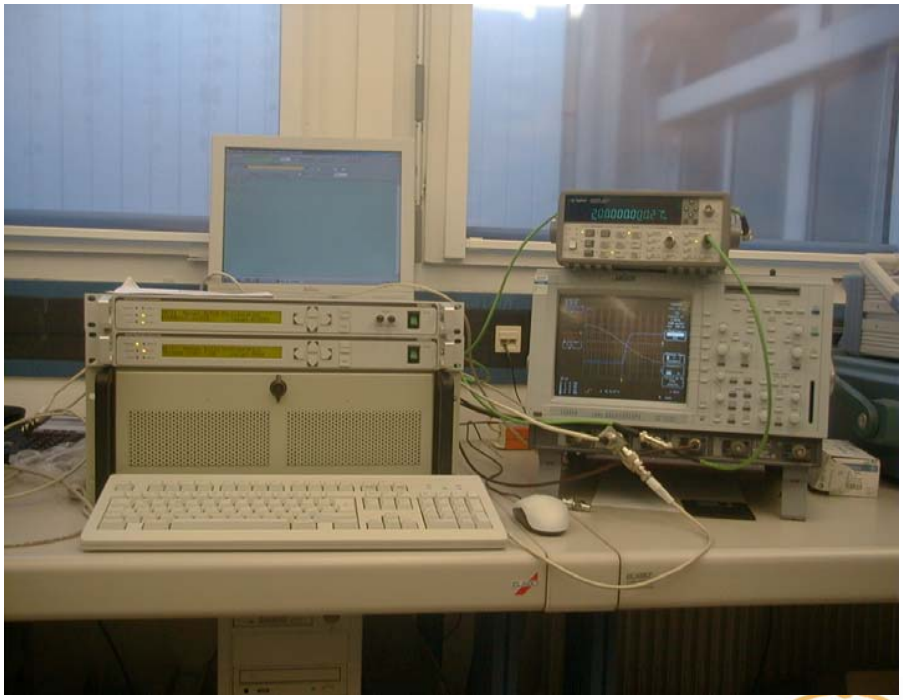
- Radioactive beams
- e – A collider
- 10^{11} stored and cooled 0.8 - 14.5 GeV antiprotons

Large Scale → Time distribution

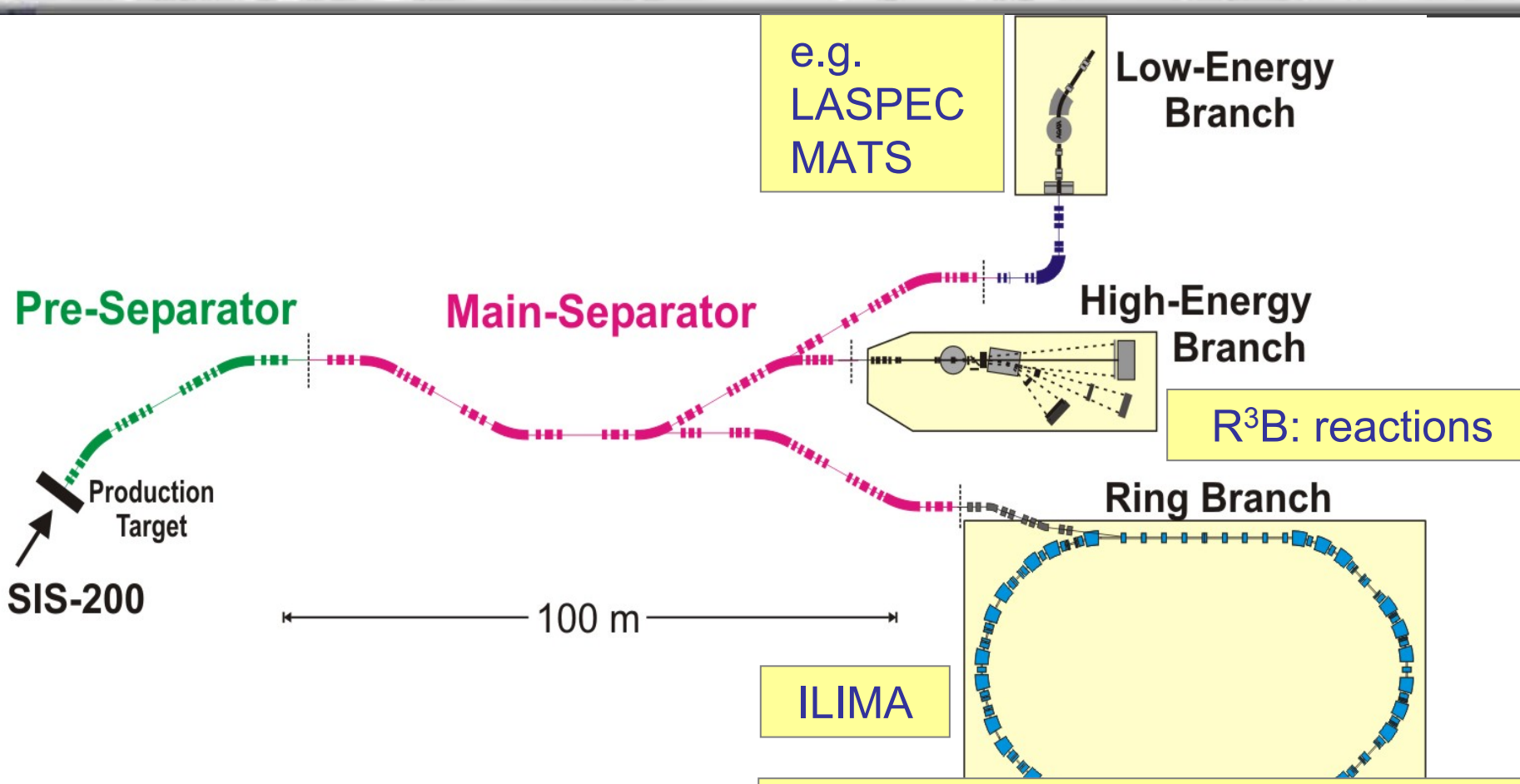
P.Moritz (GSI) collaboration with Works µ-wave GmbH

- Campus wide time distribution
  (1) Bunch timing accelerator (BuTiS) (2) Exp.: Time of flight between caves
- Synchronous local oscillators (100kHz, 10Mhz, and e.g. 200, 155 or 76 Mhz)
  +-100ps/km absolute uncertainty
  few ps oscillator jitter





(ii) NUSTAR Experiments
(NUclear STructure Astrophysics and Reactions)

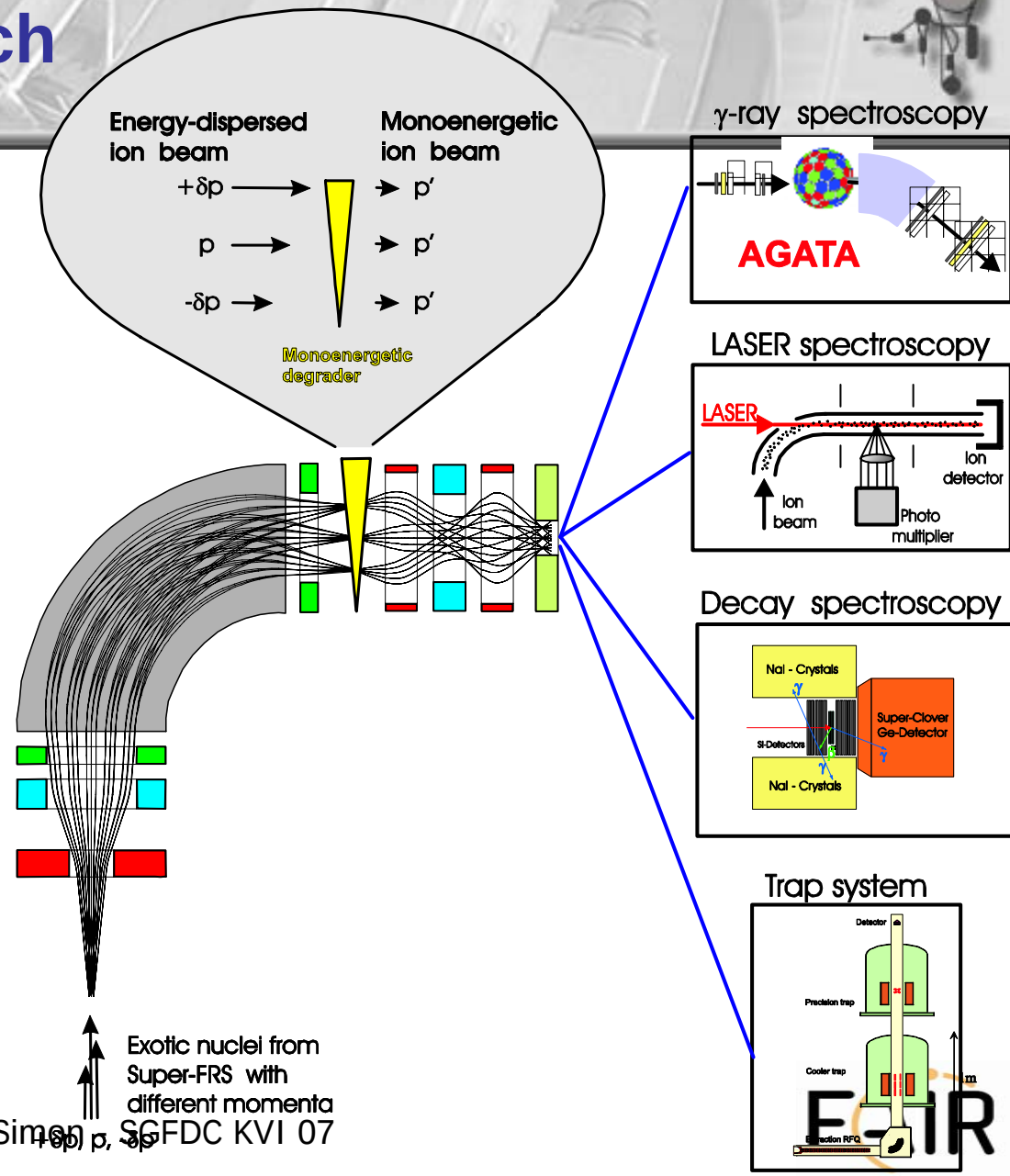


EXL : hadron scattering
ELISe : electron scattering
AIC : antiproton scattering

The low-energy branch

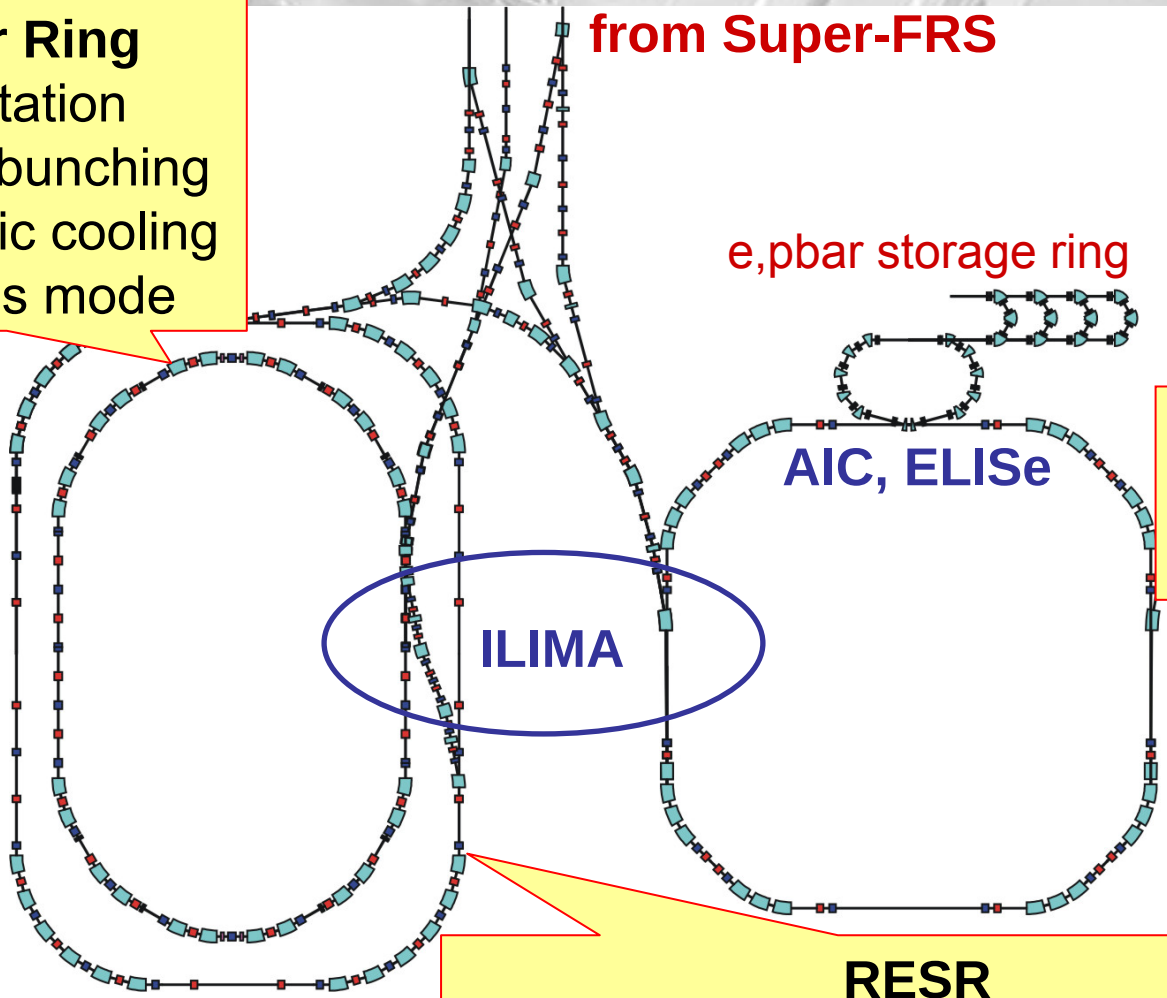
Energy-bunched slowed-down and stopped beams

- Decay spectroscopy (DESPEC)
- In-flight γ spectroscopy (3 – 100 MeV/u) (HISPEC)
- Laser spectroscopy (LASPEC)
- Ion traps (MATS)
- Neutron capture (NCAP)
- Antiprotonic nuclei (Exo+pbar)



The Ring Branch

Collector Ring
bunch rotation
adiabatic debunching
fast stochastic cooling
isochronous mode



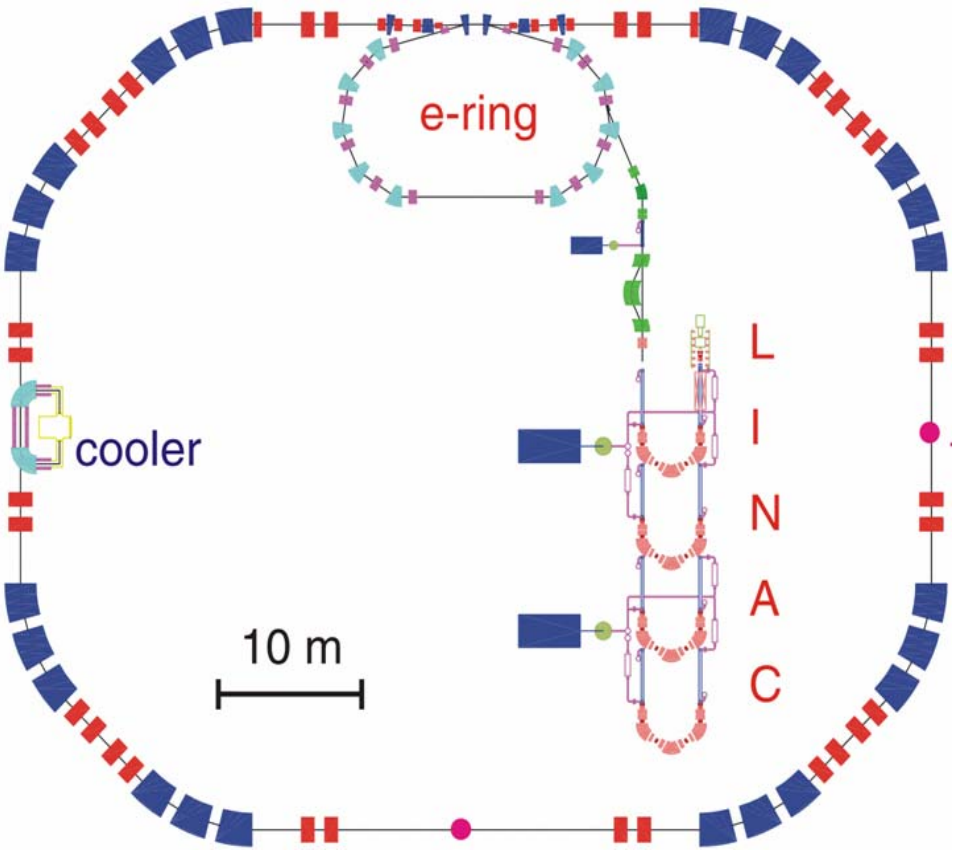
NESR
electron cooling
experiments

RESR
deceleration (1T/s) to 100 - 400 MeV/u

P.Beller, A. Dolinskii, B. Franzke, M. Steck

The ELISe experiment at FAIR

Haik Simon • Gesellschaft für Schwerionenforschung / Darmstadt



- 125-500 MeV electrons
- 200-740 MeV/u RIBs

→ up to 1.5 GeV CM energy

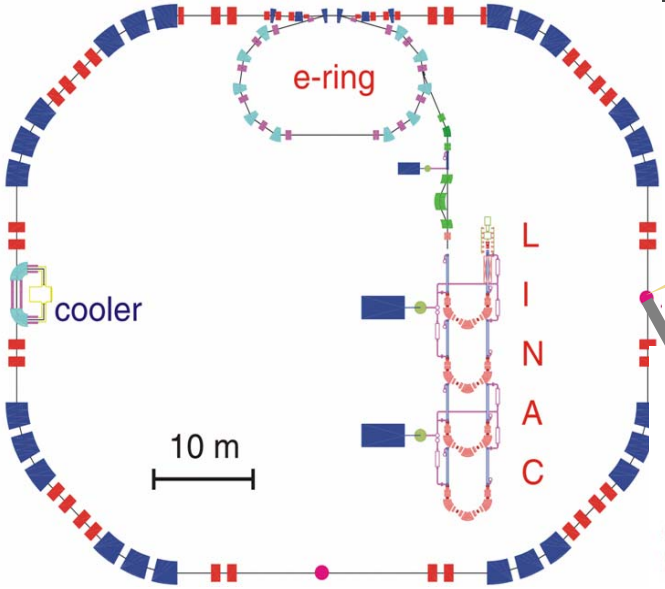
- spectrometer setup at the interaction zone & detector system in ring arcs

- Part of the core facility

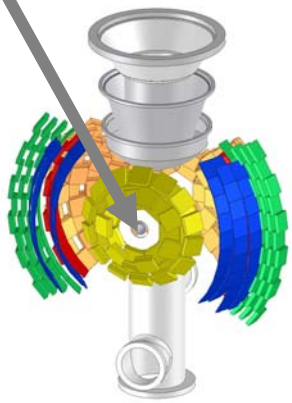
- Baseline technical report July
http://www.gsi.de/fair/reports/btr.html

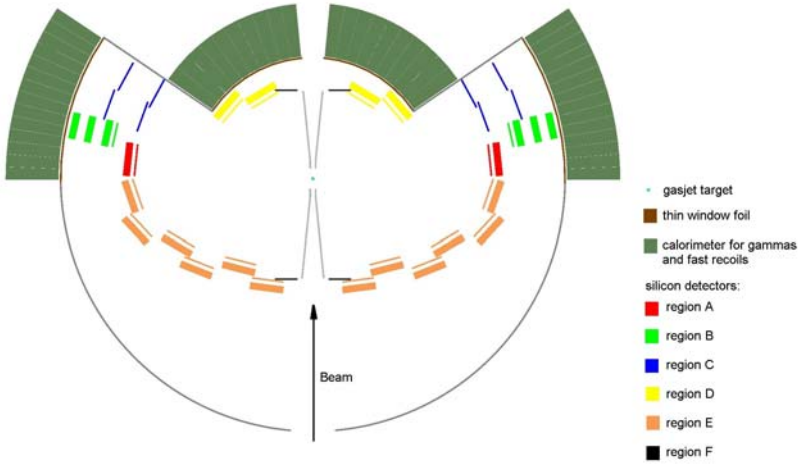
EXL

Exotic Nuclei Studied in Light-Ion Induced Reactions at NESR



Internal target

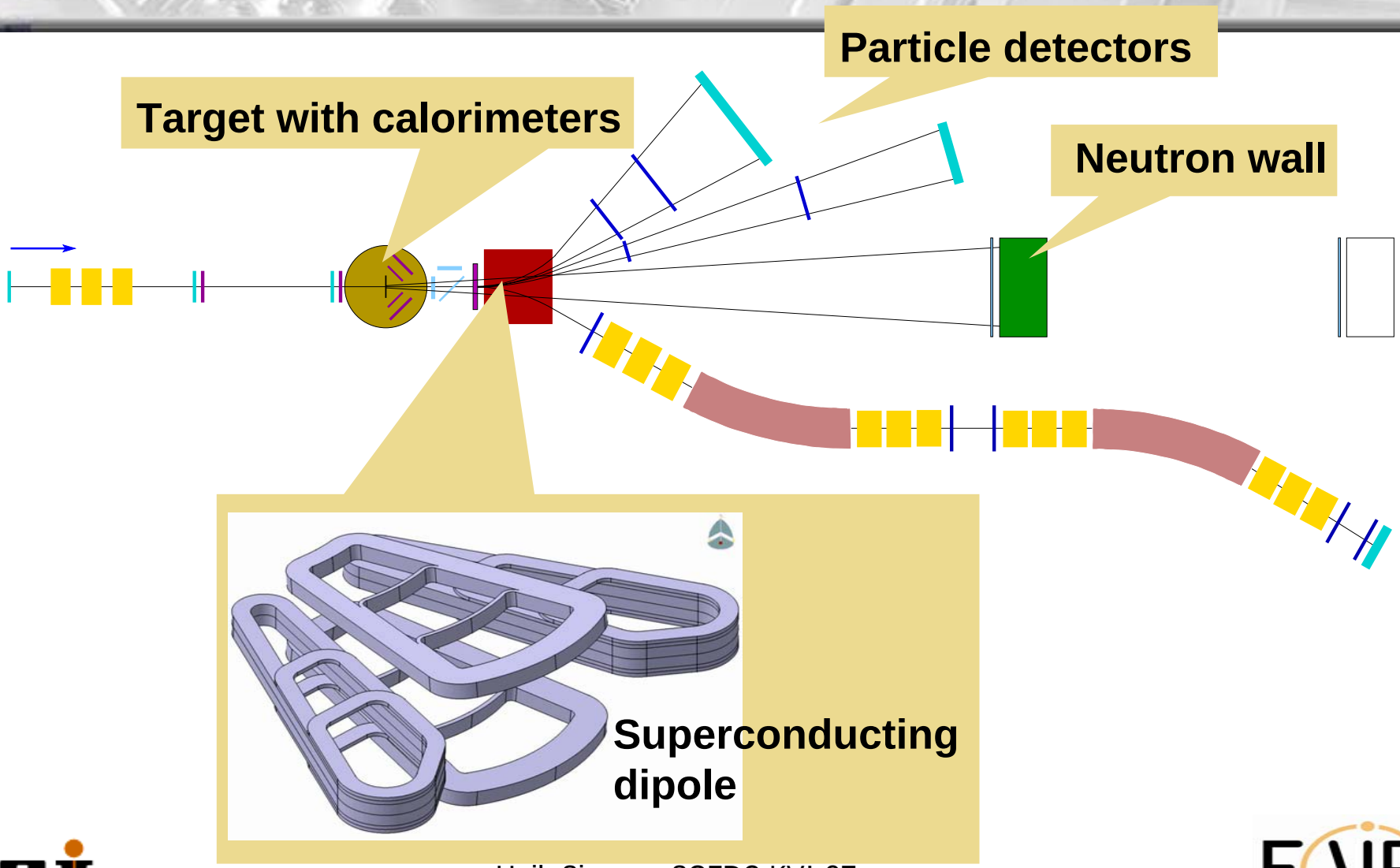




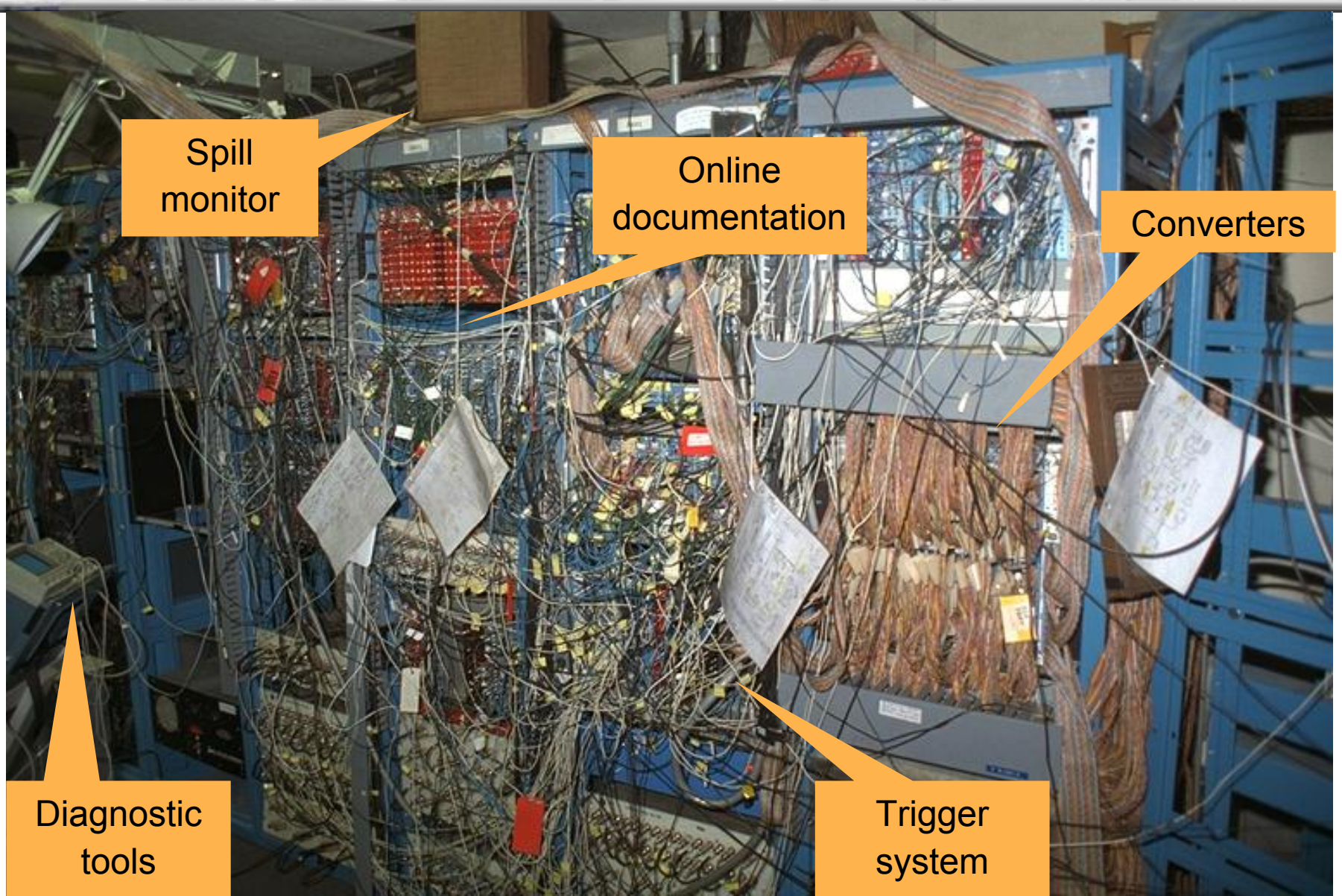
NESR

- **Target-Recoil and Gamma Detector around internal target ca. 500 000 channels**

R3B Collaboration:
Reactions with Relativistic Radioactive Beams



(iii) Our (typical) starting point



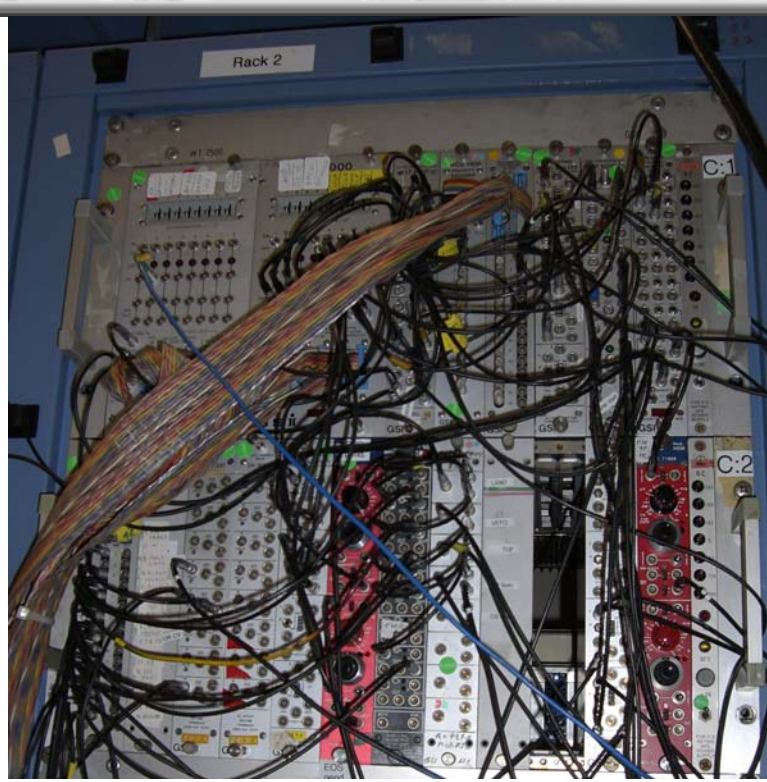
Technology

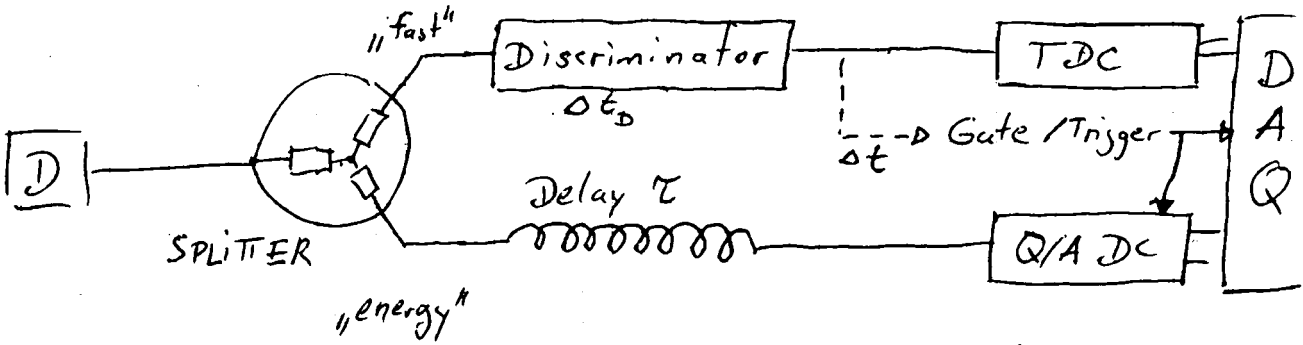
- single channels
- few channels/module
- ECL logics
- (few/single channel) analog chain

➔ power (typical few kW/kch)

➔ maintenance nightmare

➔ No memory ➔Delays (cables)



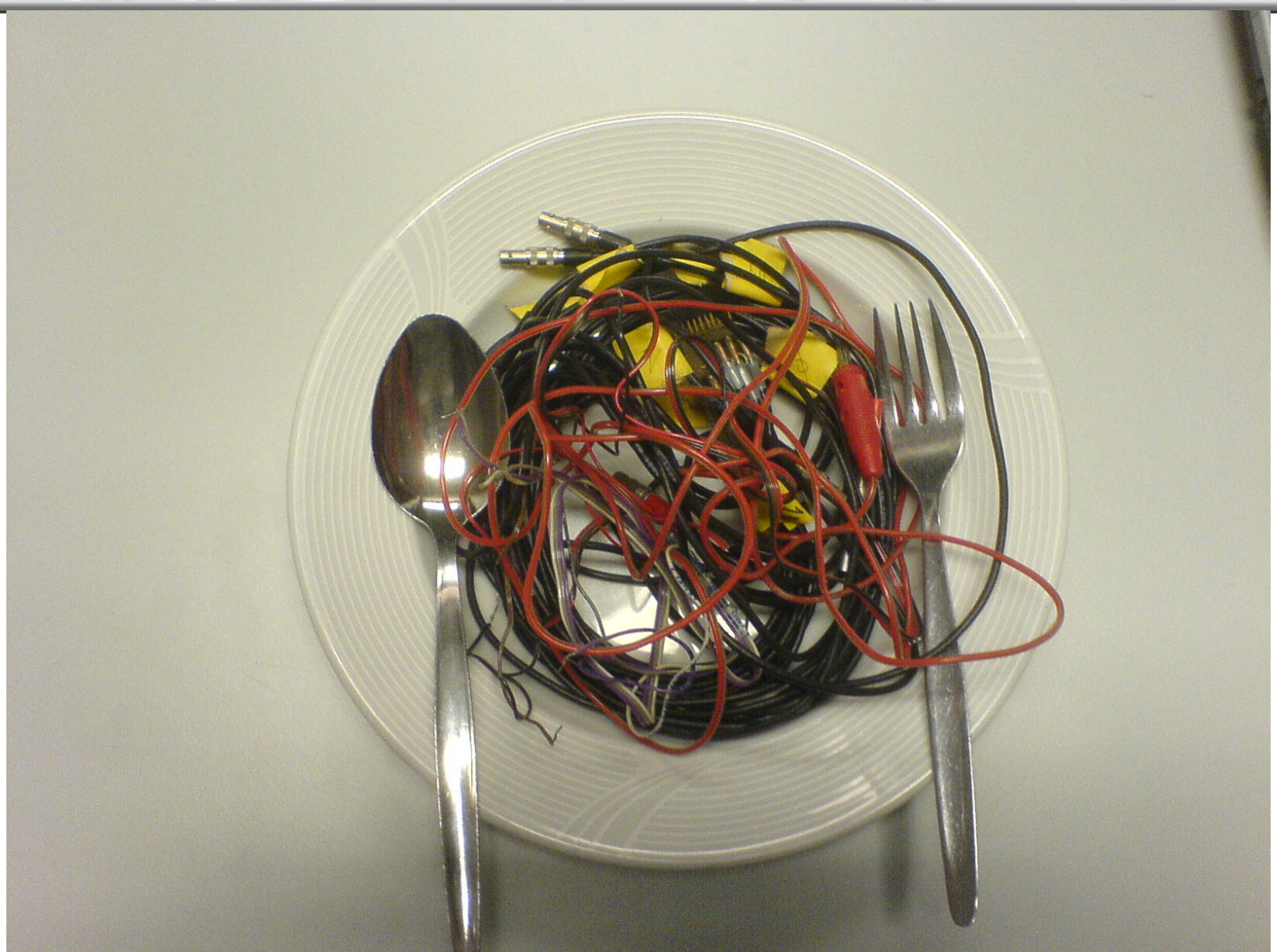


$\tau > \Delta t_D + \Delta t + \ldots$

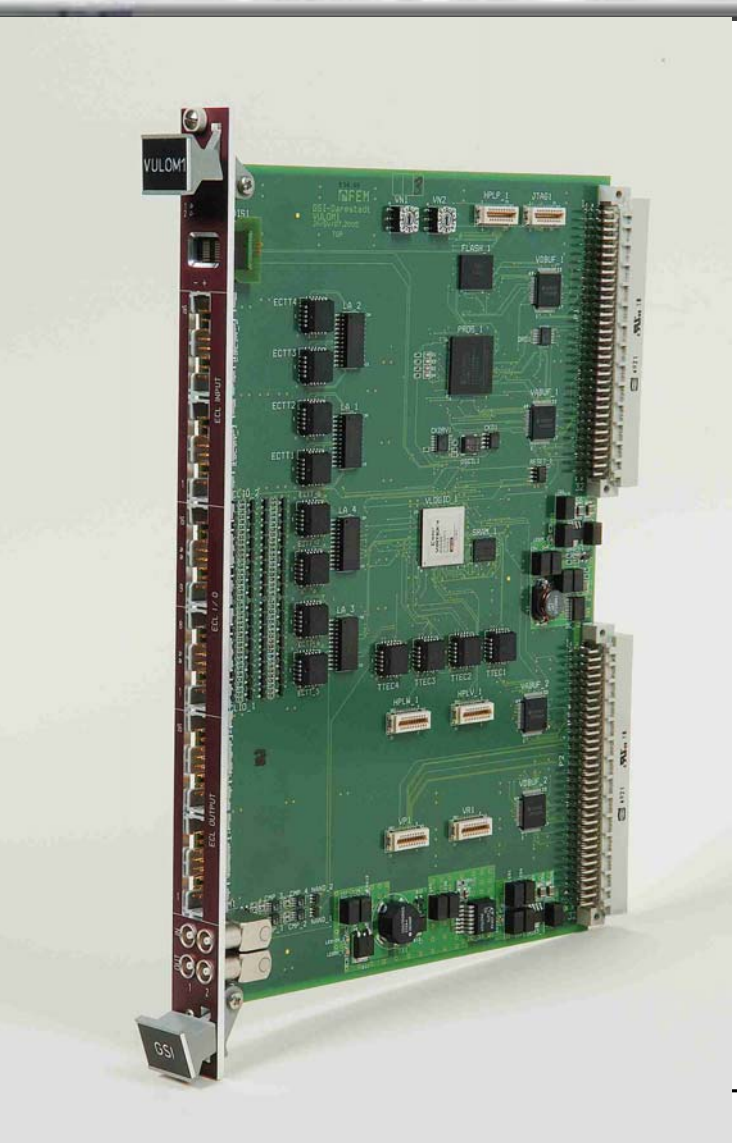
… cables !

From a few 100-1000 to half a million channels

Ways Out



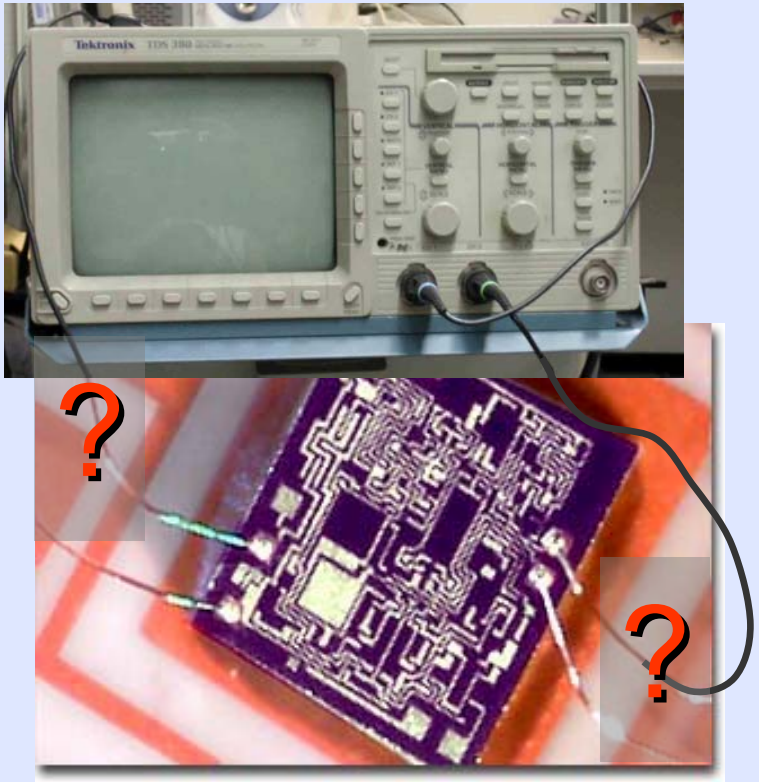
(α) Integration



VME programable FPGA + I/O

Physics defines logics for coincidences

User friendly →
- Libraries
- Diagnostics

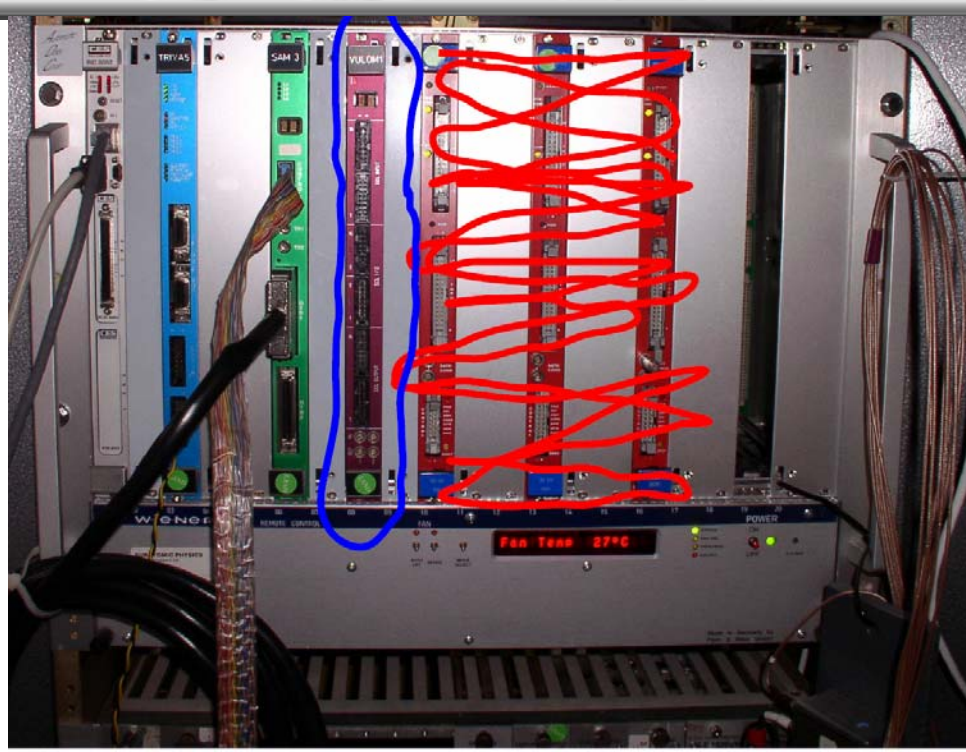


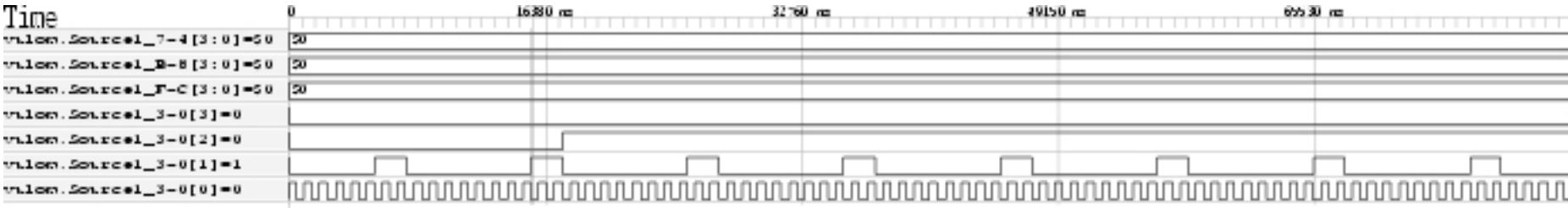
Monitoring (example: Vulom Trigger Electr.)

Logic Module (FPGA)
Master Thesis: Softscope
M. Fuhrmann, FH-Coburg

→GTKwave output
→programming
via DAQ channel

Test: Summer student
P. Lubberdink (KVI)





(β) Integration / „Intelligent detectors“

- high channel count → ASICS/AGICS

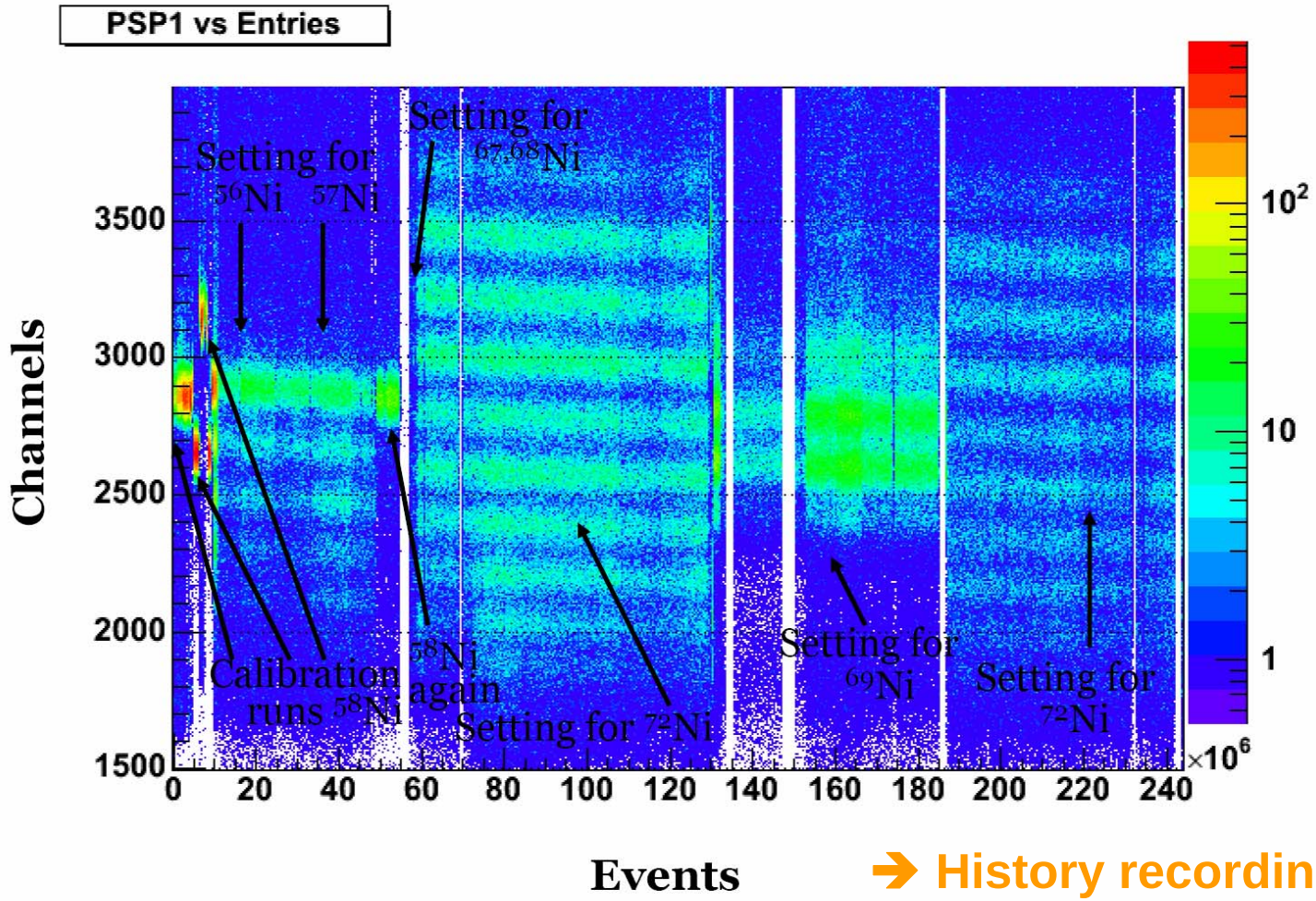
- complicated response & data rate
  - – of detector channel → online signal proc.
  - – of detector → online reconstruction

- „zero“ suppression → zero might be a complictated object

- stability

Stability: Drifts et al.

ADC channel vs. time

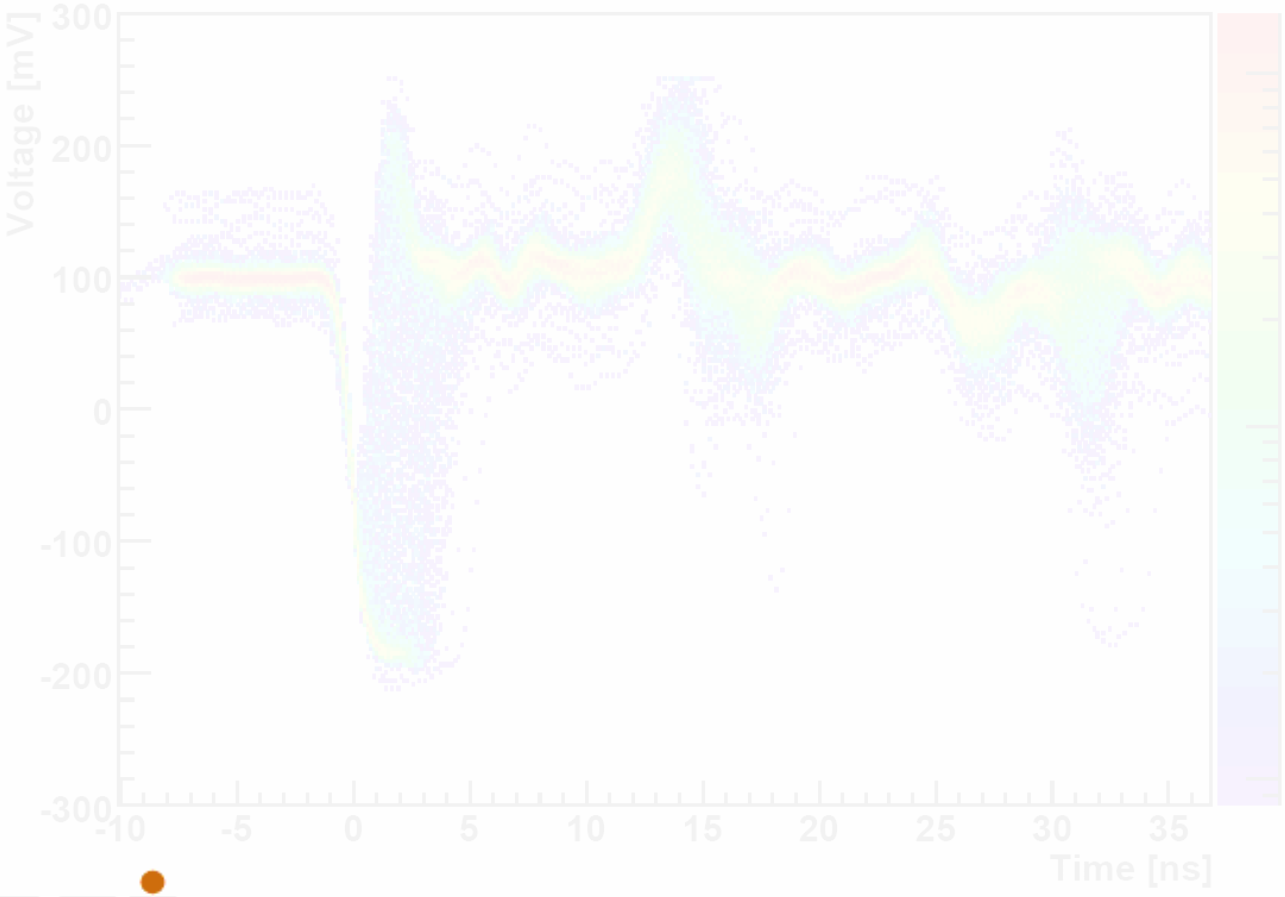


➔ History recording

Signal Processing ! (TIME)

- **RPC impedance matching, protons at various energies**

- **Messy signal structure Dedicated analog FEE**

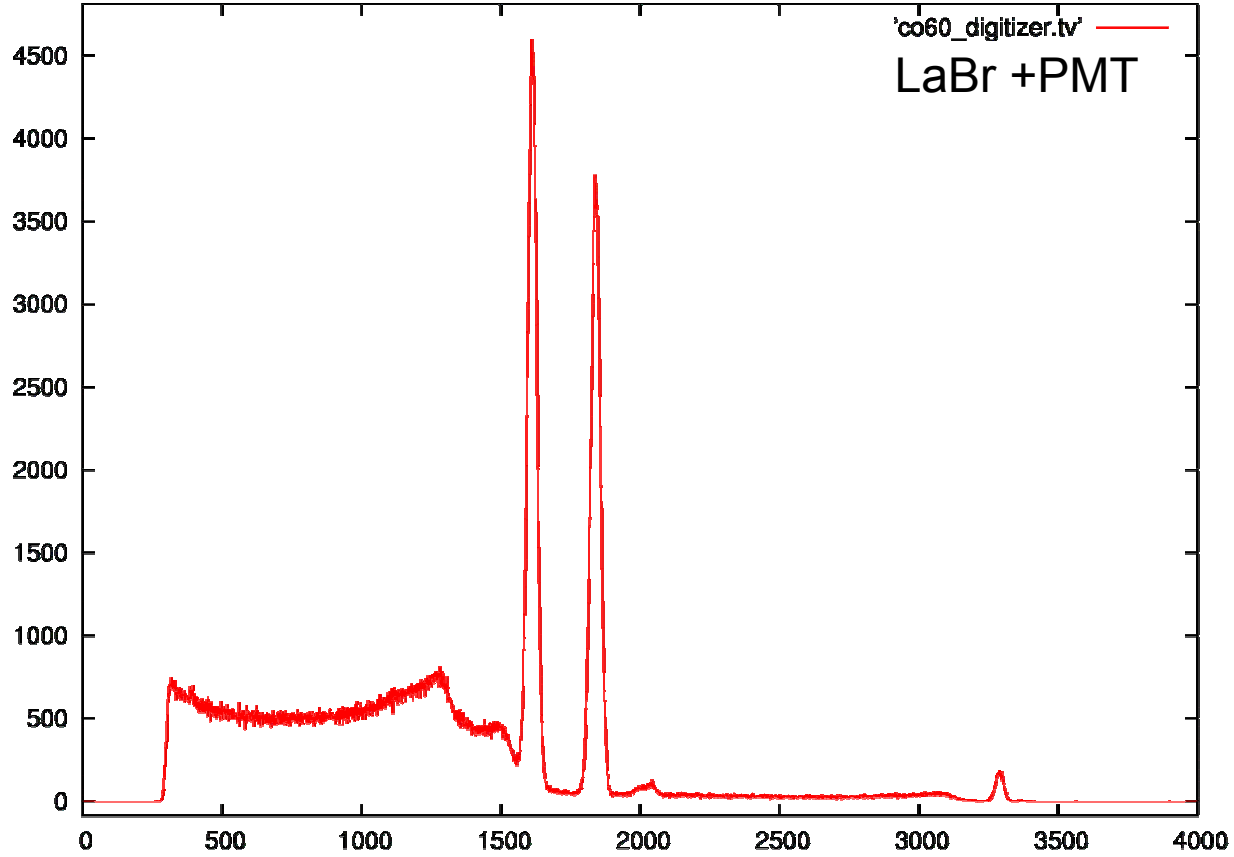


- Digization & Signal Processing on-line

vs.

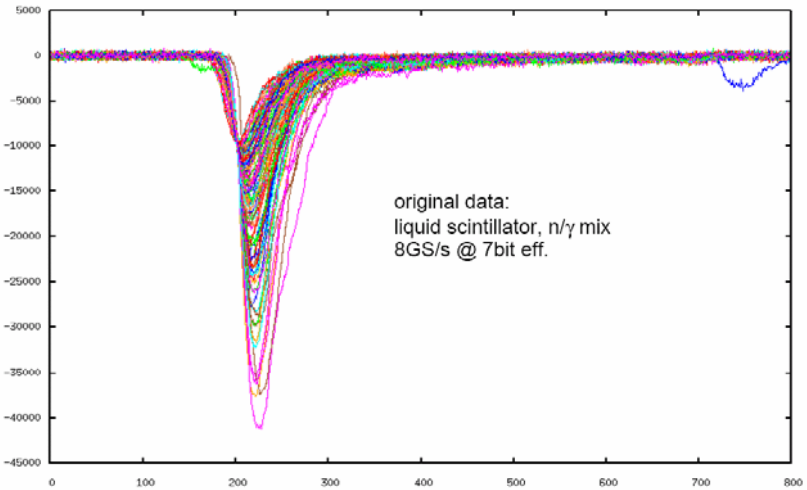
- Offline/Near line energy -- time correlations

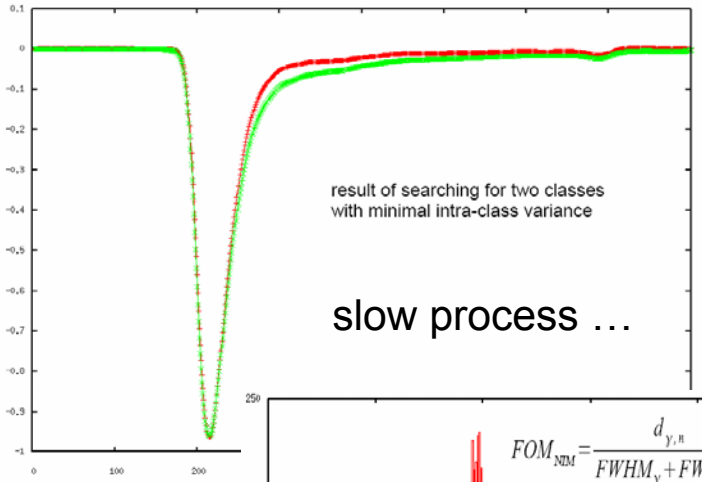
Signal Processing ! (ENERGY)



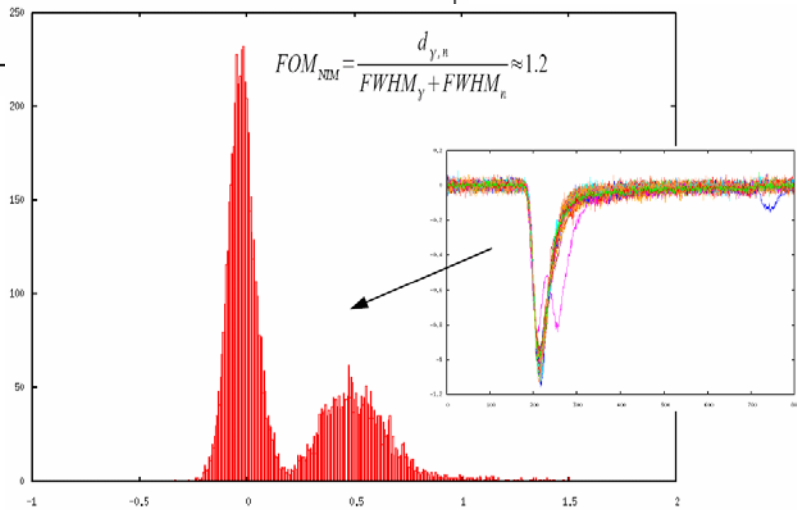
- oversampling 2GS, intelligent averaging
- comparable resolution to conventional spectroscopy setup …

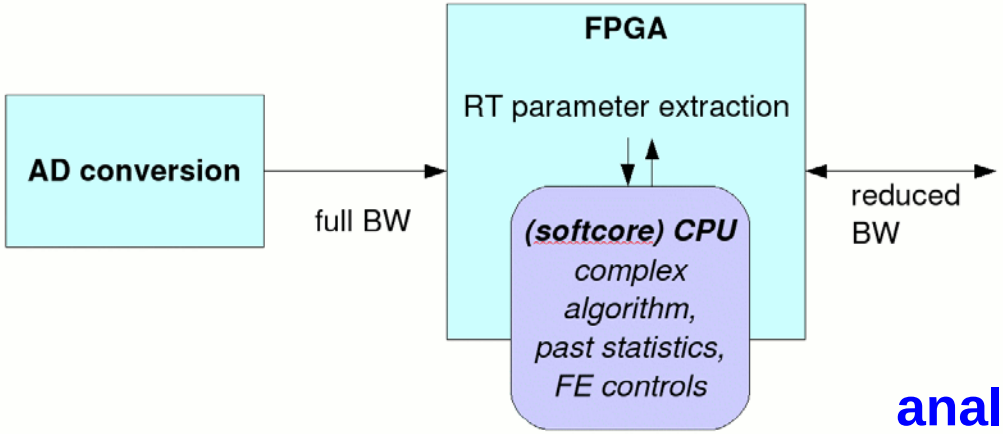
Signal Processing ! (PULSE SHAPE)





slow process …



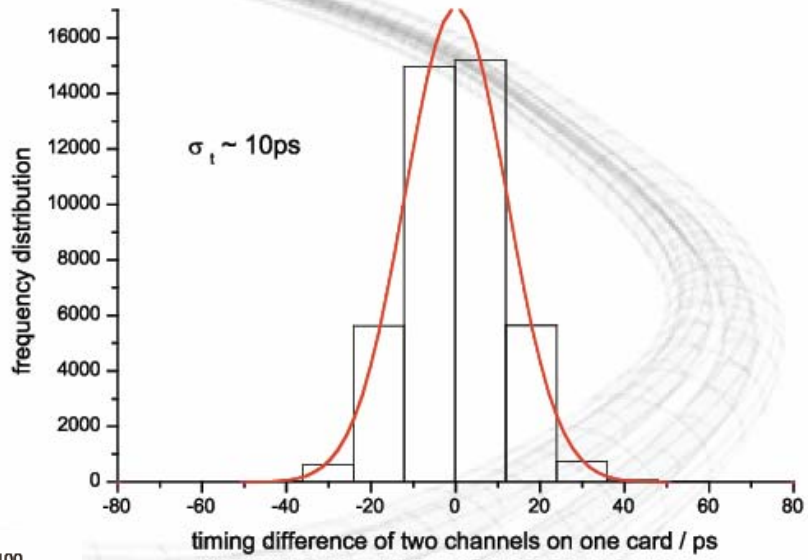


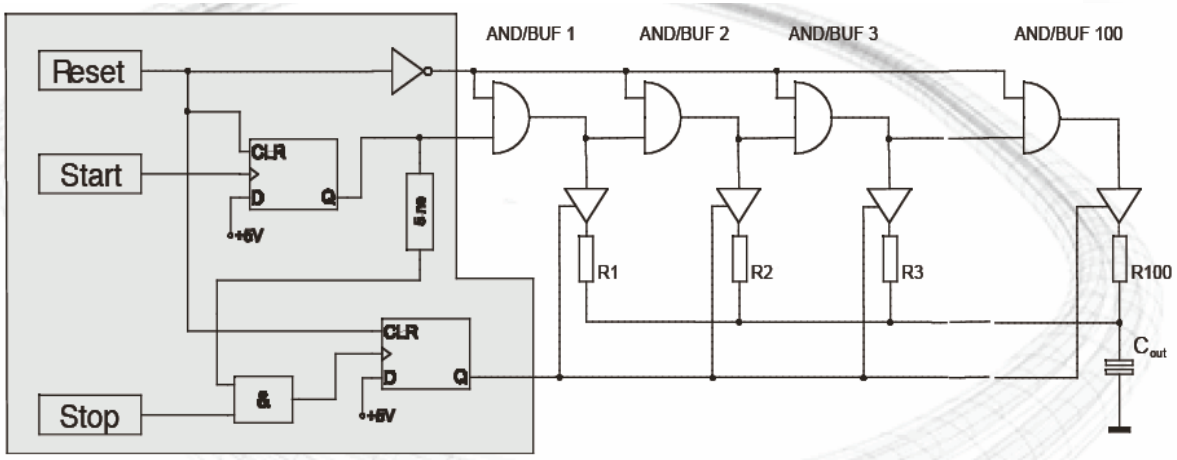
analogous timing/amplitude/charge
→ PSP project (P. Lubberdink)

ASIC: Tacquila (TAC27)

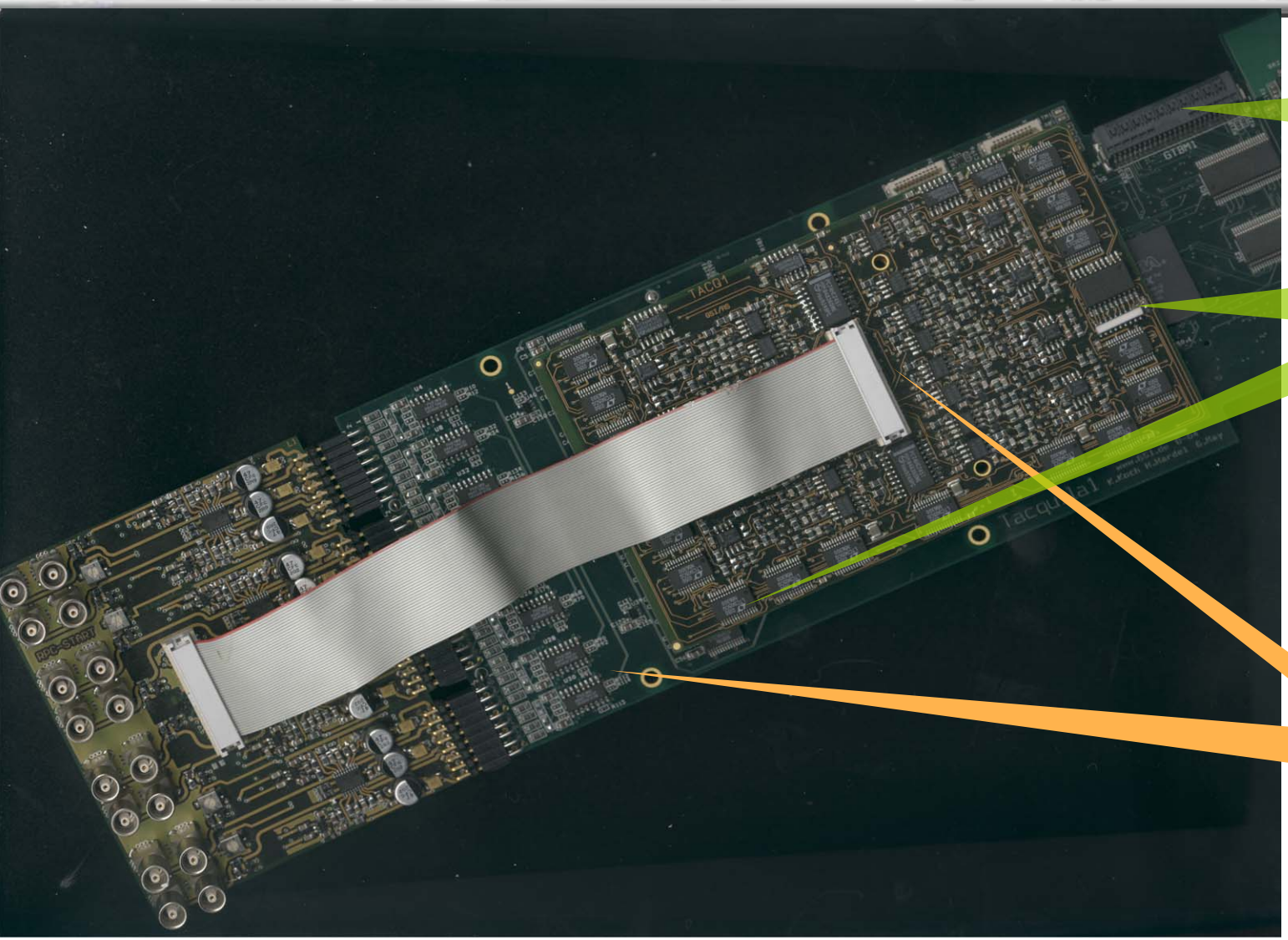
For our application (400-10000 ch)

- **PM signals (LAND, TOF-wall, …)**
- **+ slow control + monitoring → dedicated front end card**





ASIC: Tacquila System



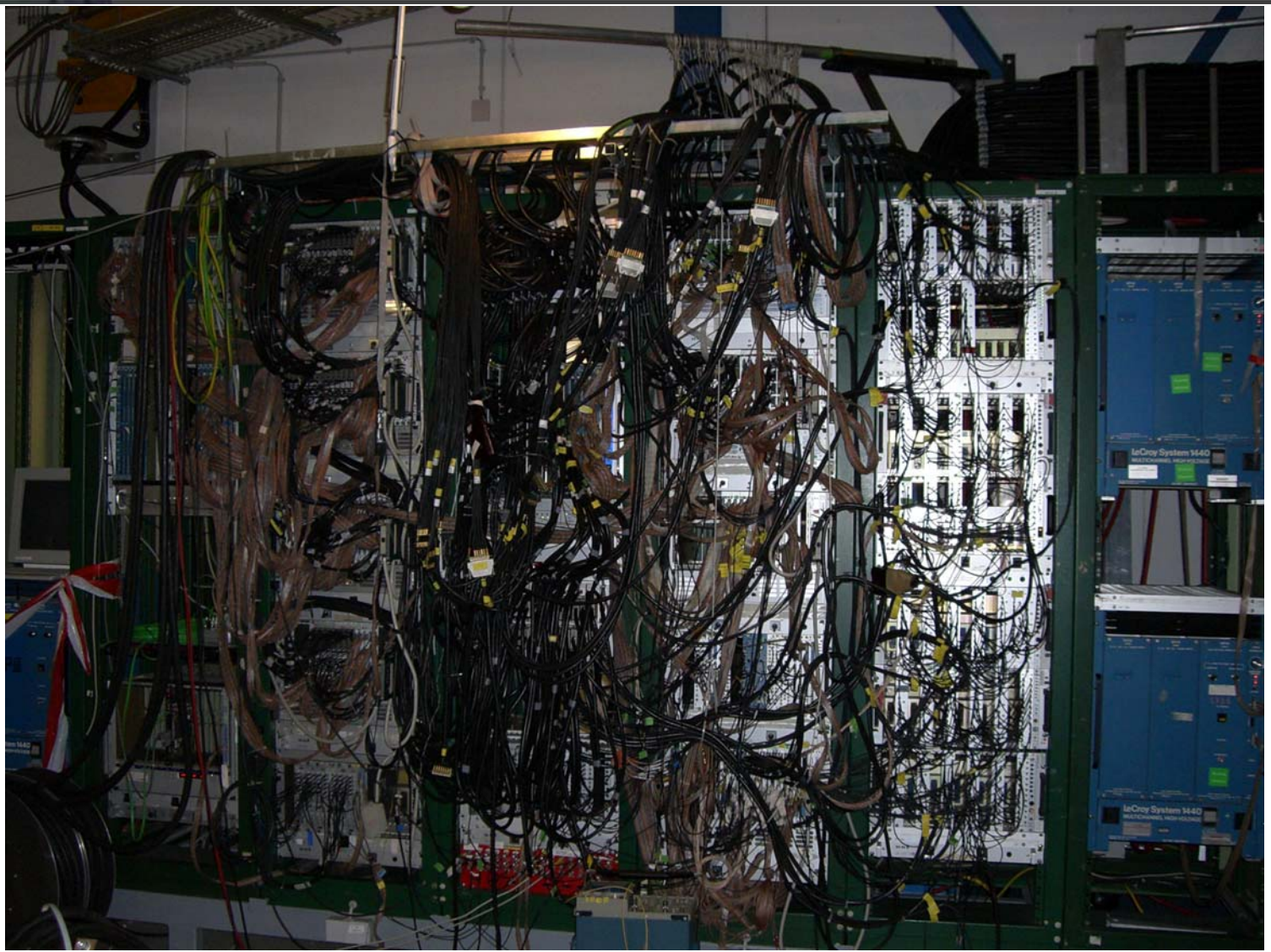
GTB interface

12 Bit ADCs

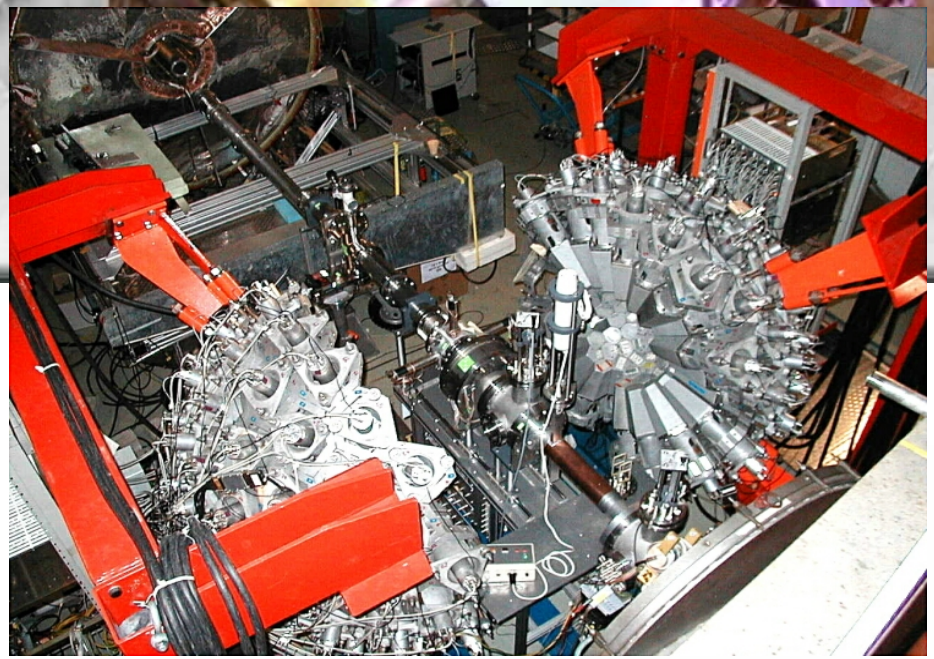
10 Bit read ...

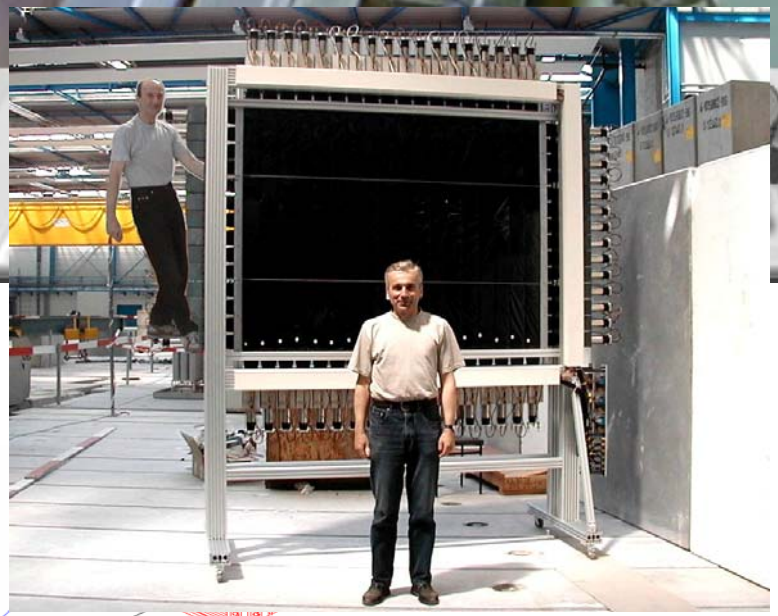
TAC Q uila

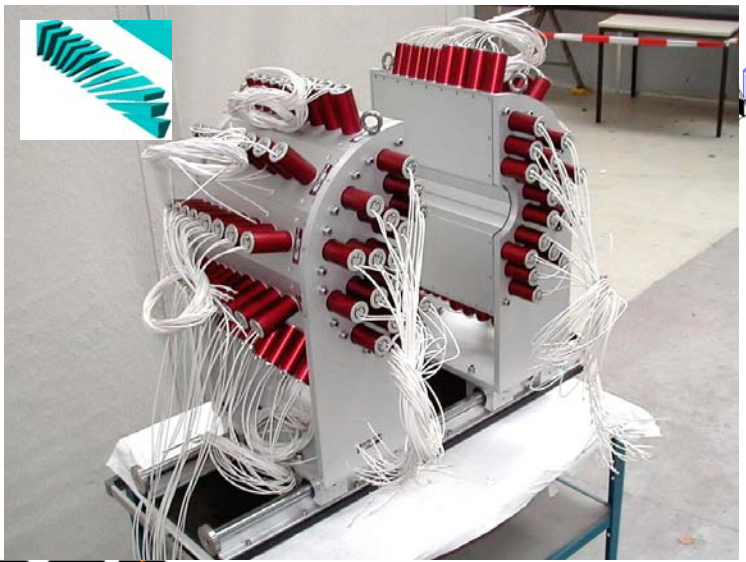
LAND electronics ~600 ch 7 → 1 + ε crates !



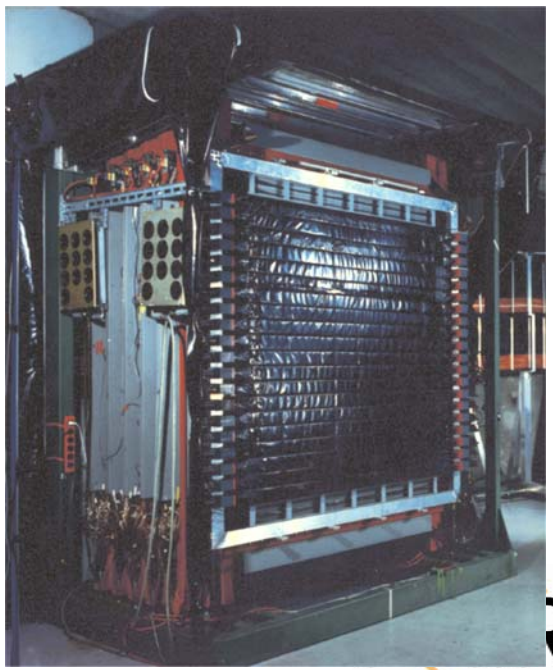
= 30 Tacquila cards with LAND FEE +
2 VME helper modules +
1 VME CPU
+ 10 VME QDCs
+ 3 HV bins







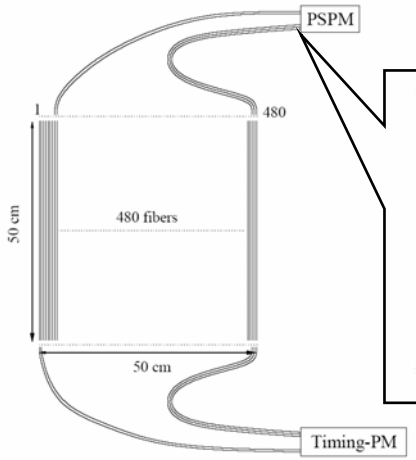
handling of complex detector response



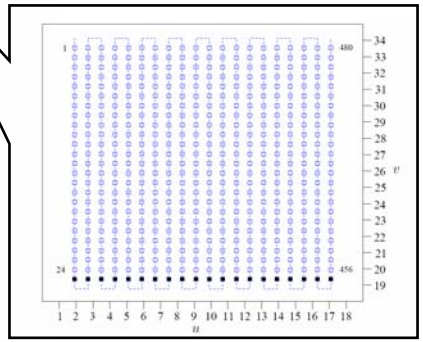
Simple example: Fibre detector

- position: automatic calibration

Hamamatsu R3941

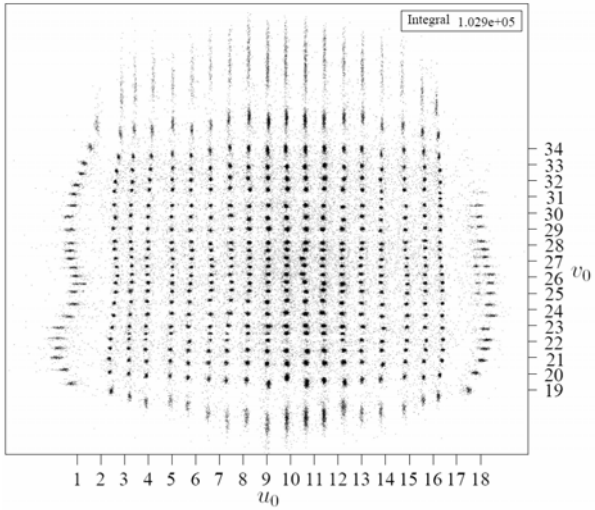


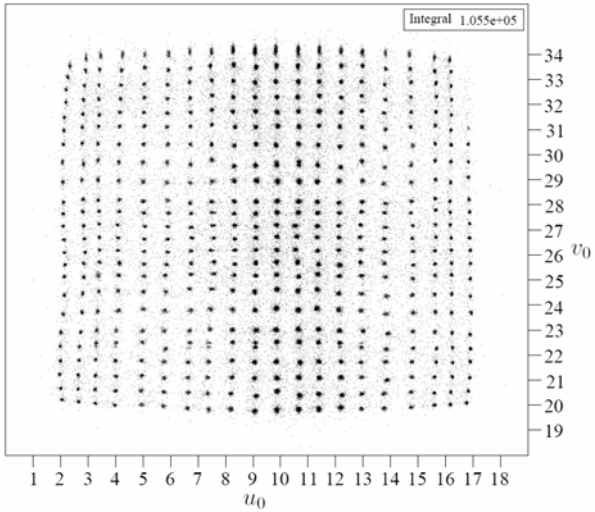
mechanical grid
with fibres



PSPM:
18(x) & 16(y) mesh wires
→ 34 QDC channels

(i) gain matching





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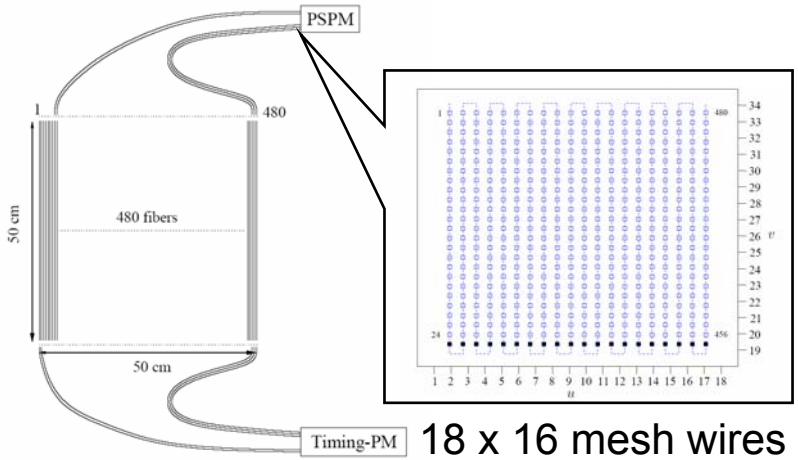
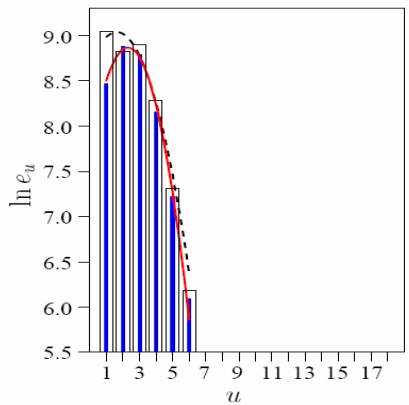
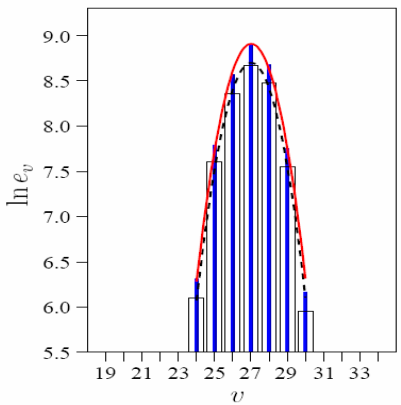


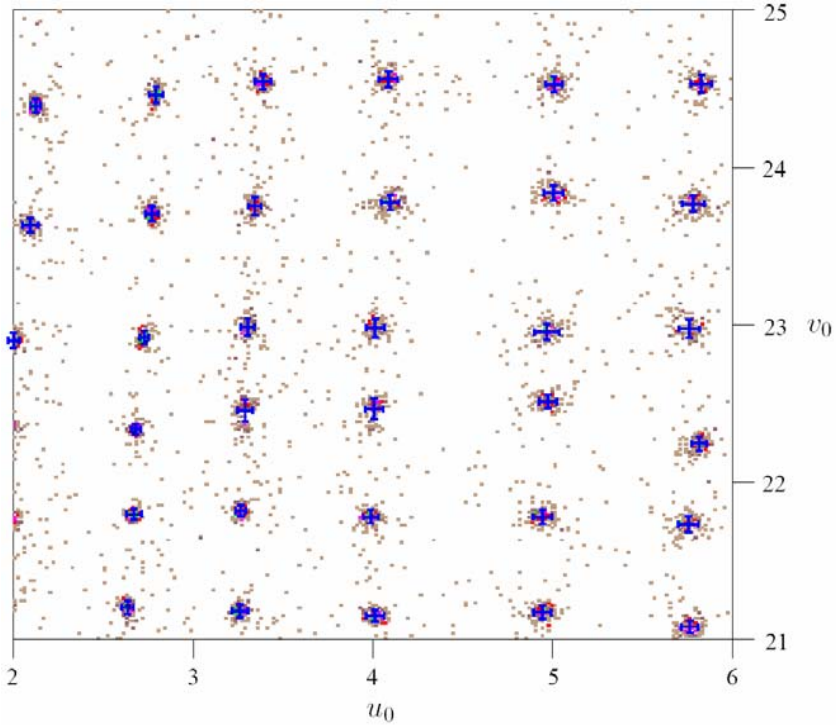
18 x 16 mesh wires
→ QDC

(ii) mean position on grid

least squares linear eq.
parabola ← ln e







Simple example: Fibre detector

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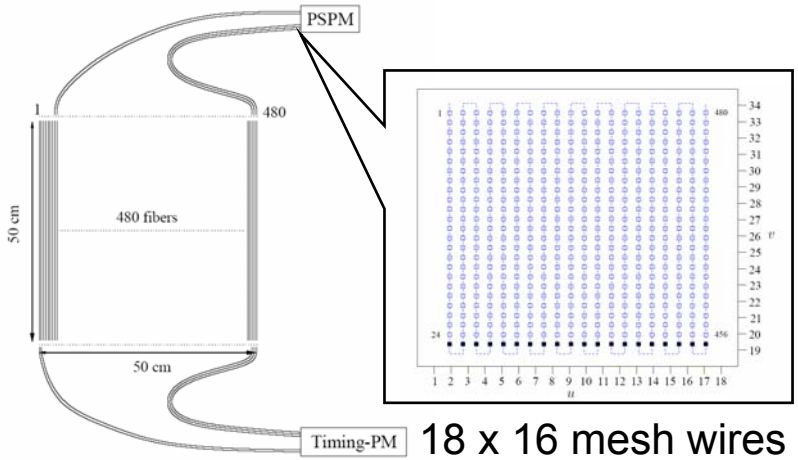
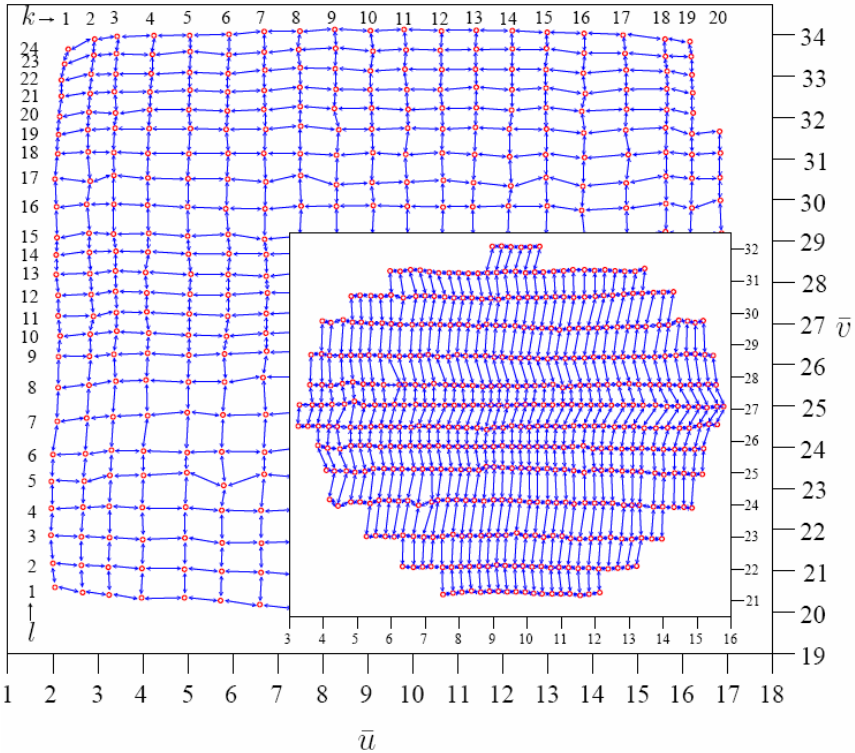
Hamamatsu R3941



18 x 16 mesh wires
→ QDC

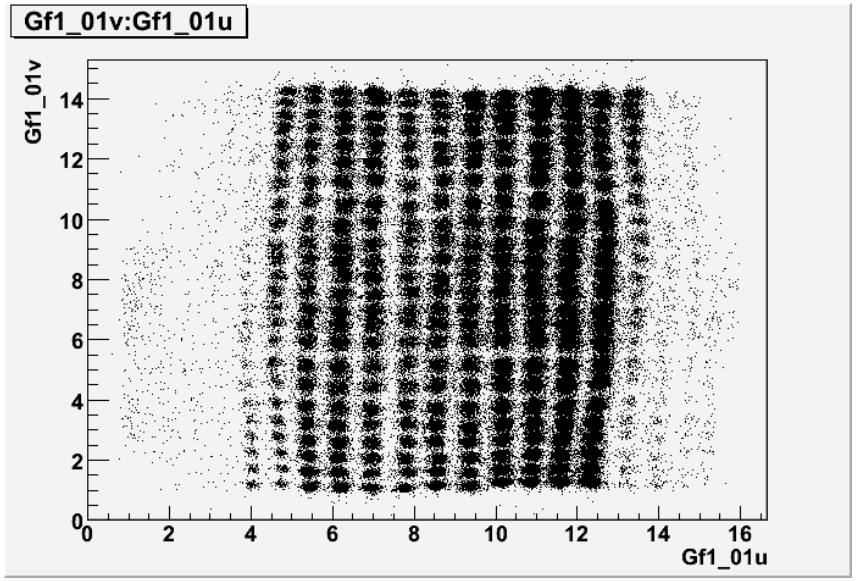
(iii) automated grid finding

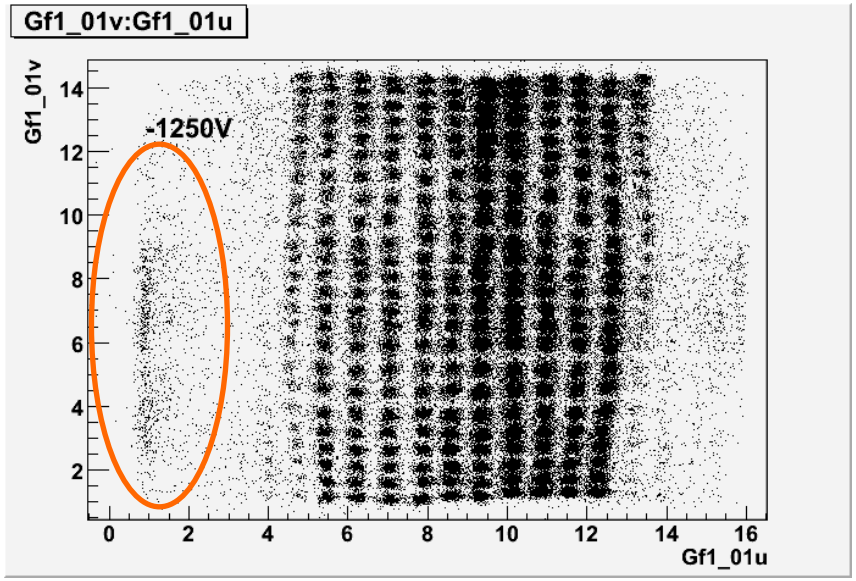


NIM paper in preparation …

Robustness !

Response depends on controls parameters





100 V HV change

- optimization couples slow control, online analysis and fast DAQ process

(iv) Summary

- High channel count / increased complexity → (dedicated) Front end electronics

- FEE design with (FPGA,DSP,CPU) allows for „intelligent detectors/sensors
  - calibration (5 Min/ch * ½ M ch ≈ 5 manyears !)
  - optimization

- Controls / DAQ / Online Analysis strongly interdependent

- FIN