Tracking and Q^2 determination for P2

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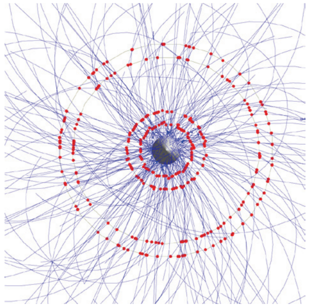
Trento, August 2016

Cluster of Excellence Precision Physics, Fundamental Interactions and Structure of Matter

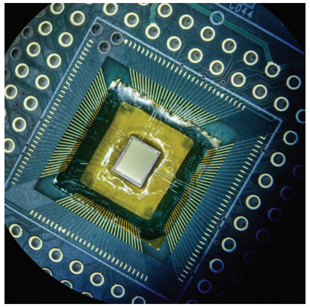
PRISMA

Overview



- The Challenge:

  Tracking a lot of low momentum particles



- Technical Solution:

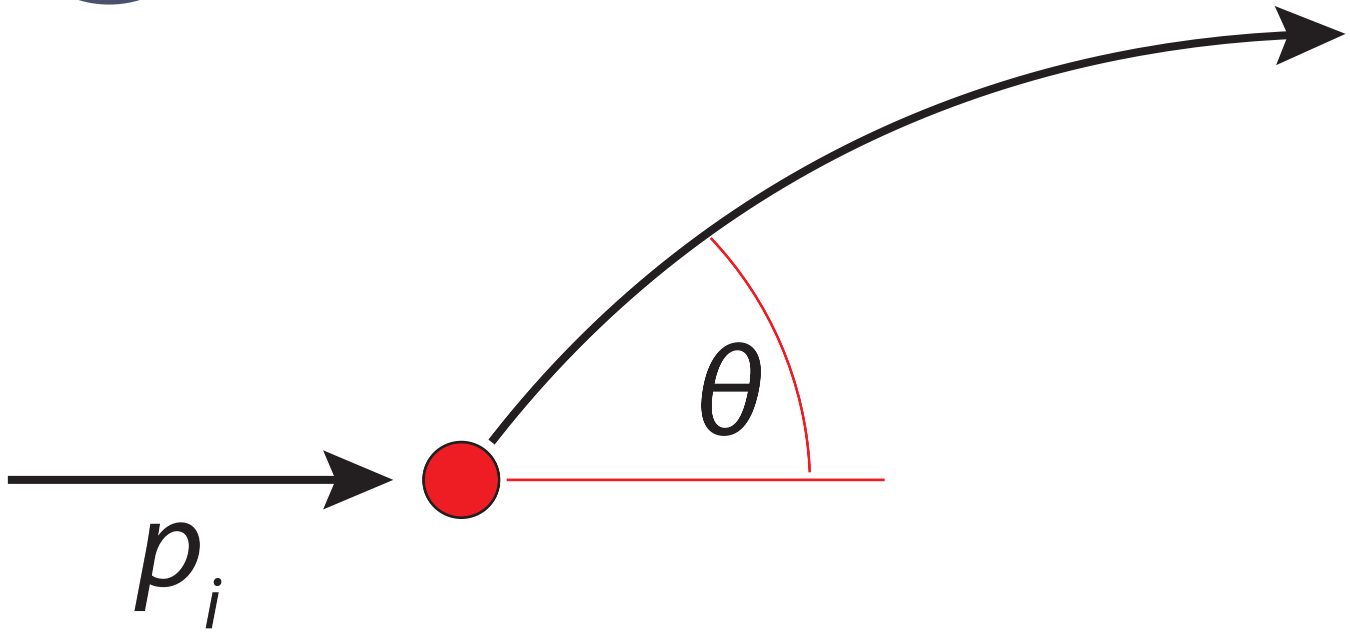
  High Voltage Monolithic Active Pixel Sensors

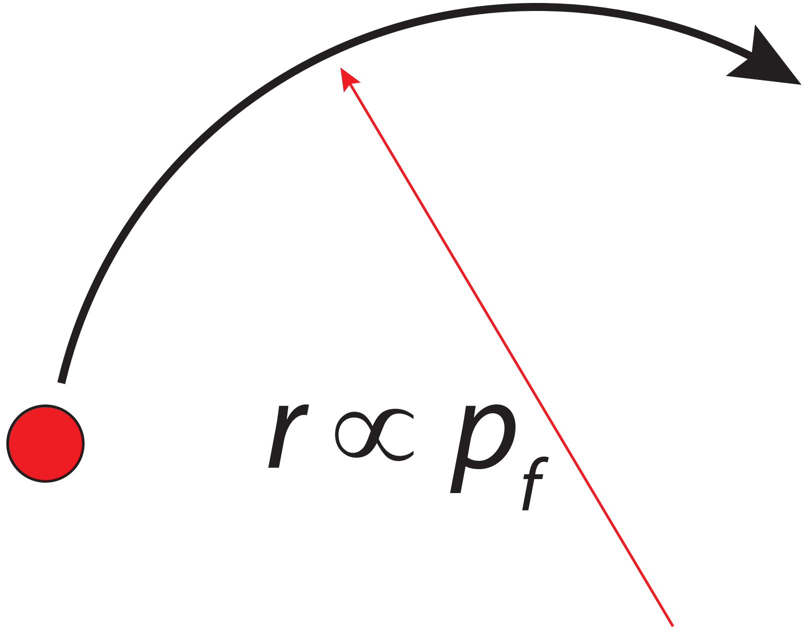
- Work in Progress:

  Geometry, Mechanics, Services

Why
tracking?

Elastic scattering, point target

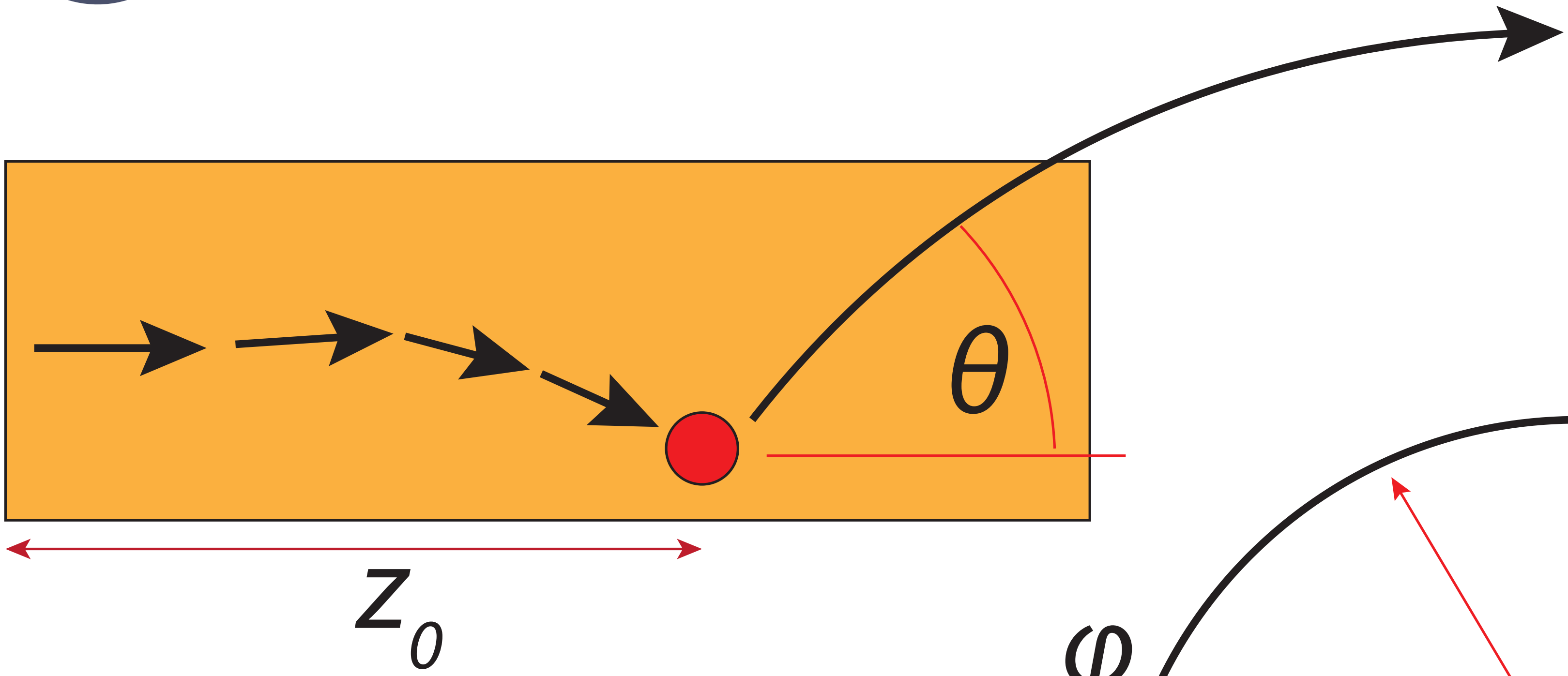


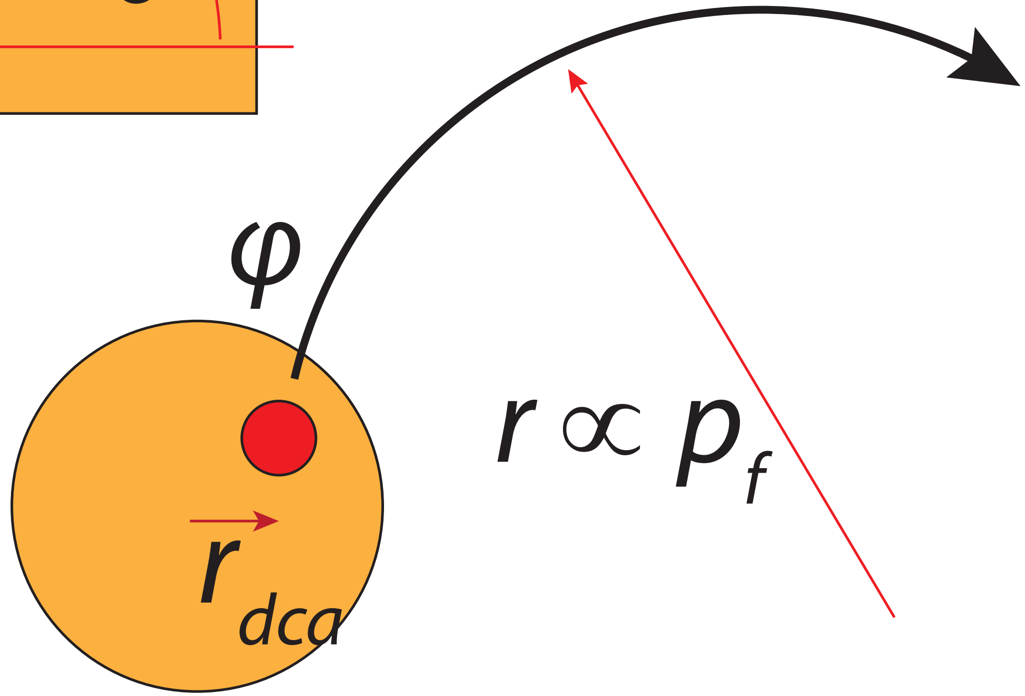


One free variable:

Measure scattering angle,
determine momentum, Q^2 etc.

Elastic scattering, extended target





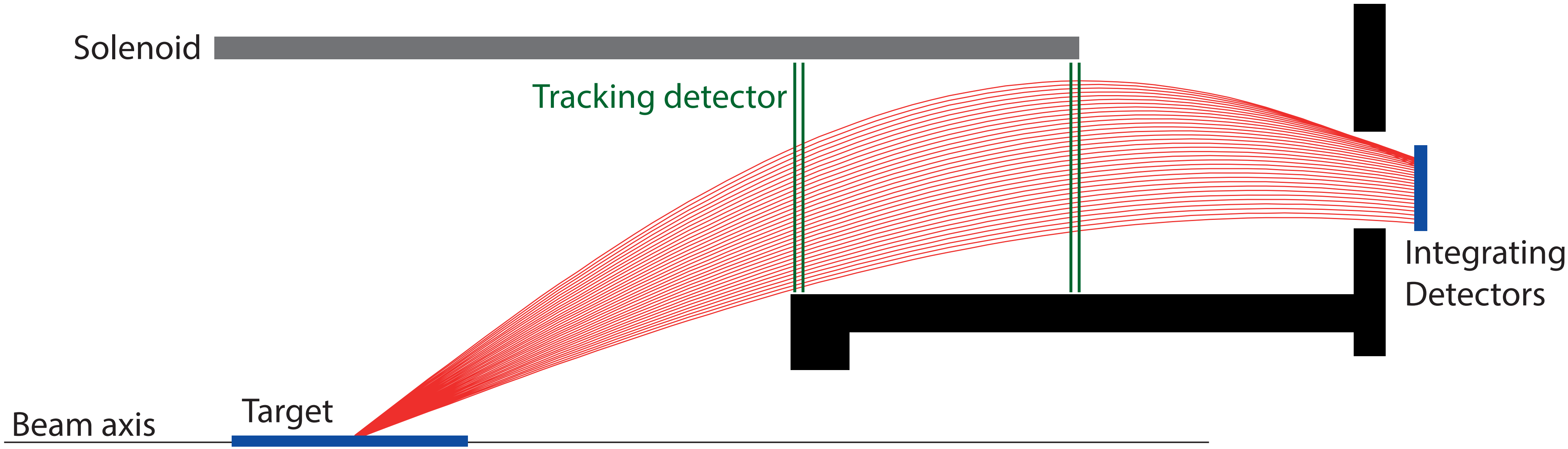
Initial momentum not known any more:
Reconstruct full track

- z_0 gives a handle on energy loss
- r_{dca} gives a handle on direction
- θ and p constrain scattering

Need full track with high precision

Inside solenoid: Background challenge

- Need enough path in field to measure bending
- See O(10^3) photons from target for every electron
- Have to track in inhomogeneous field
- Would like to run as close as possible to full beam rate
- Should not disturb integrating measurement



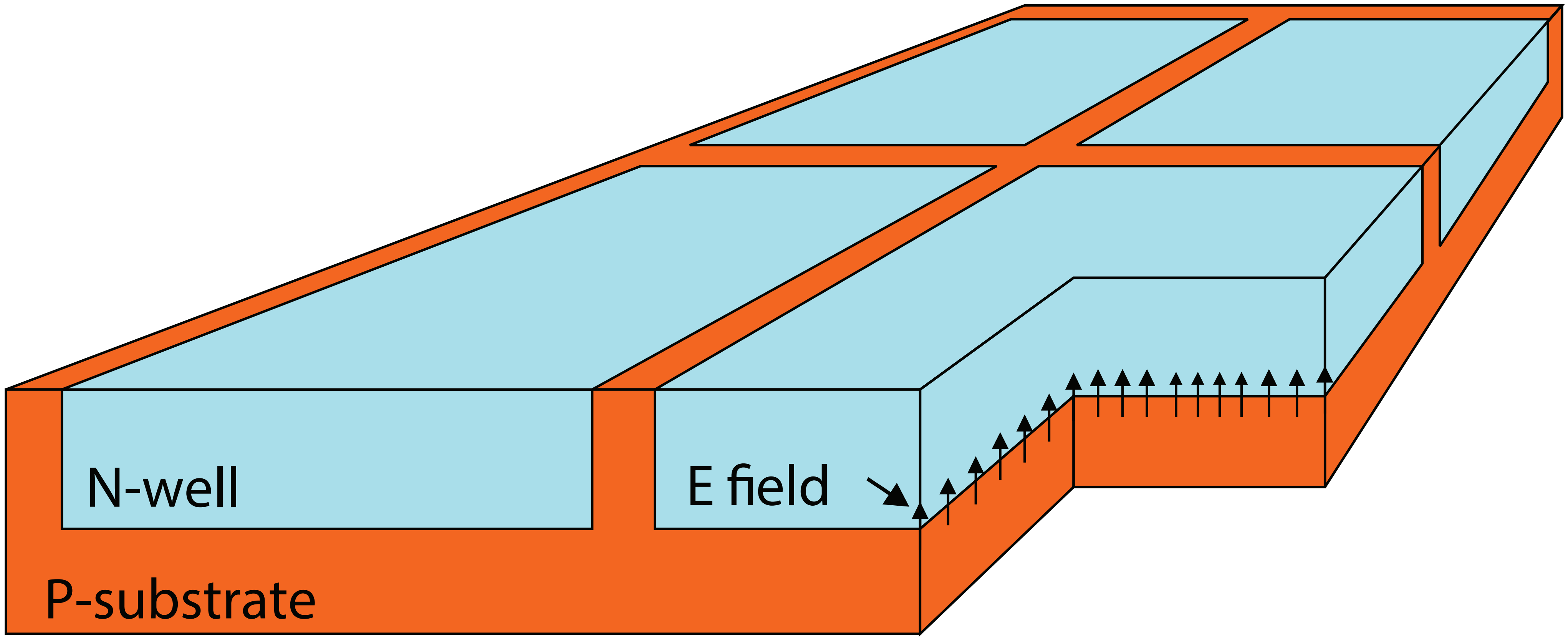
Fast, thin, cheap pixel sensors

High Voltage Monolithic Active Pixel Sensors

Fast and thin sensors: HV-MAPS

High voltage monolithic active pixel sensors - Ivan Perić

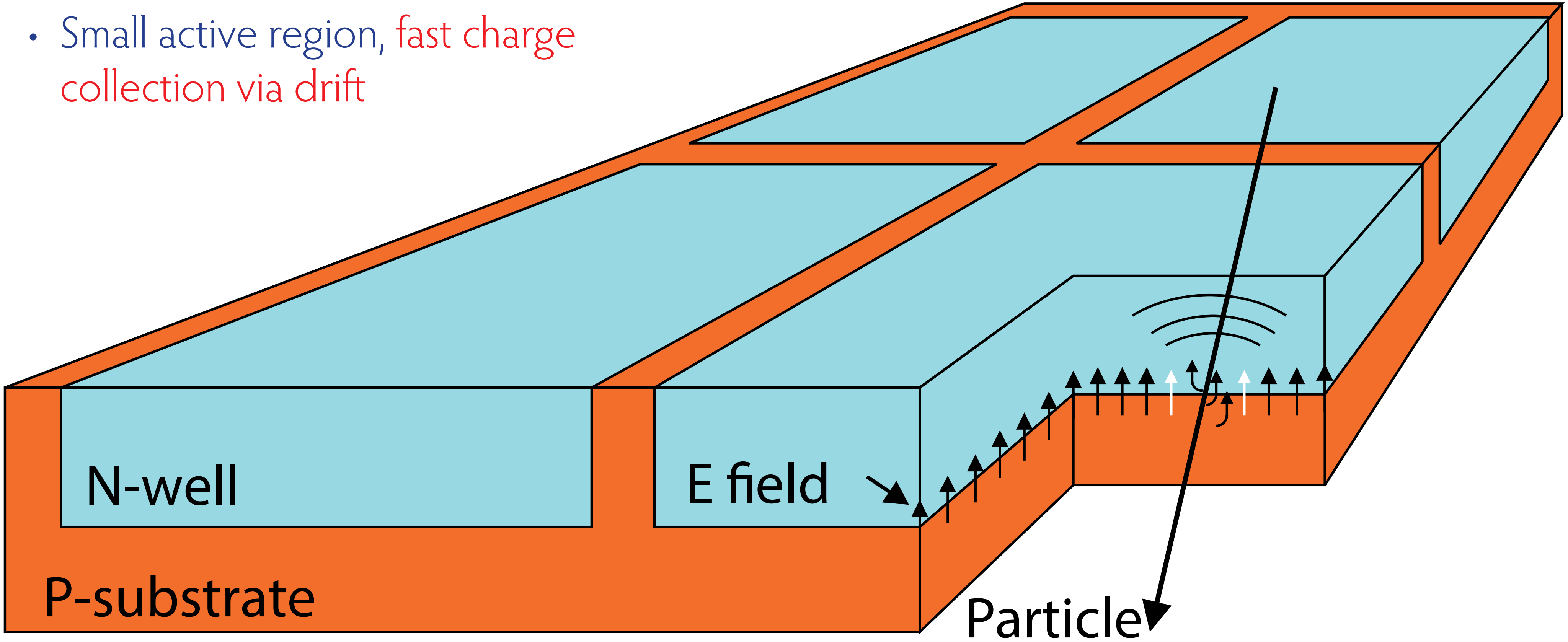
- Use a high voltage commercial process (automotive industry)



Fast and thin sensors: HV-MAPS

High voltage monolithic active pixel sensors - Ivan Perić

- Use a high voltage commercial process (automotive industry)
- Small active region, fast charge collection via drift



Fast and thin sensors: HV-MAPS

High voltage monolithic active pixel sensors - Ivan Perić

- Use a high voltage commercial process (automotive industry)
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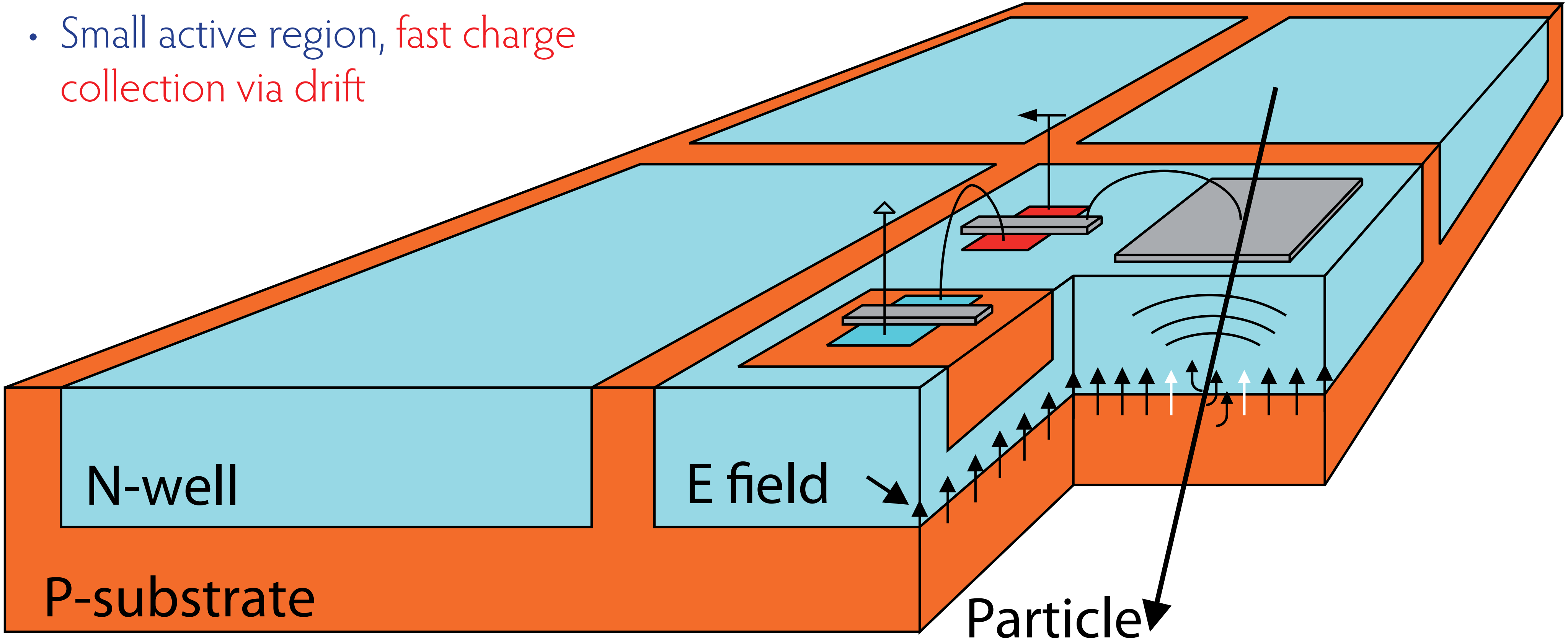
- Implement logic directly in N-well in the pixel - smart diode array

(I.Perić, P. Fischer et al., NIM A 582 (2007) 876)

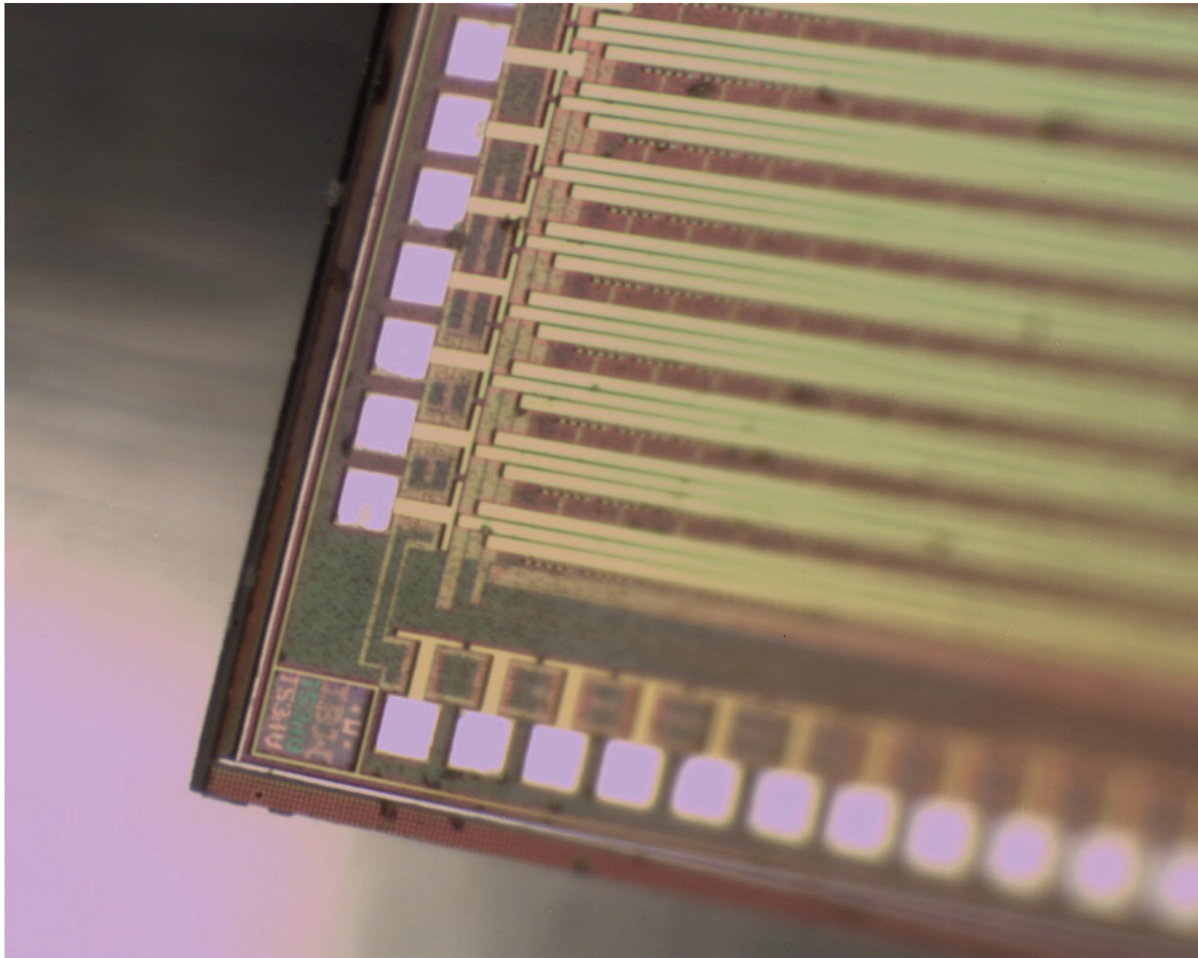


Fast and thin sensors: HV-MAPS

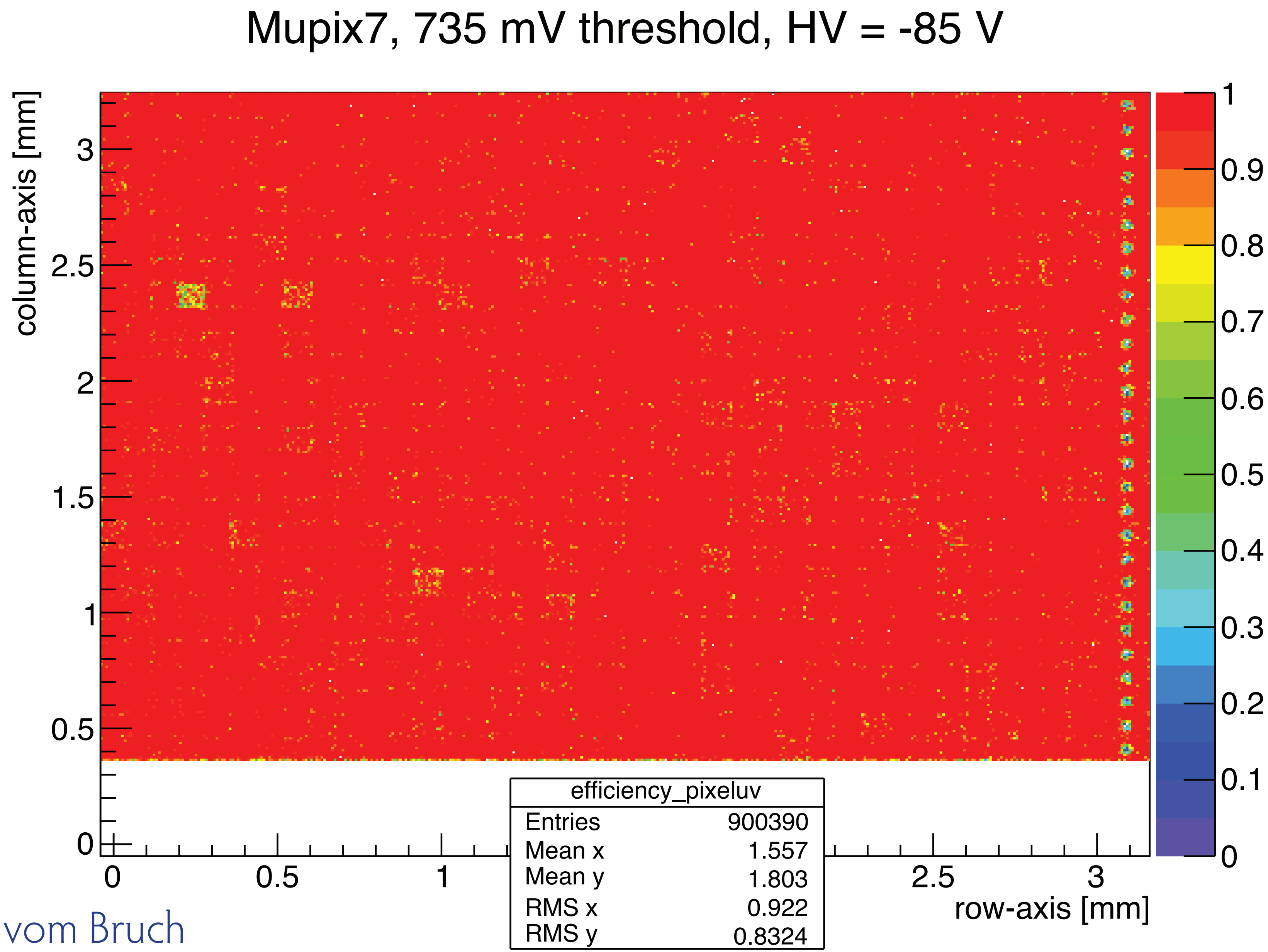
High voltage monolithic active pixel sensors - Ivan Perić

- Use a high voltage commercial process (automotive industry)
- Small active region, fast charge collection via drift

- Implement logic directly in N-well in the pixel - smart diode array
- Can be thinned down to < 50 µm



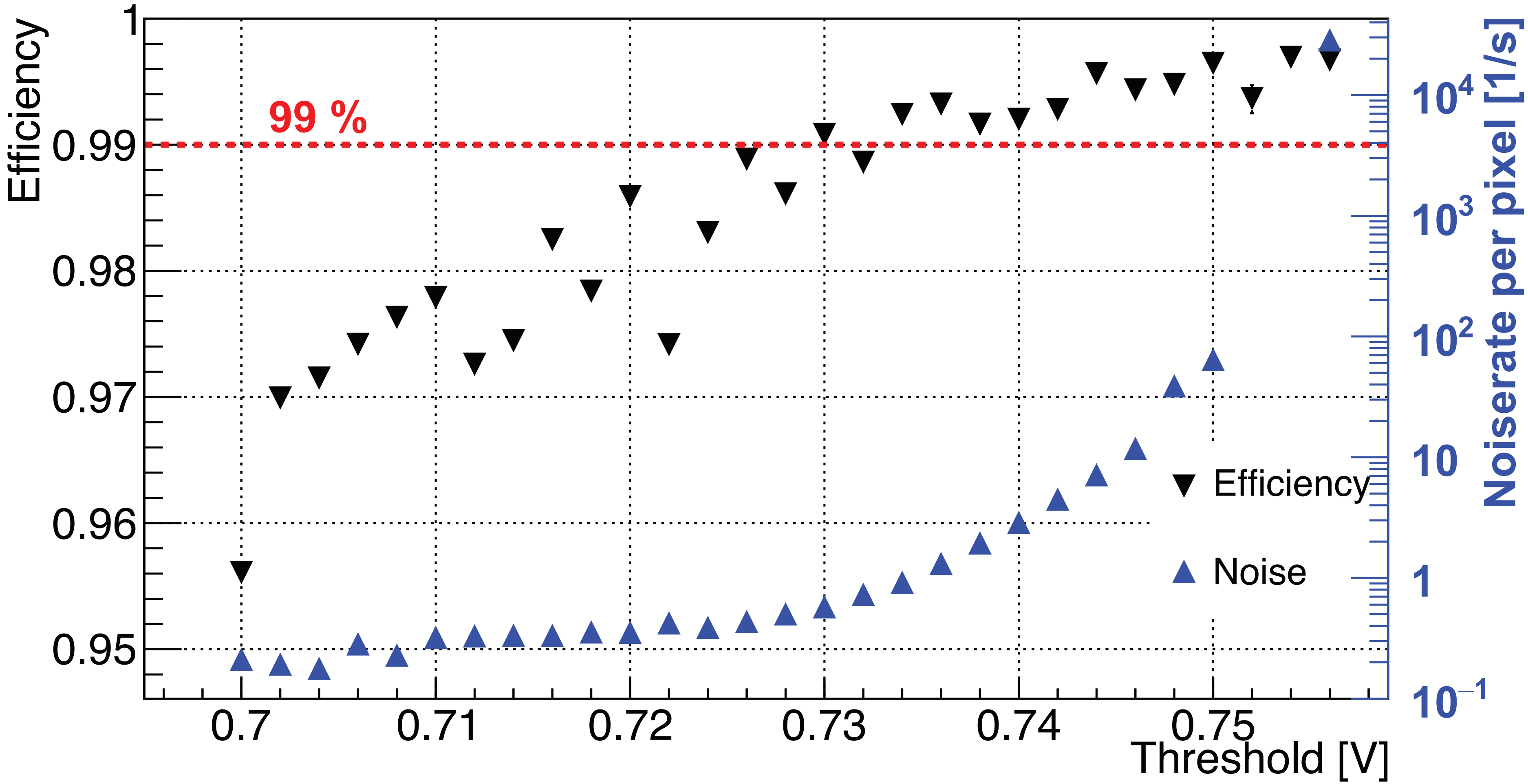
Performance: efficiency



Dorothea vom Bruch

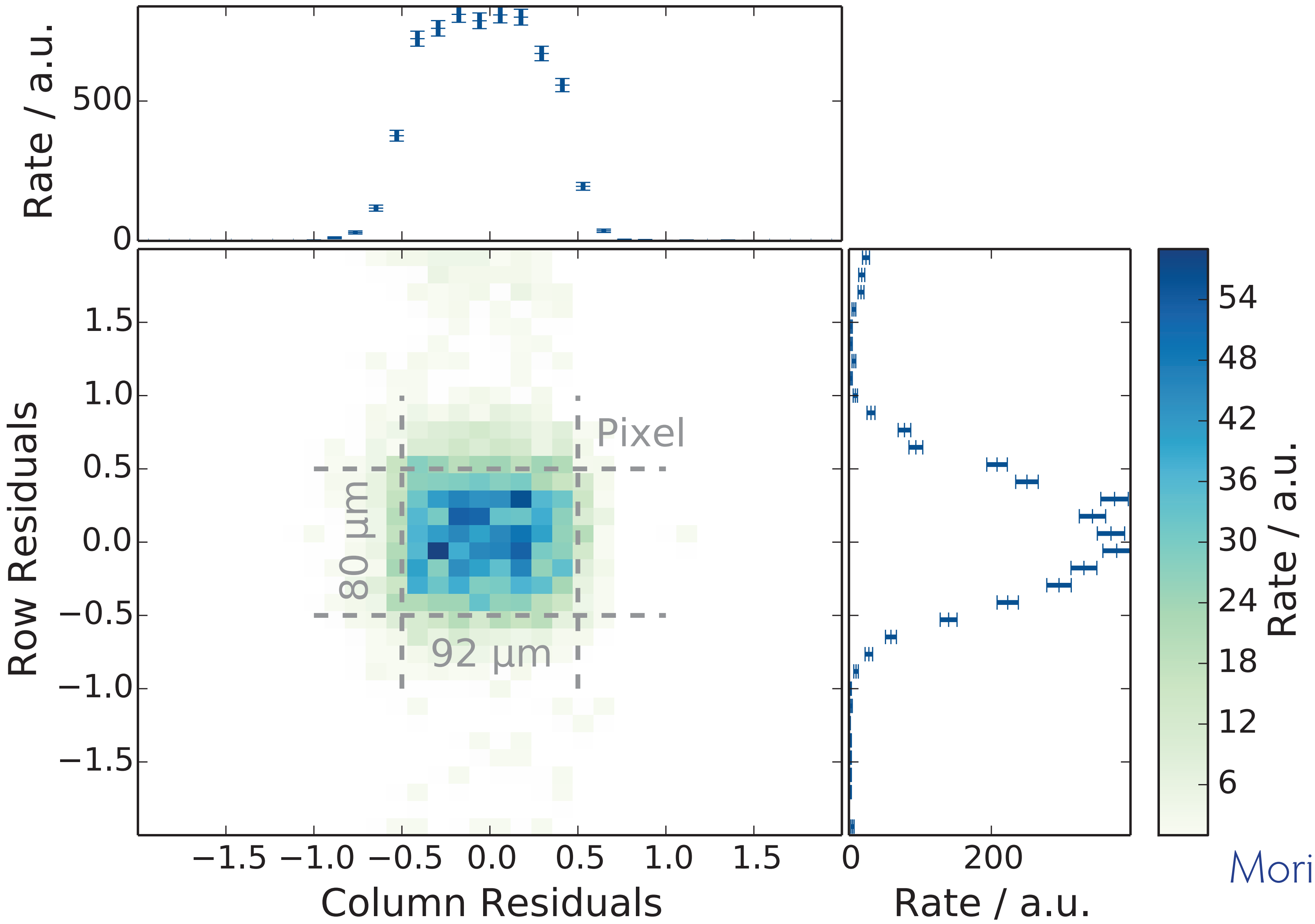
Performance: efficiency and noise

Lennart Huth



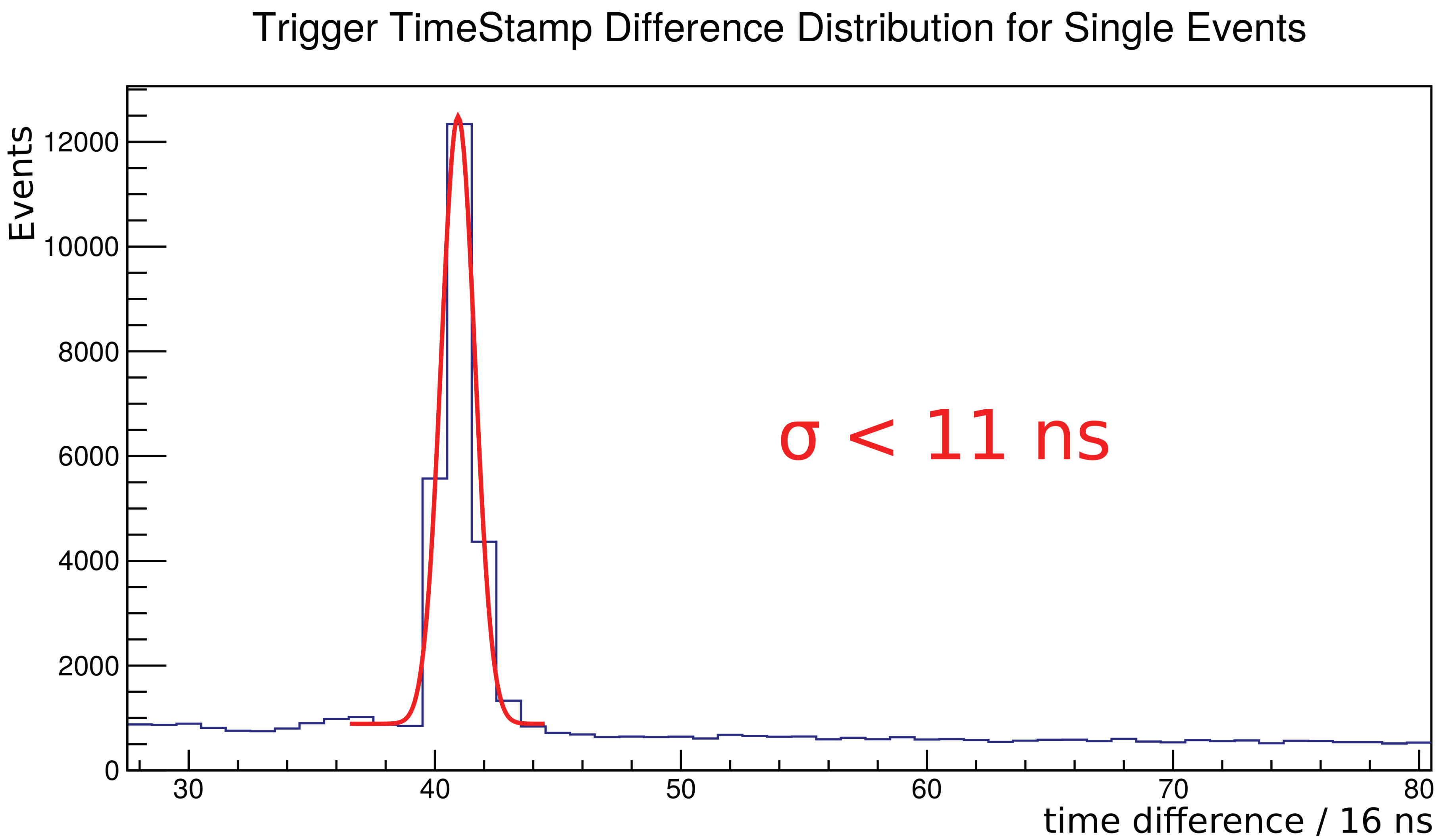
Position Resolution

Position resolution given by pixel size

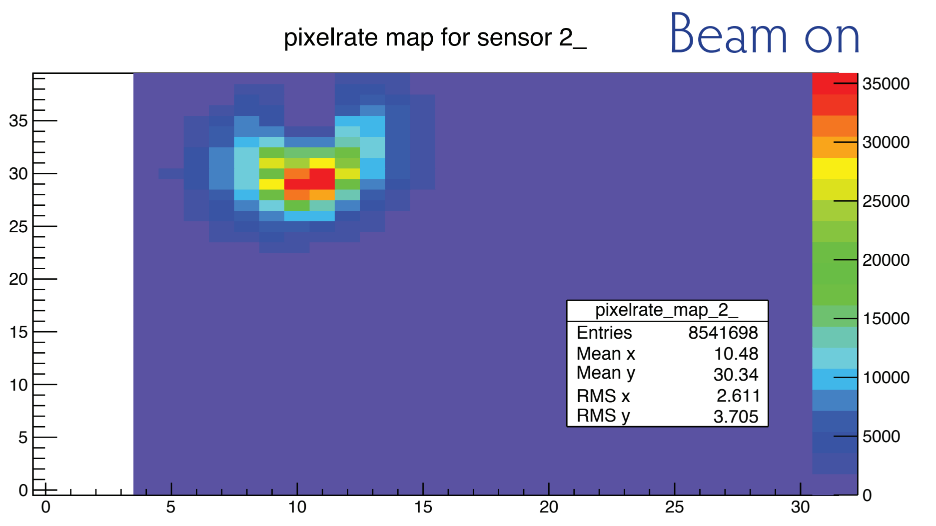


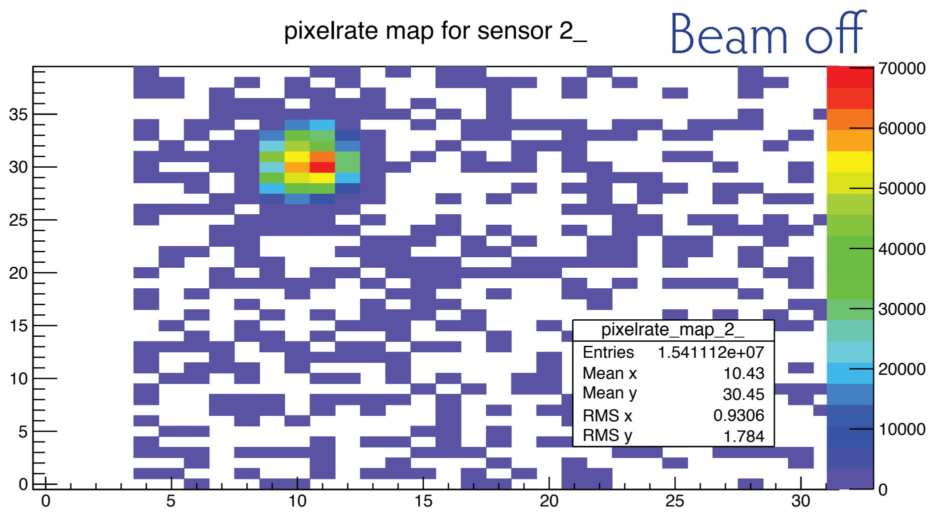
Moritz Kiehn

Performance: time resolution



Radiation Hardness

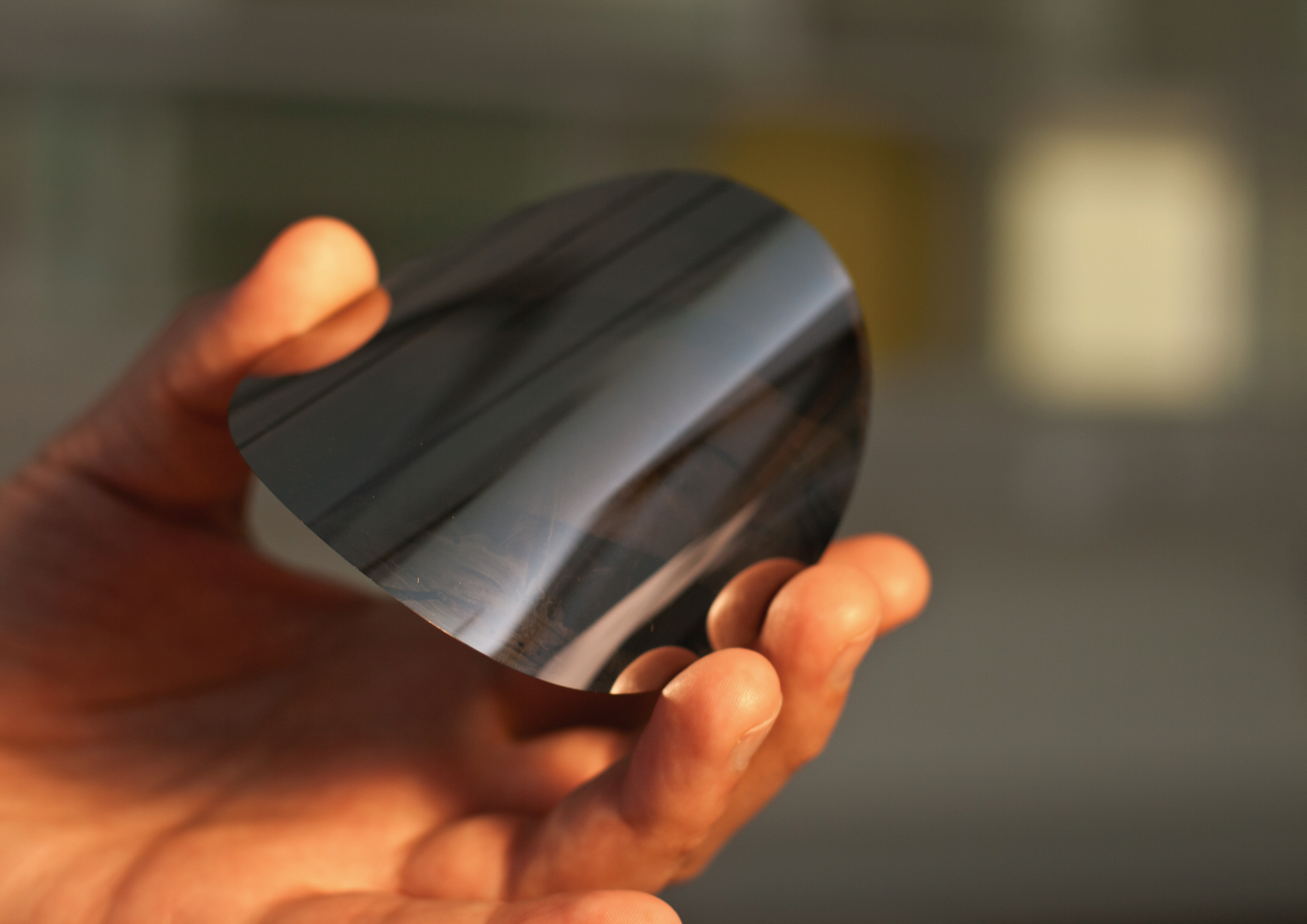


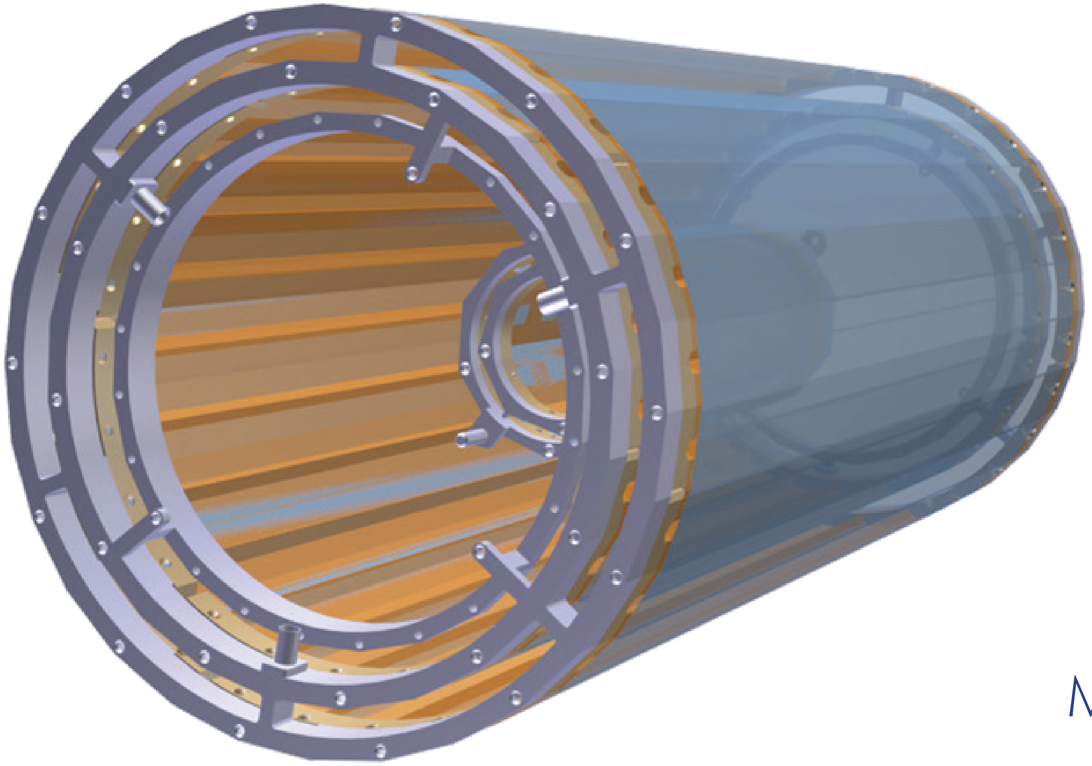


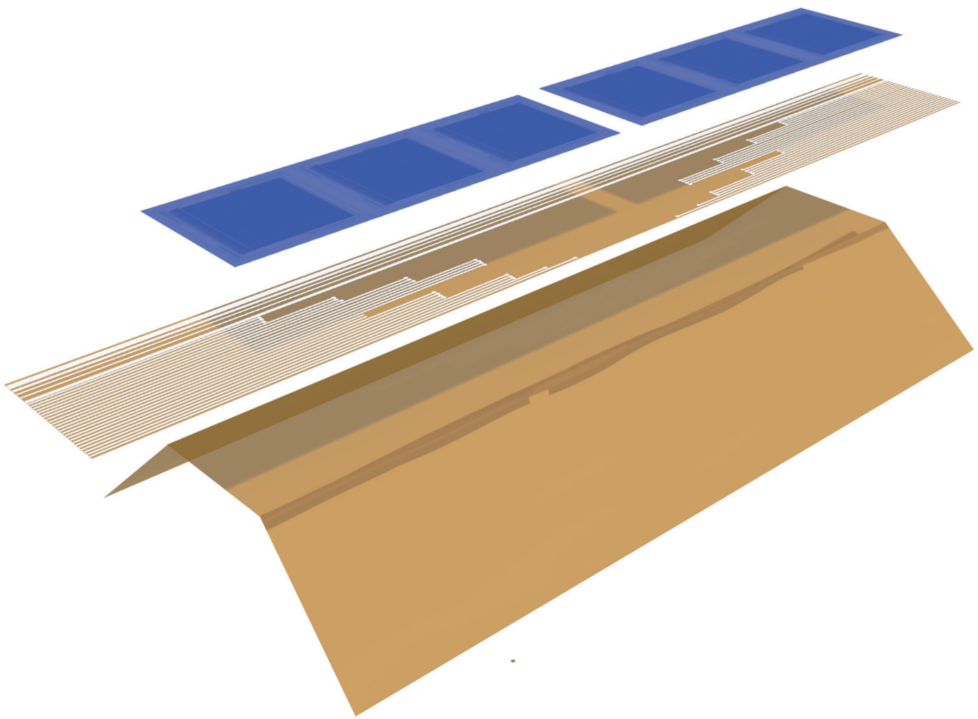
- Technology also discussed in ATLAS
- Irradiation campaign ongoing, so far:
- Chips work after 862 MRad X-Rays
- Chips work after $2 \cdot 10^{15}$ n/cm^2
- Also after $2 \cdot 10^{15}$ n_{eq}/cm^2 protons

- Last test beam in Mainz: Charge-up (?) seen at rates in excess of 40 KHz/pixel (~0.5 GHz/cm^2, more than full P2)
- Only two out of four sensors
- Under study - beam time in September

Alexey Tyukin







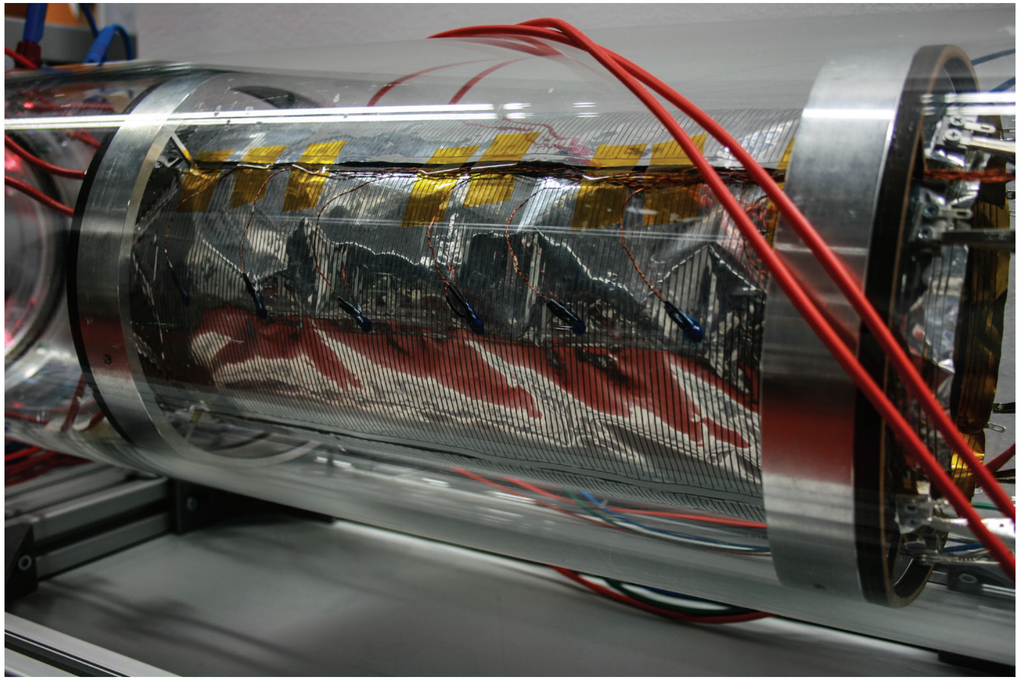
Mu3e prototyping (Heidelberg)

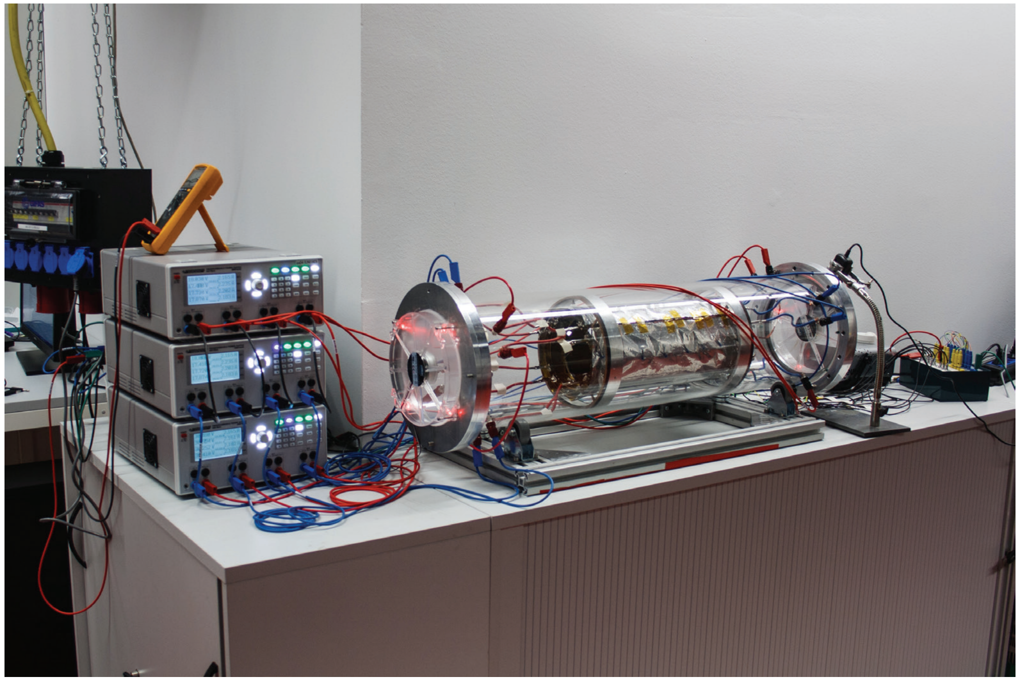
- 50 μm silicon
- 25 μm Kapton™ flexprint with aluminium traces
- 25 μm Kapton™ frame as support
- Less than 1‰ of a radiation length per layer

Cooling

- Add no material:
  Cool with gaseous Helium
  (low scattering, high mobility)
- ~ 300 mW/cm^2 - total >2 kW
- Simulations: Need ~ several m/s flow

- Full scale heatable prototype built for Mu3e
- 36 cm active length
- Vibrations under control (Michelson interferometer)

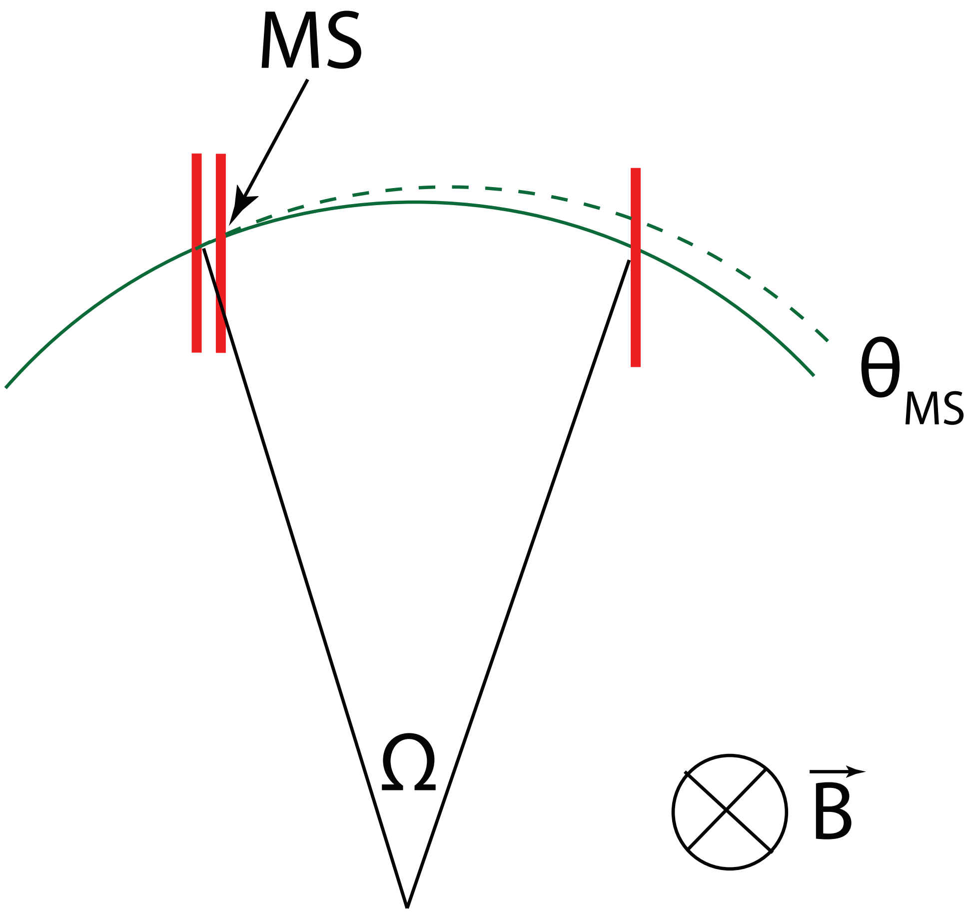




Work in progress:

Mechanics, Services, Geometry, Readout, Reconstruction, ...

Momentum measurement

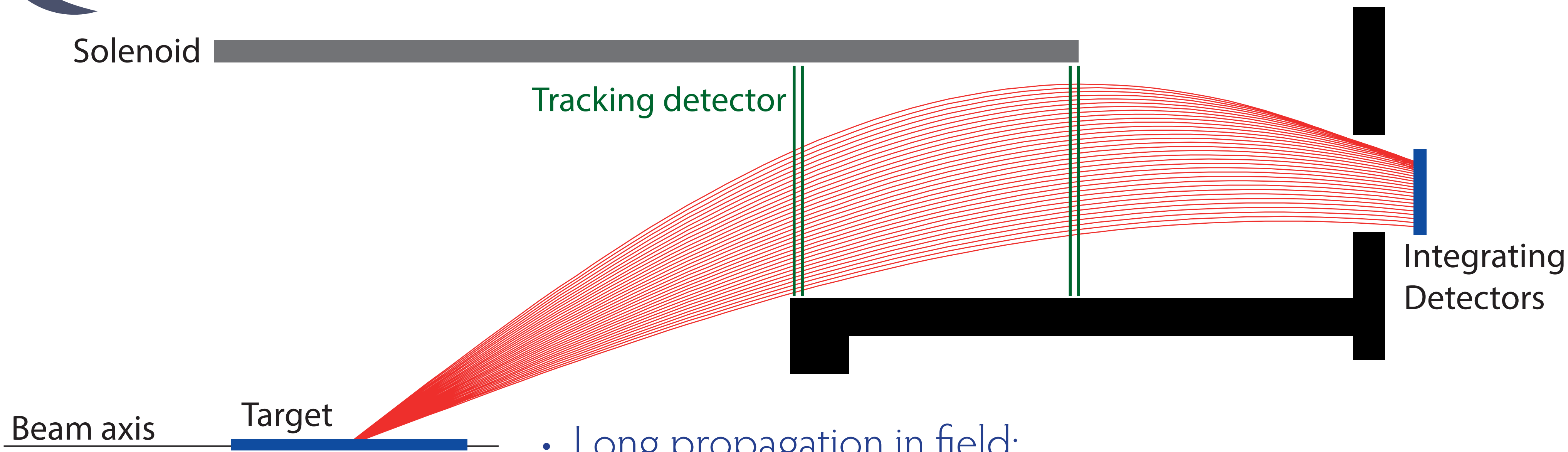


- Resolution dominated by multiple scattering
- Momentum resolution to first order:

$$\sigma_P / P \sim \theta_{MS} / \Omega$$

- Precision requires large lever arm (large bending angle Ω) and low multiple scattering θ_{MS}

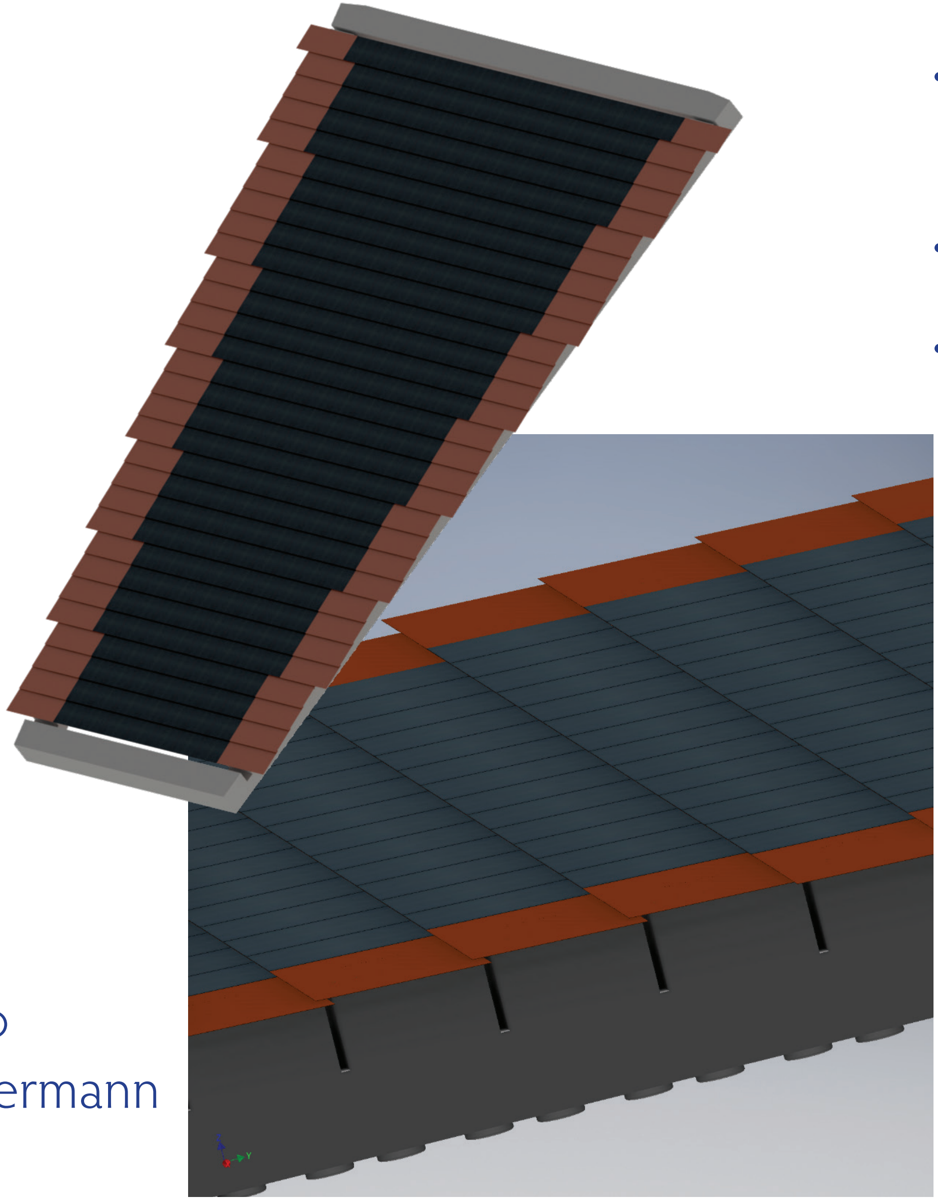
Tracker geometry



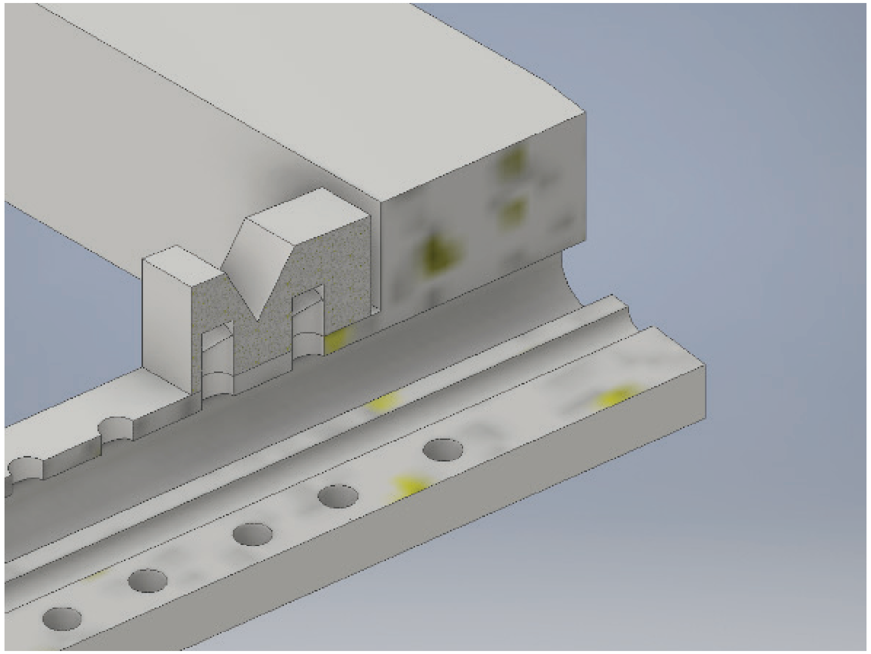
- Long propagation in field:
  Momentum resolution
- Double planes:
  Ease of reconstruction
- Two plane pairs:
  Minimum material
- Partial azimuthal coverage:
  cost reduction

Tracker module

- One layer phi-slice
- Flexprints with chips mounted to plastic/ carbon frame
- Frame distributes cooling helium
- Integrated PCB for signal transmission and powering

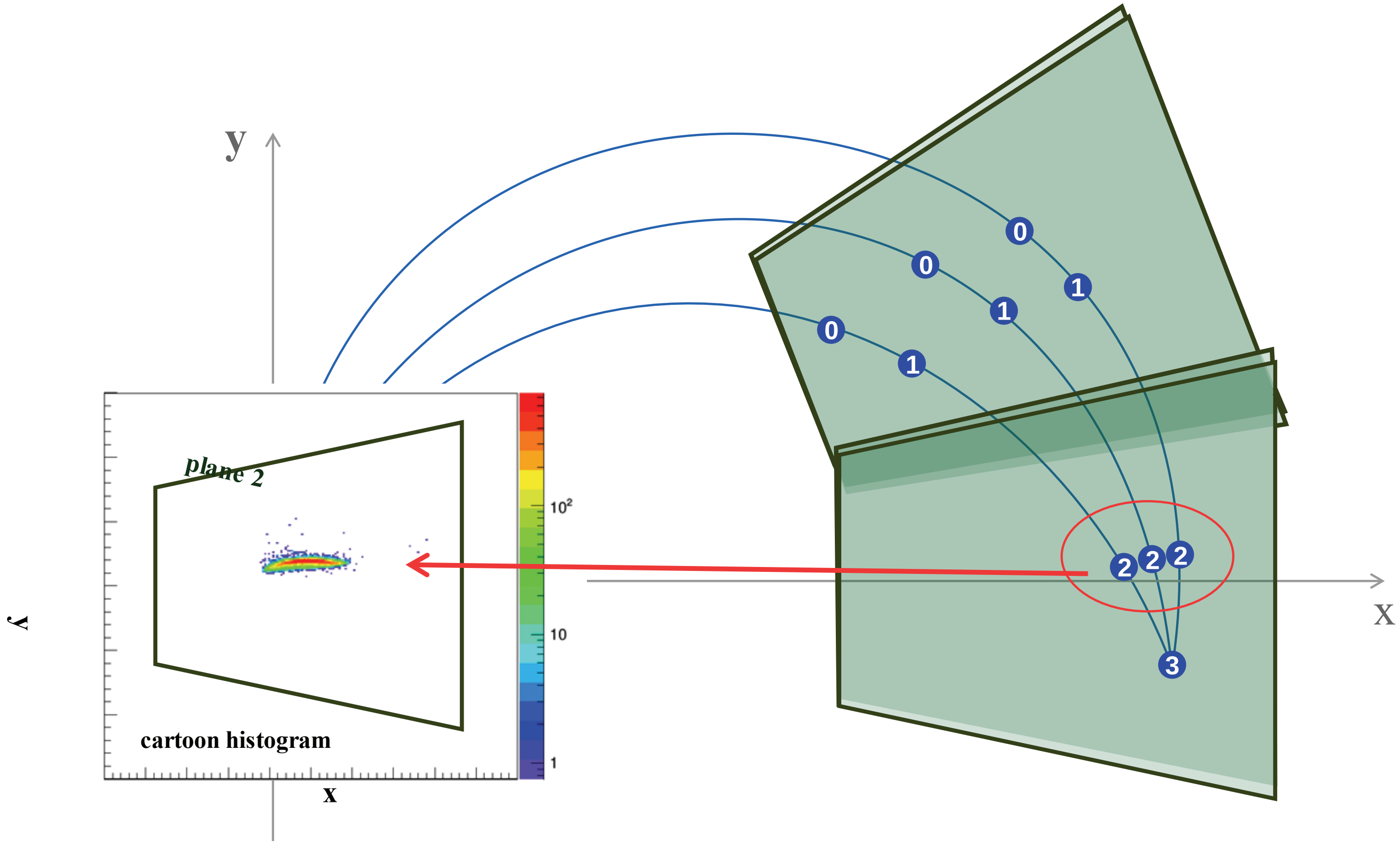


Marco Zimmermann



Track finding

- Narrow momentum range allows for efficient parametrization
- Start from back planes, extrapolate towards target



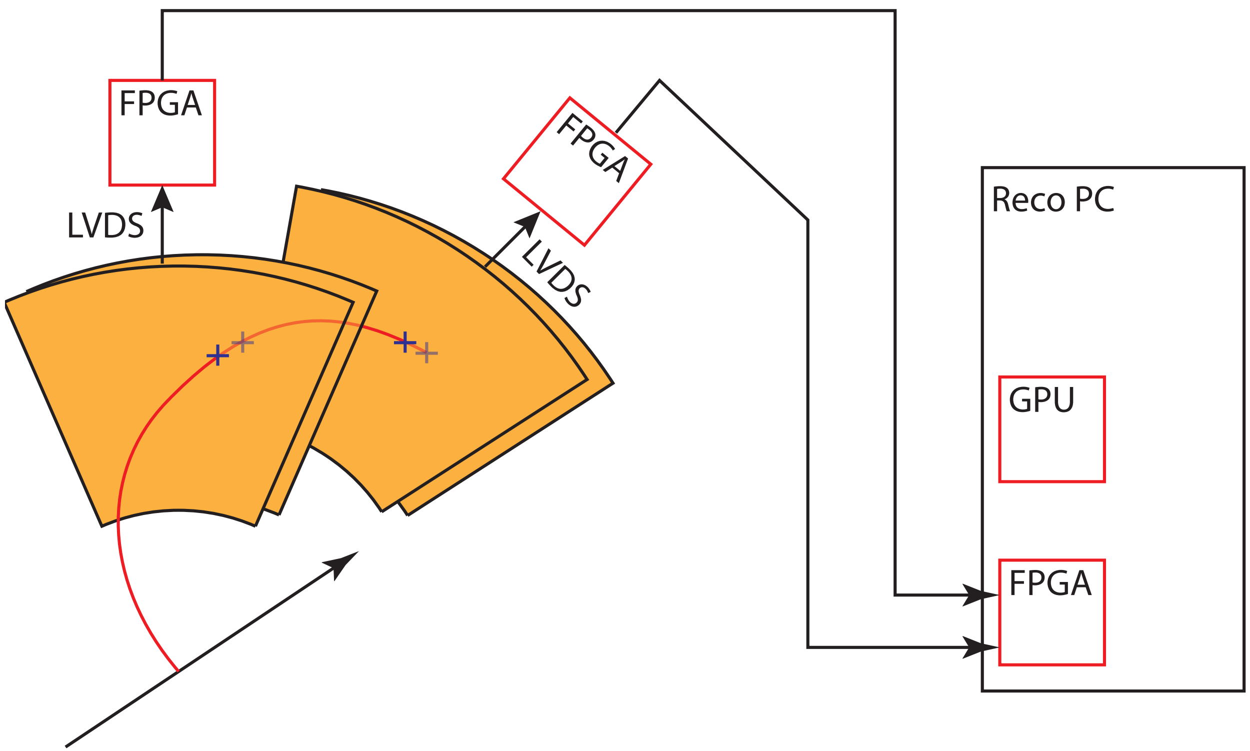
Current performance:
~ 1% fake rate at 10% nominal rate

~ 1/1 fake/real tracks at full rate

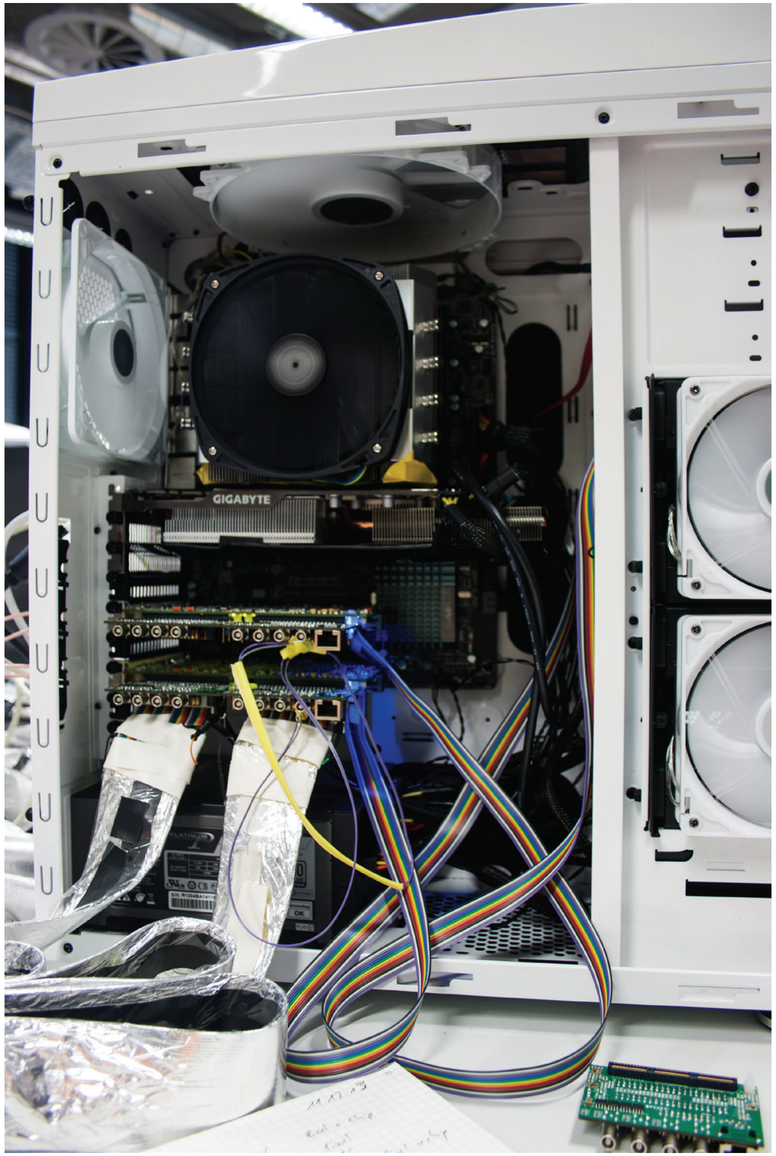
Iurii Sorokin

Data acquisition / online reconstruction

- Algorithms well suited for FPGA implementation
- Localized track search - simple readout topology
- Online reconstruction: Rate too high for complete storage



Online filter farm - similar to Mu3e

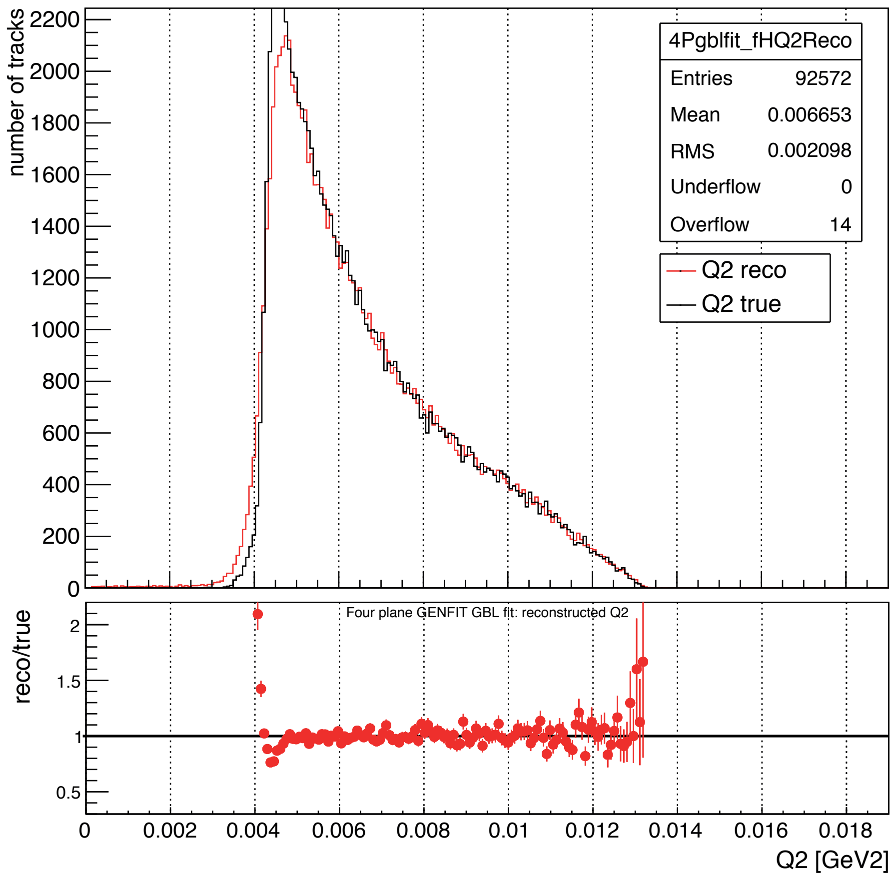


Online software filter farm

- Continuous front-end readout (no trigger)
- ~ 1 Tbit/s
- PCs with FPGAs and Graphics Processing Units (GPUs)
- Online track reconstruction
- 10^9 3D track fits/s achieved

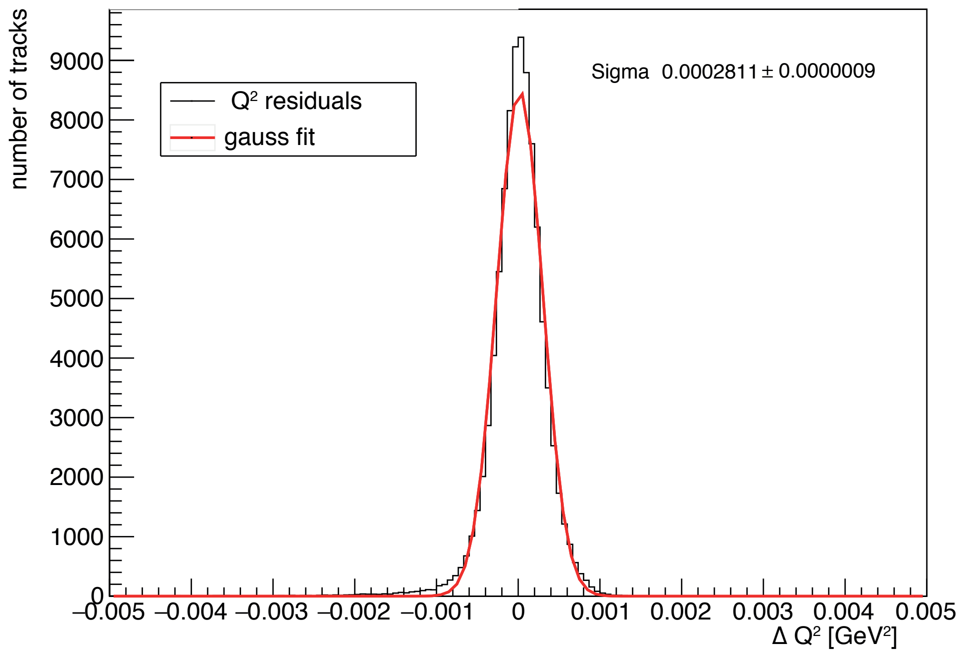
Performance

Reconstructed Q^2

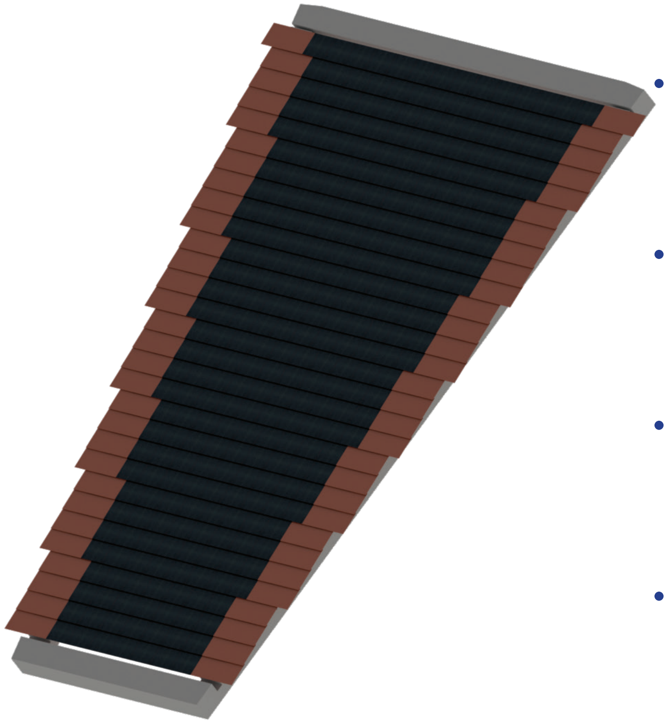


Alexey Tyukin

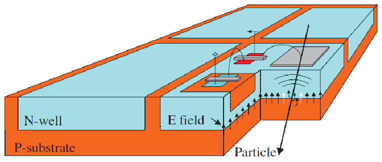
- Reconstructed Q^2 resolution 4.2% per track
- Sub-percent resolution with very few tracks
- All the work in the systematics - under study
- Can we also obtain a tracker/pixel asymmetry?



Conclusion



- HV-MAPS well suited for tracking in P2
- Can build detector layers thinner than a hair



- Reconstruct tracks online
- Can track at or close to full rate
- What else can we do?

Backup Material

MUPIX electronics