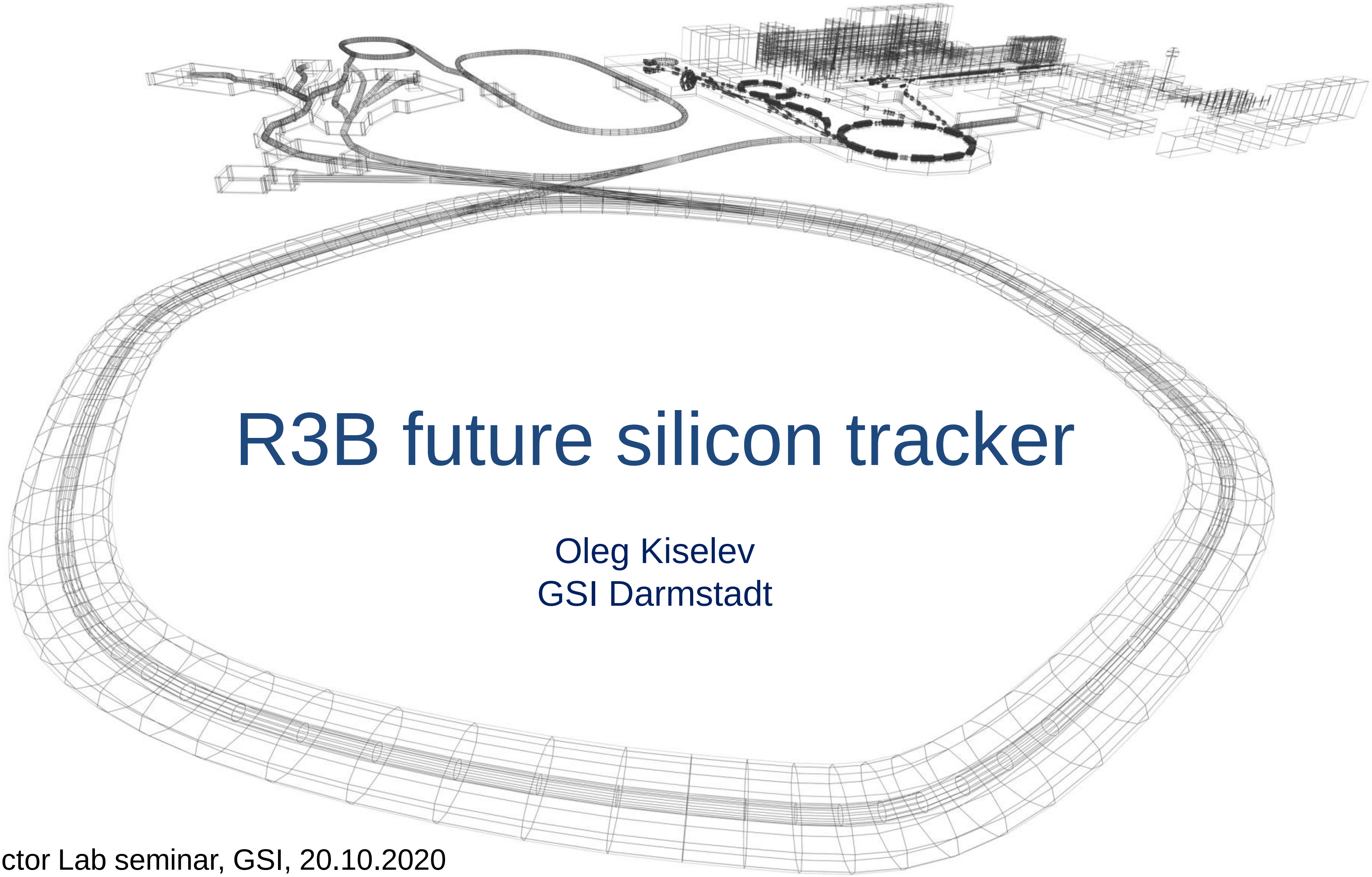
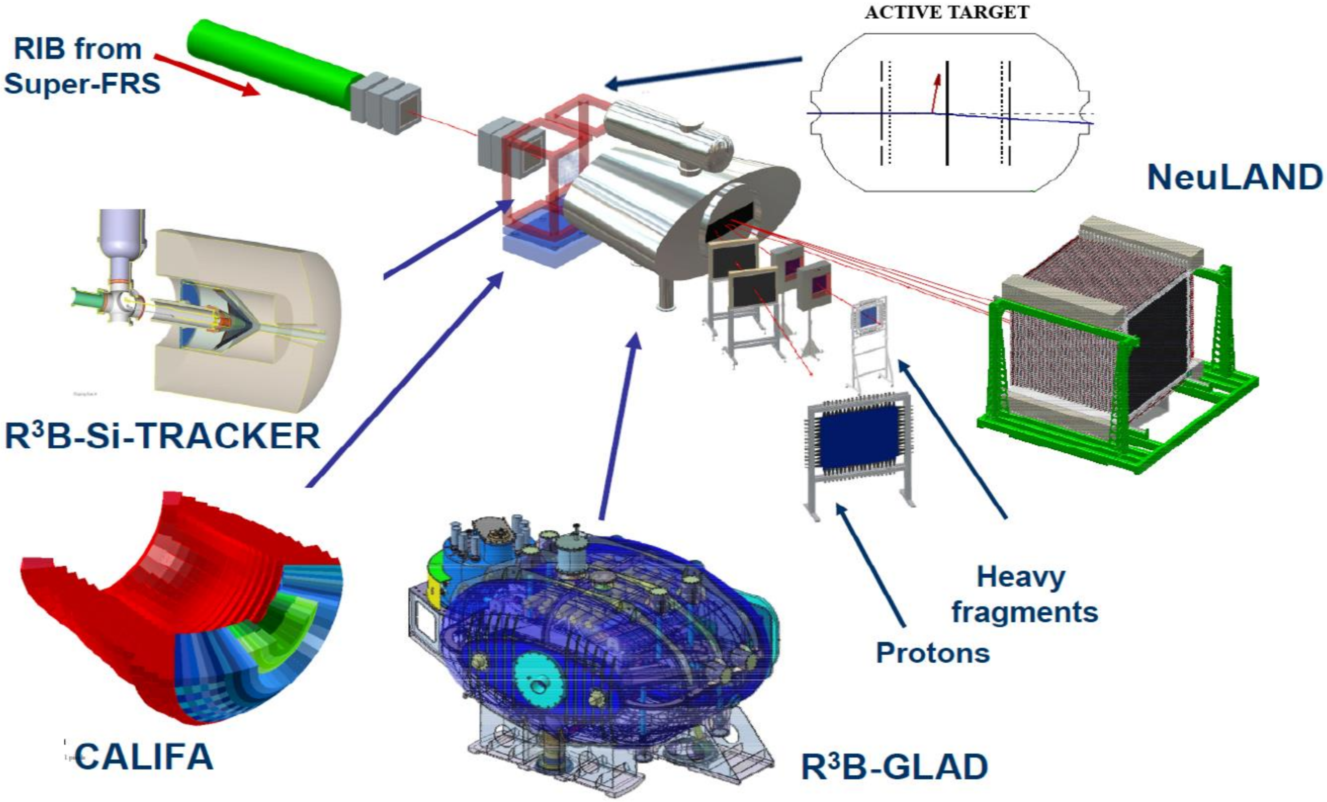


R3B future silicon tracker

Oleg Kiselev
GSI Darmstadt

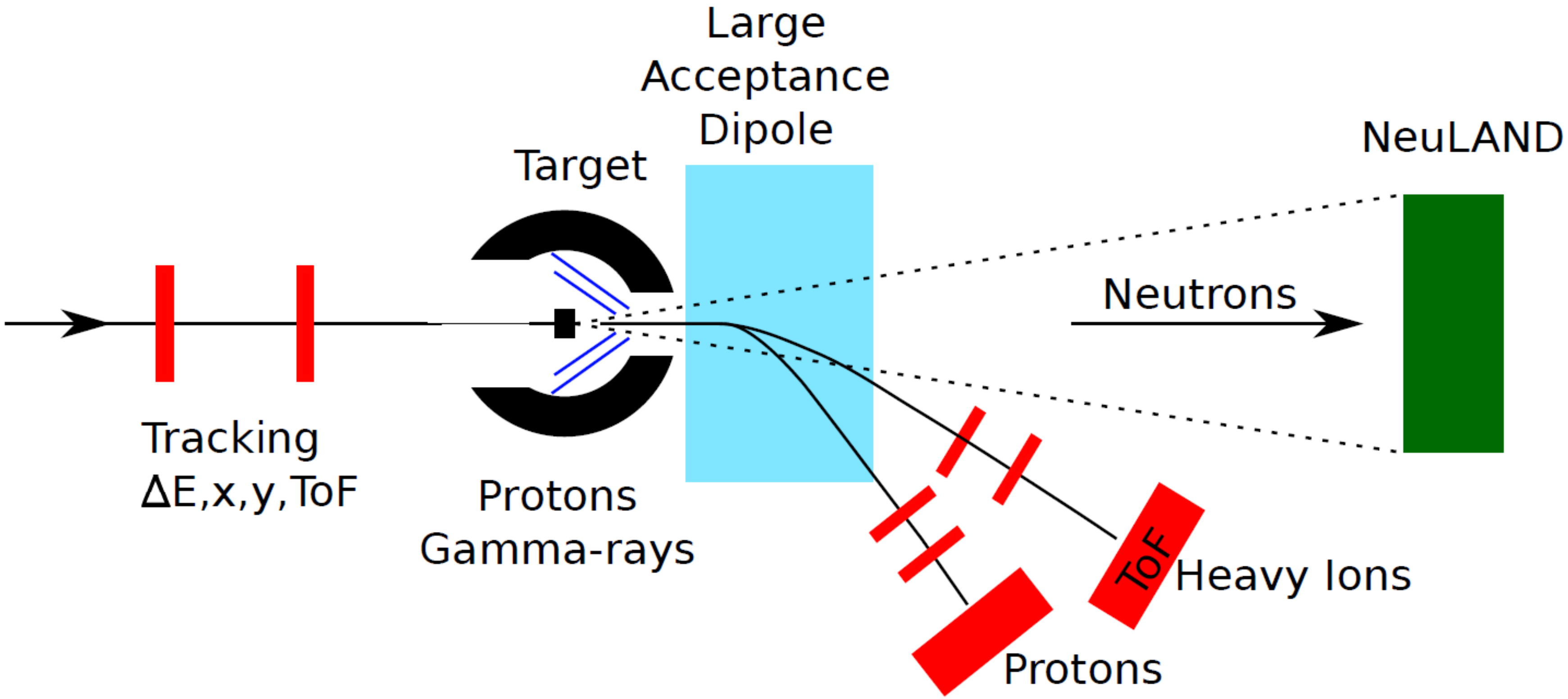
Detector Lab seminar, GSI, 20.10.2020

R3B (Relativistic Reactions with Radioactive Beams)



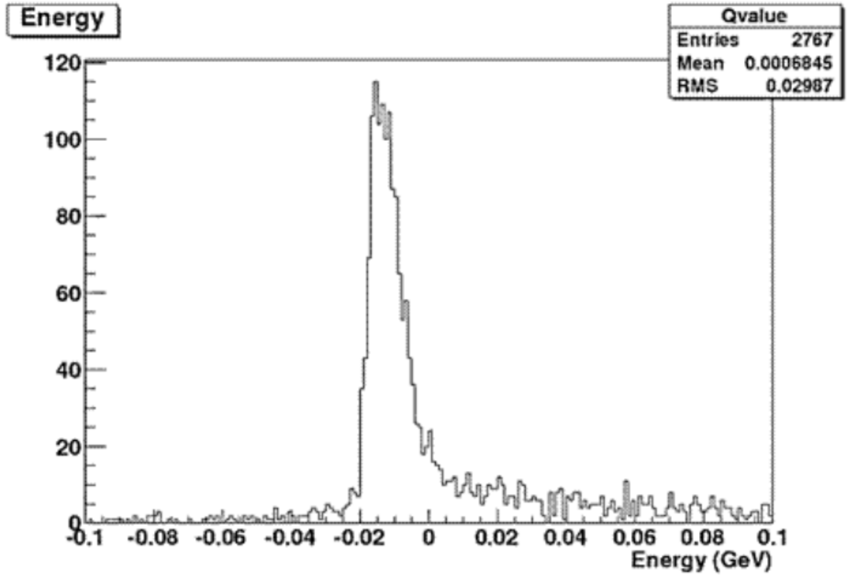
- The aim of the R3B collaboration is to construct a versatile experimental setup and perform experiments using relativistic radioactive beams across the full energy range available at FAIR
- The experimental assembly is designed to conduct kinematically complete nuclear reactions in inverse kinematics with fixed-targets

Scheme of the experiments

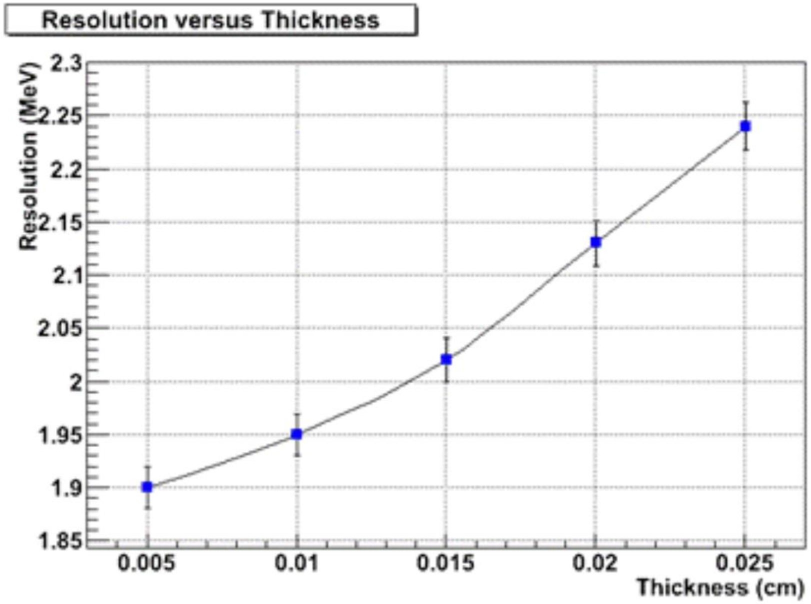


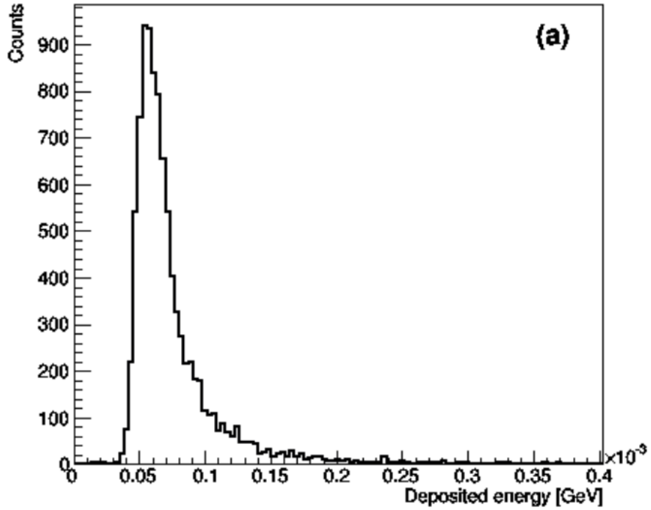
- The target region is surrounded by the silicon tracker (blue lines) and a CALIFA calorimeter (black)
- Neutrons are detected by NeuLAND (green)
- Beam-like particles are tracked before and after the dipole magnet by an array of detectors (red)

Requirements for recoil system



Q resolution $^{12}C(p,2p)^{11}B$ @400 MeV
Q ex = 5 MeV
Full CALIFA

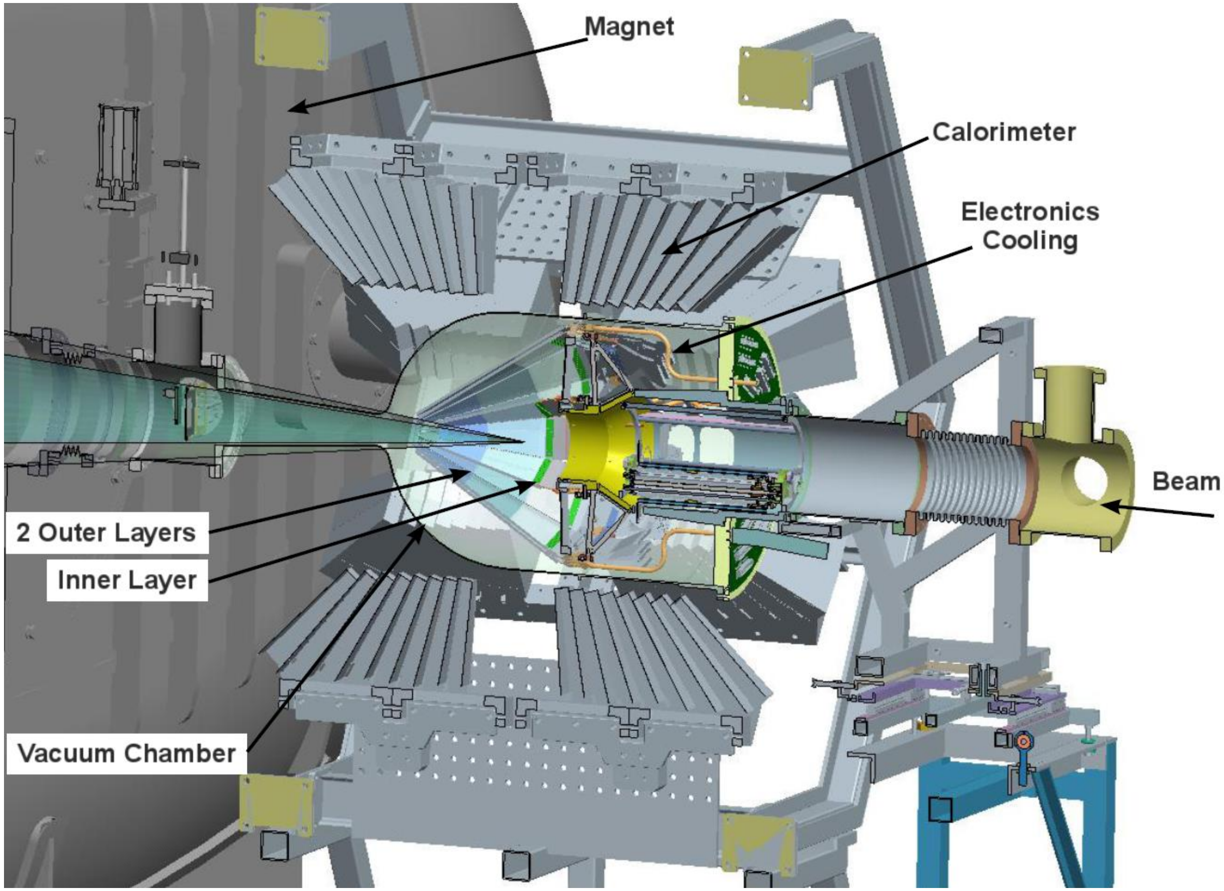




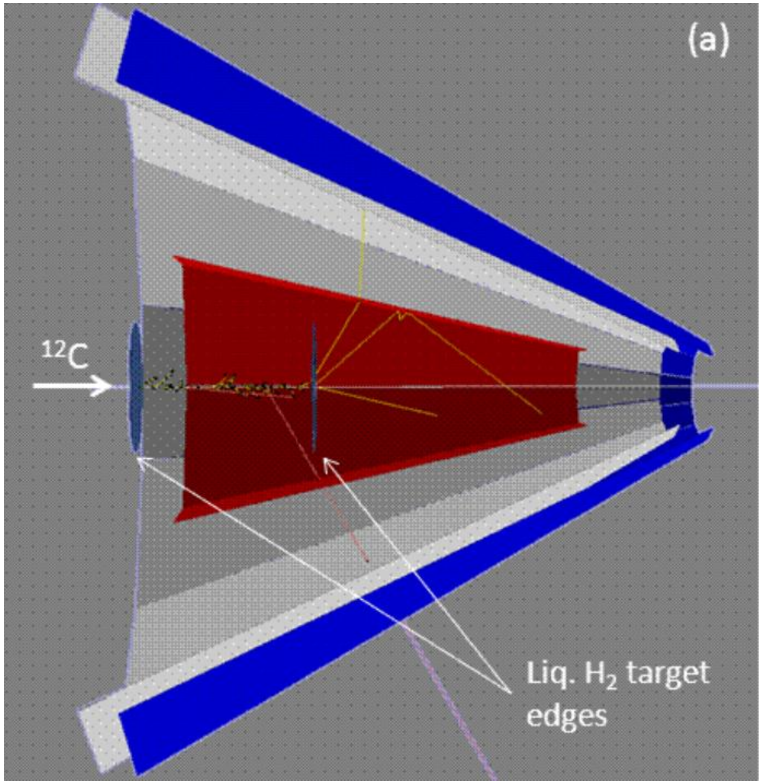
- *Elastic/inelastic and quasi-elastic scattering*
- *E = 300 – 700 MeV*
- *Minimum – 2 layers, vertex determination (1-2 mm)*

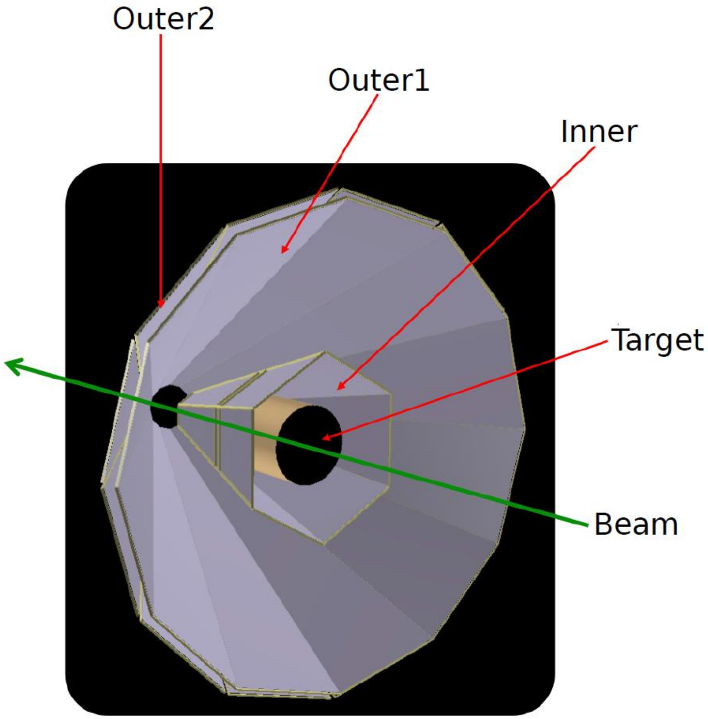
Requirements for recoil system

- Hit rate up to 5 kHz/ch
- First layer 50-100 μm, second 300 μm thick
- Low energy threshold 40 keV
- Strip size 100 μm, better 50 μm
- No heating of the liH$_2$ target
- Minimum material in the theta angles ≤90°



Requirements for recoil system

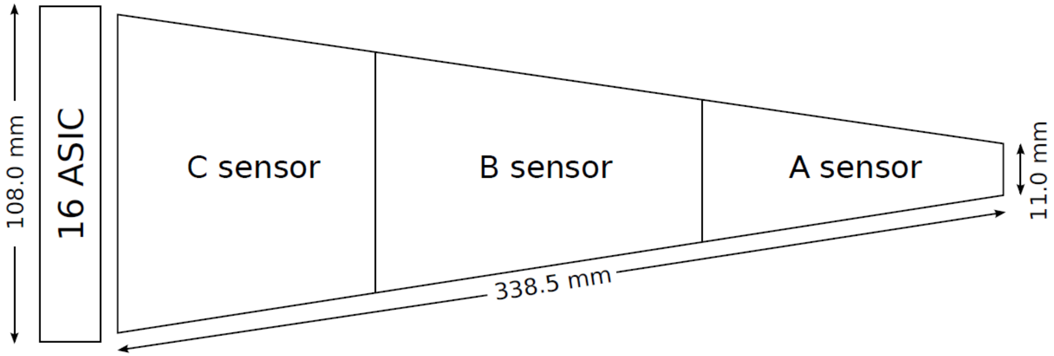


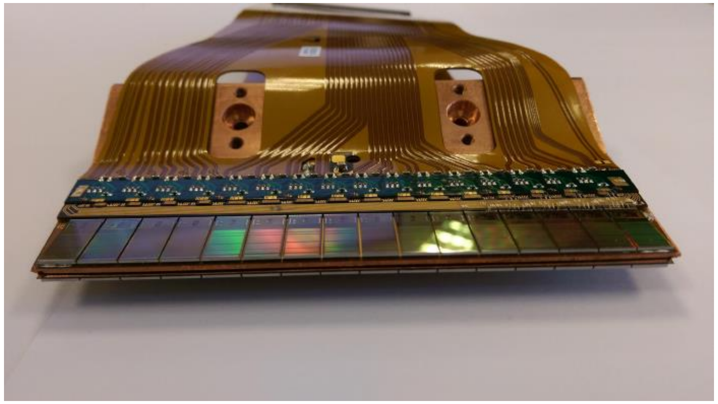


- Lampshade design is preferreable against a barrel
- Electronics in the backward section

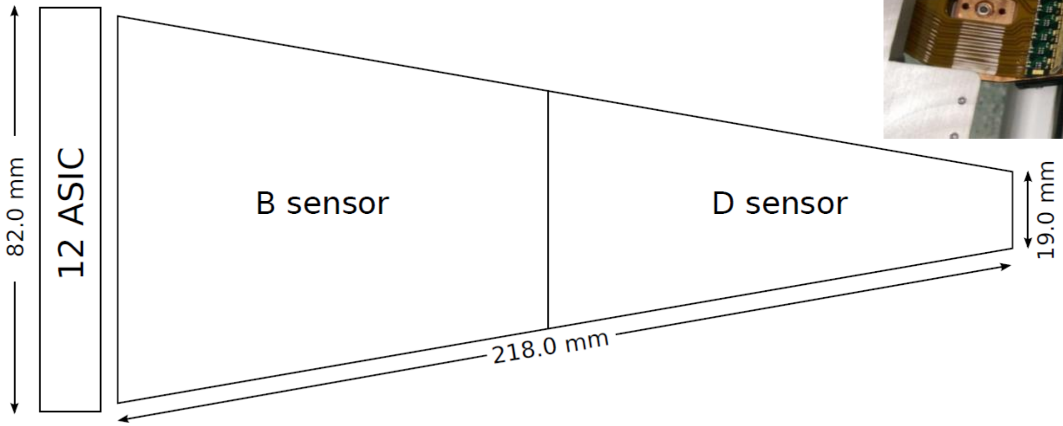
Detector units

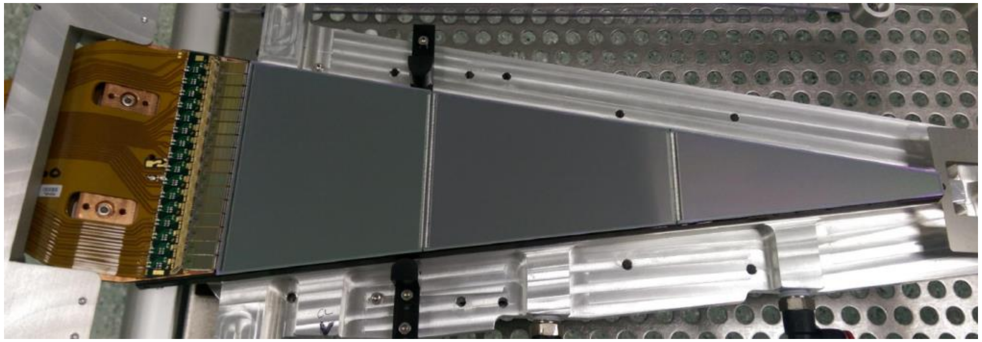
Outer Detector



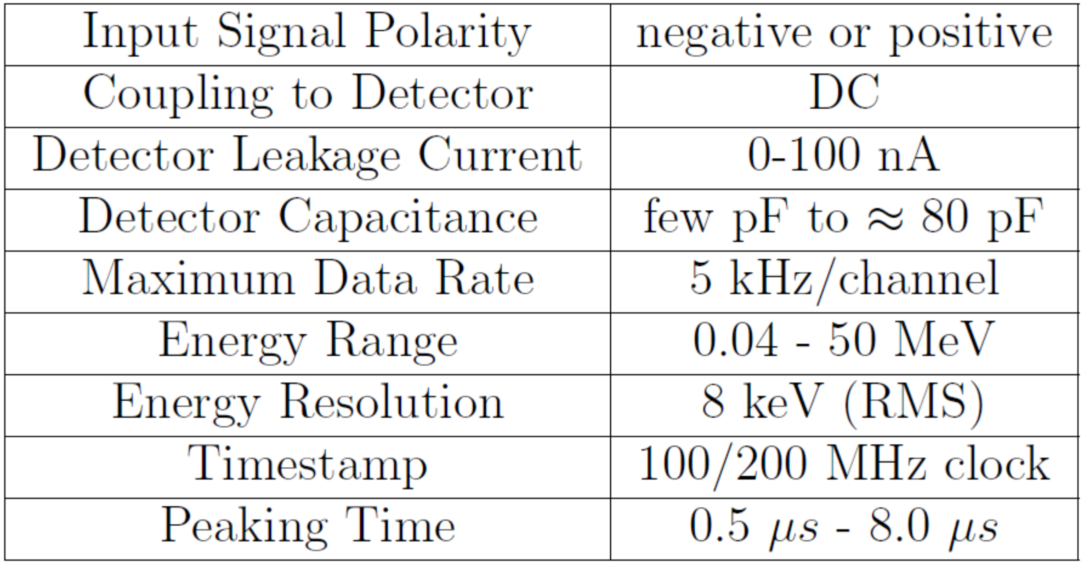


Inner Detector





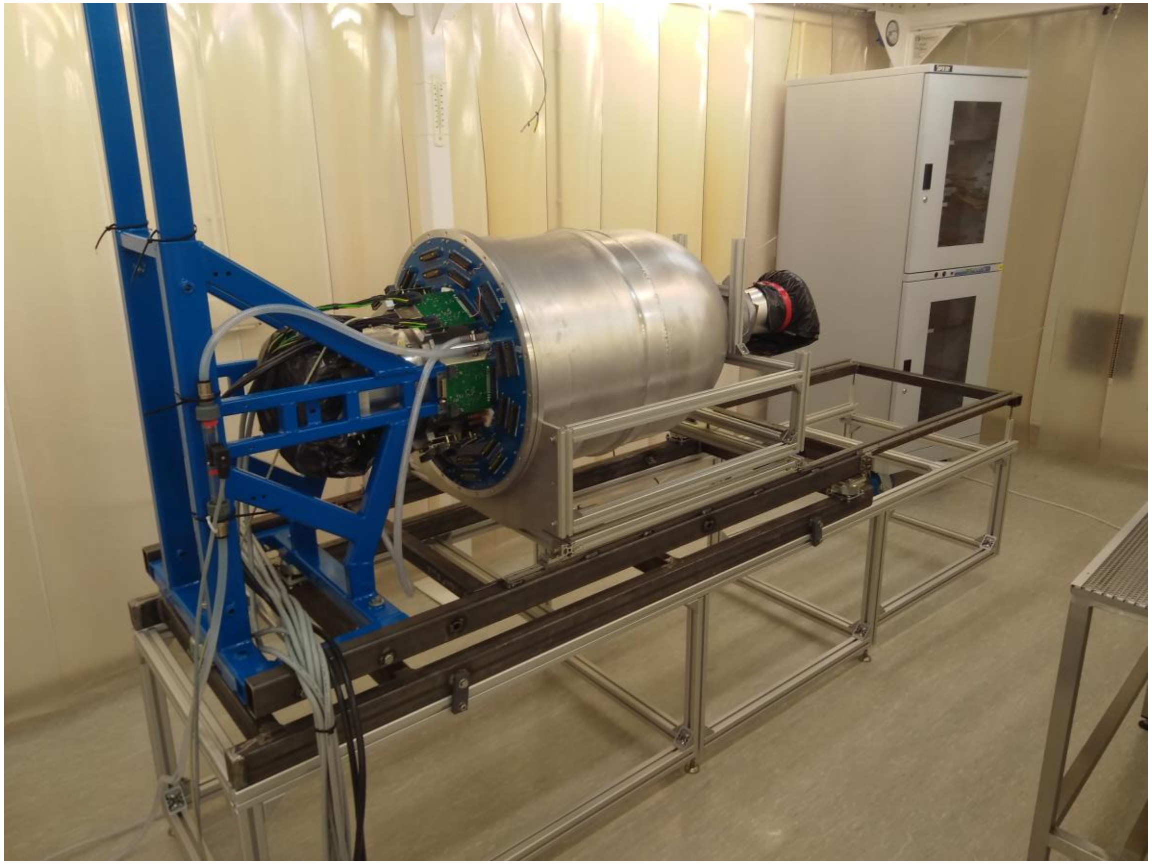
R3B ASIC



Input Signal Polarity	negative or positive
Coupling to Detector	DC
Detector Leakage Current	0-100 nA
Detector Capacitance	few pF to $\approx$ 80 pF
Maximum Data Rate	5 kHz/channel
Energy Range	0.04 - 50 MeV
Energy Resolution	8 keV (RMS)
Timestamp	100/200 MHz clock
Peaking Time	0.5 μs - 8.0 μs

- Fully custom design
- Self-triggering, time-stamp sync
- Slow control of all thresholds, integration time and other parameters
- 12-bit energy measurement

Full system



300 μm inner layer
(100 μm detectors did
not work properly)

Second outer layer is
possible but not installed

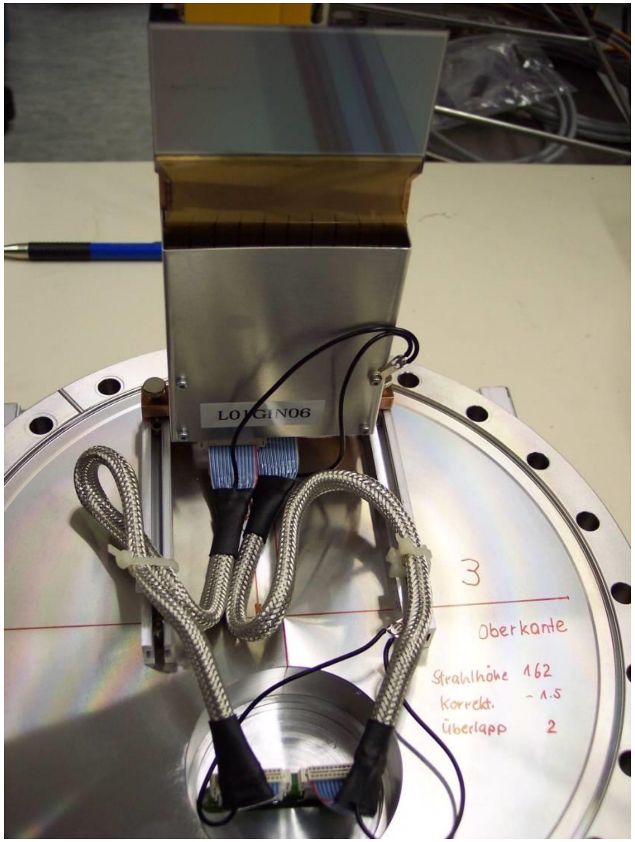
- 2-layer (one inner and one outer layer) system
- Full electronics, slow control, HV system
- Cooling with water circulation

L3T performance

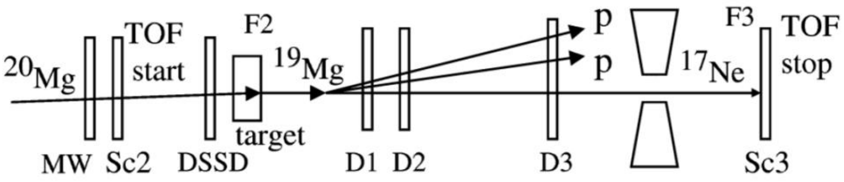
- 300 μm inner layer is a large limitation on vertex and angular resolution
- Noise level of the ASIC is far above the design
- Minimum energy threshold of 150 keV (120 keV for some channels) instead of 40 keV
- Very low efficiency of the proton detection – proved with cosmics and special test at KVI in 2019
- ***At this stage L3T is not usable as a recoil detector for R3B***
- ***L3T is an official In-kind contribution of UK, issue is reported to STFC, 6-months study is initiated, decision is expected in Q2-Q3 2021***

Present recoil system

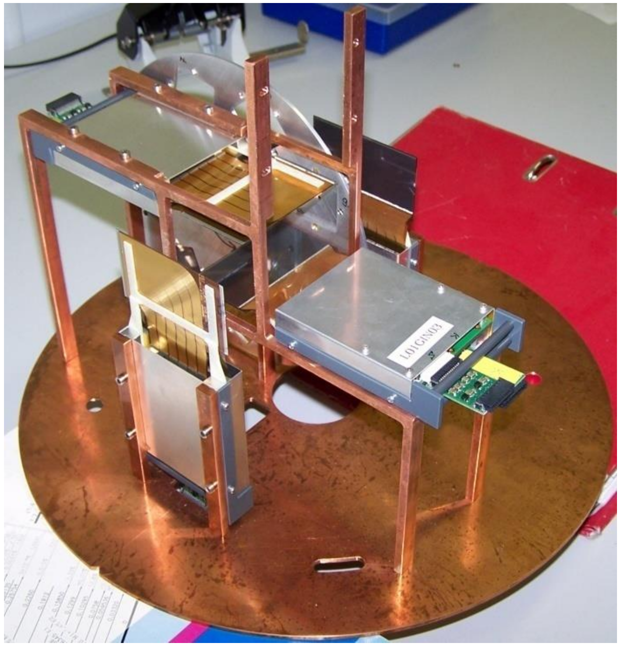
- Double-sided Si microstrip detectors
- Area 28 cm^2, 300 µm, 100 µm strip pitch
- Energy resolution ~1%
- Dynamic range – from p to Fe (can detect protons and heavy ions)
- Very low energy dissipation of FE electronics - works in vacuum without active cooling
- 1024 channels, multiplexed readout (trigger rate 2.5 kHz max)
- ***Position resolution ~40 µm for protons, ~15 µm for ions***

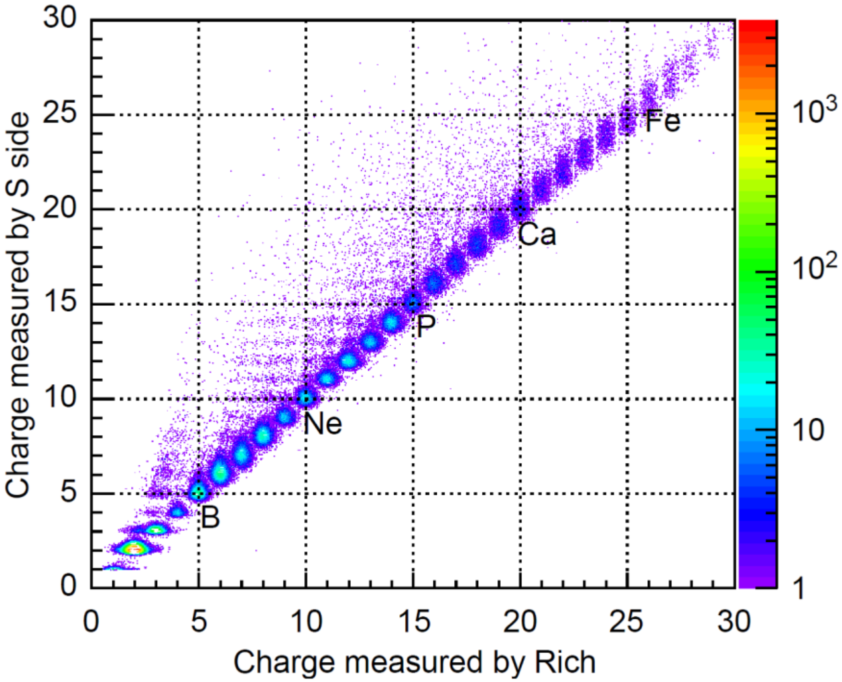


Precise tracking + spectroscopy



S271, S388 experiments at FRS, tracking of ions + protons

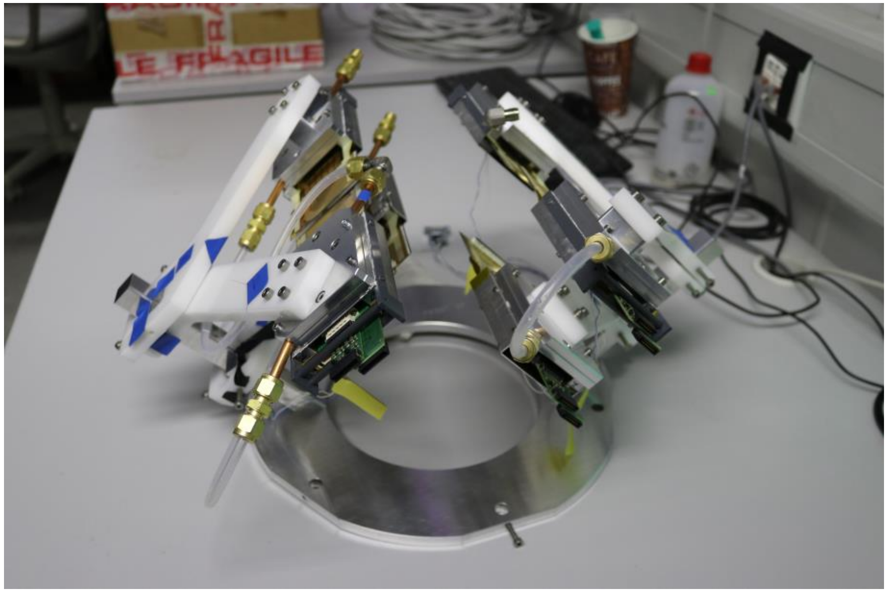


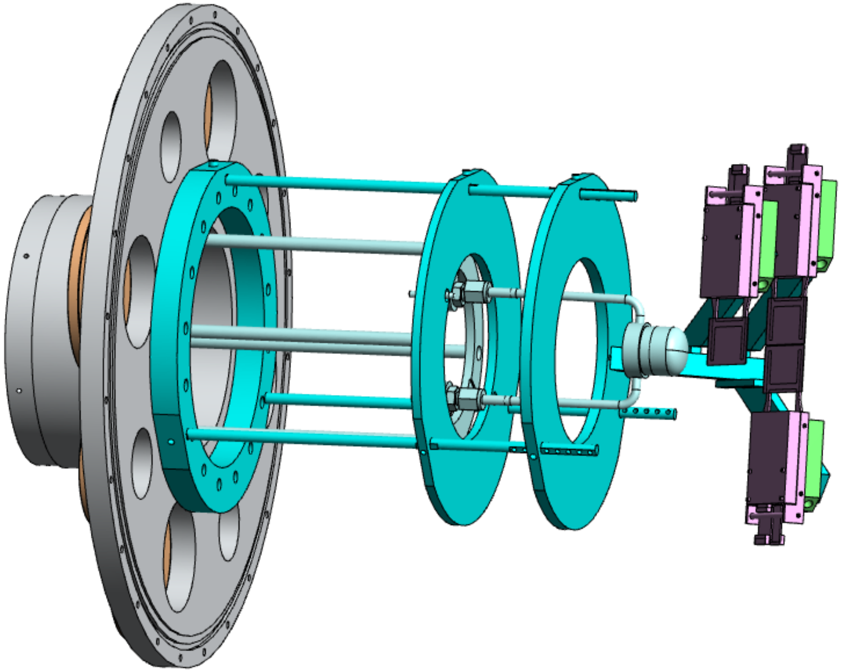


Si – RICH correllation (AMS data)

- ***Key to success*** of 2p-radioactivity measurements at FRS and R3B QFS experiments
- Forward tracking and recoil tracker configurations

Recoil tracker, Cave C, 2020 - 2021

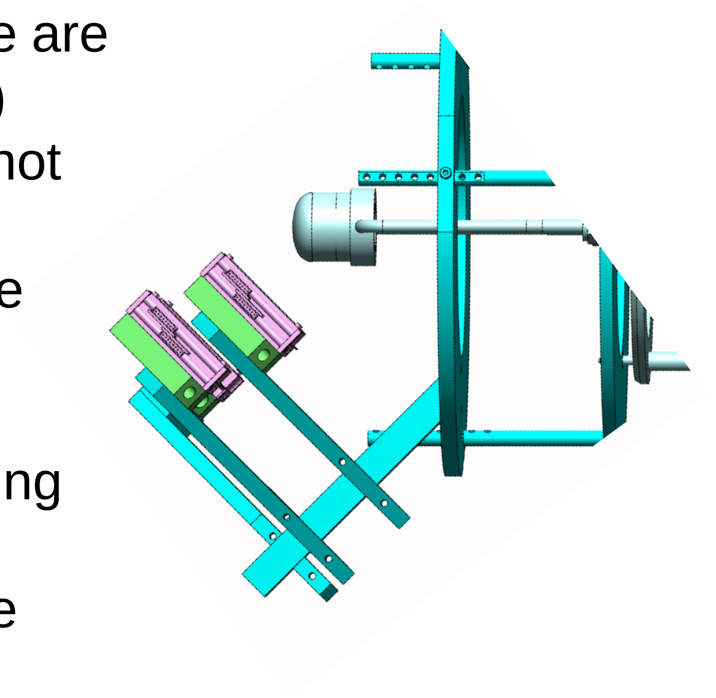




- Two-arm design for the experiments in Cave C
- Reactions like (p, 2p), (p, p’), (p, pn)
- 6 AMS detectors
- First layer – 300 µm thick
- Solid angle (~20%) coverage, much smaller as L3T

Status AMS detectors, October 2020

- More than 6 detectors are available but some are not anymore good (noisy strips, high current)
- Sensors and few components of the FE are not available any more
- Trigger rate is limited – the slowest part of the whole setup

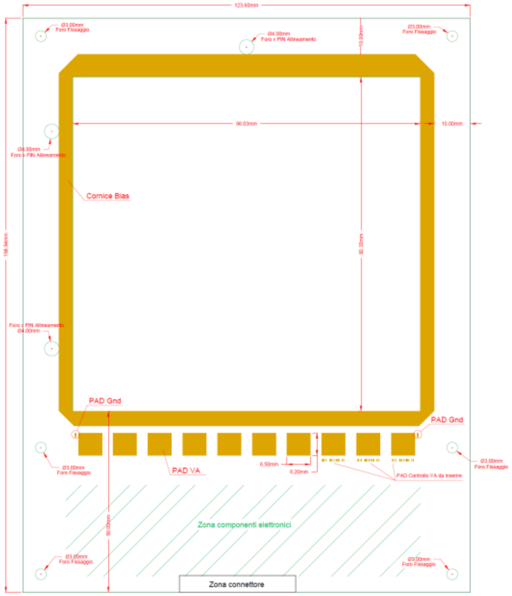


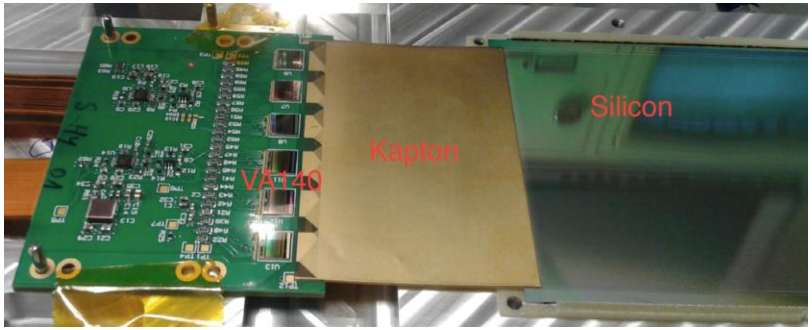
- Only 6 SIDEREM readout modules are working
- SIDEREM modules and VME SAM5 concentrator board are old and not repairable
- AMS DAQ from INFN Perugia made working with MBS (backup solution)

- Solid angle coverage is very limited

New microstrip detectors

- ✓ New detectors designed for FOOT ESA experiment by Hamamatsu / INFN Perugia
- ✓ 10 x 10 cm, single-sided, 150 µm thick, 150 µm strip pitch
- ✓ Same front-end ASICs as AMS detectors, 15-20 keV energy threshold should be reachable
- ✓ New FPGA-based DAQ system for these detectors will be available at the end of 2020-beginning of 2021
- ✓ FEBEX-based DAQ is under consideration
- ✓ Trigger rate up to 10 kHz is expected

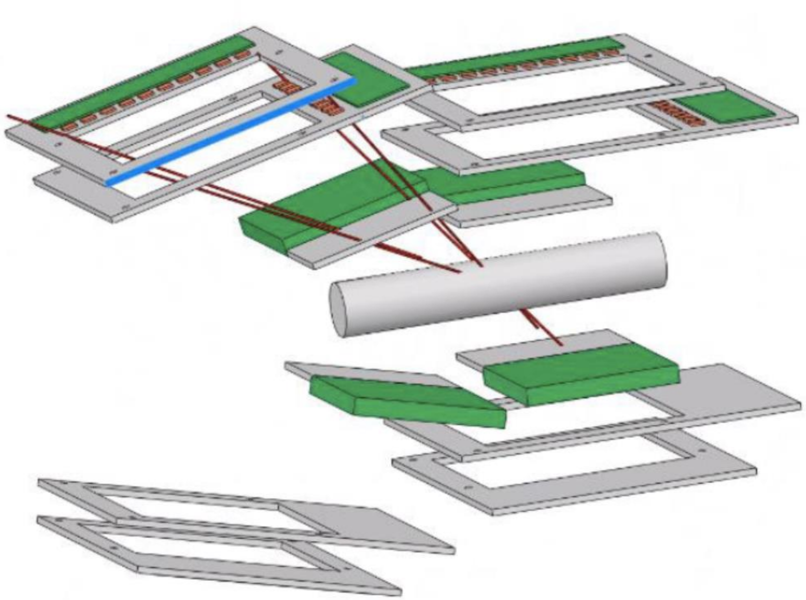


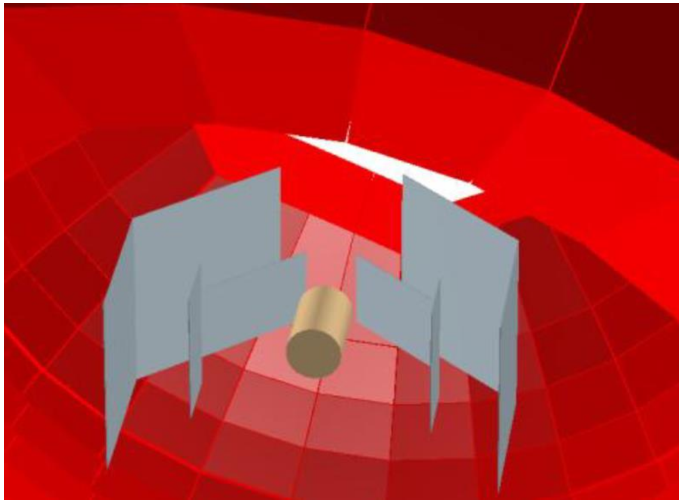


New microstrip detectors

- ✓ Few new detectors are ordered and come in Q2 2021
- ✓ Will be used in pairs providing X-Y measurements
- ✓ First layer – AMS detectors
- ✓ Solid angle coverage for (p, 2p) reactions will be higher
- ✓ Long liH$_2$ target can be used increasing the event rate
- ✓ Aim is making combined set ready for the 2022 (and later) campaign

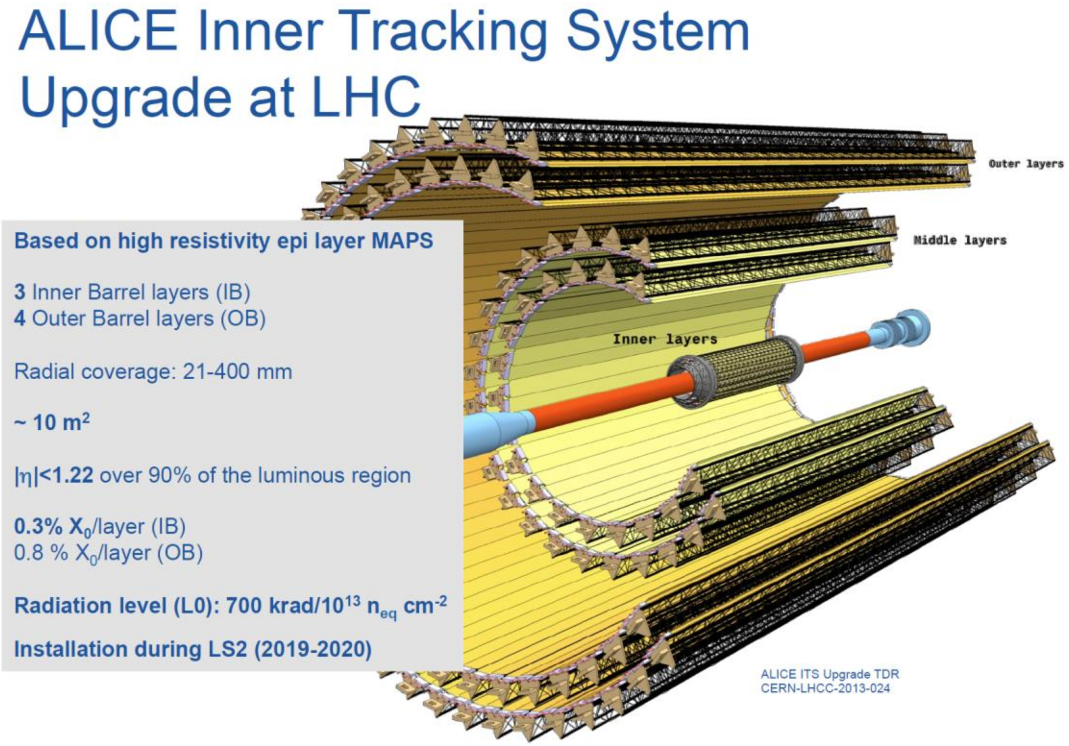
- ✓ ***Not a replacement of L3T***





Inner Tracker System / ALICE

- CMOS Monolithic Active Pixel Sensor (MAPS) combining the sensor and the readout electronics in one single device
- Thickness of 50 µm or 100 µm (two options)
- Sensor size 15 x 30 mm^2 and hosts 512 x 1024 pixels
- Pixel size 29 x 27 µm^2
- TowerJazz 0.18 µm technology (Tower Semiconductors is an Israeli-American company)
- Power consumption 40 nW/ pixel or 20 mW/sensor, can work in vacuum with moderate cooling
- Operation in magnetic field up to 0.5 T is possible



ALICE Inner Tracking System Upgrade at LHC

Based on high resistivity epi layer MAPS

3 Inner Barrel layers (IB)
4 Outer Barrel layers (OB)

Radial coverage: 21-400 mm

~ 10 m^2

$|\eta|$**<1.22** over 90% of the luminous region

0.3% X_0/layer (IB)
0.8 % X_0/layer (OB)

Radiation level (L0): 700 krad/10^{13} n_{eq} cm^{-2}

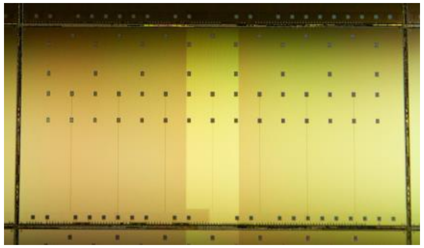
Installation during LS2 (2019-2020)

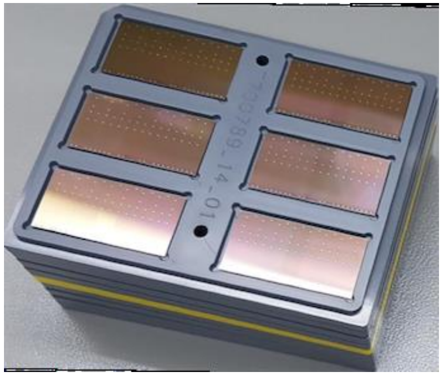
ALICE ITS Upgrade TDR
CERN-LHCC-2013-024

Radiation hard technology, with official certificate. According to the law, potentially dual-use device -> official licence for every new usage is needed.

ALPIDE sensors

- Each pixel cell contains a sensing diode, a front-end amplifier and shaping stage, a discriminator, and a digital section
- Digital readout with priority encoder
- Pixels with no hits are not read out
- Hits recorded independently of trigger and saved in the internal buffer. Trigger starts data transfer from the chip via FPGA to a computer/data storage
- Maximum trigger rate – 100 kHz
- Time resolution ~5 μs
- The detection efficiency is higher than 99% for MIPs
- Spatial resolution - 5 μm for MIPs
- Noise – around 6 e^-, threshold – 100 e^-
- Fake hit rate < 1 Hz per sensor





Inner Tracker System / ALICE

ITS2 commissioning

M. Mager | ITS3 | TREDI 2020 | 18.02.2020 | 5

Inner Tracker System / ALICE

ITS2 Inner Barrel

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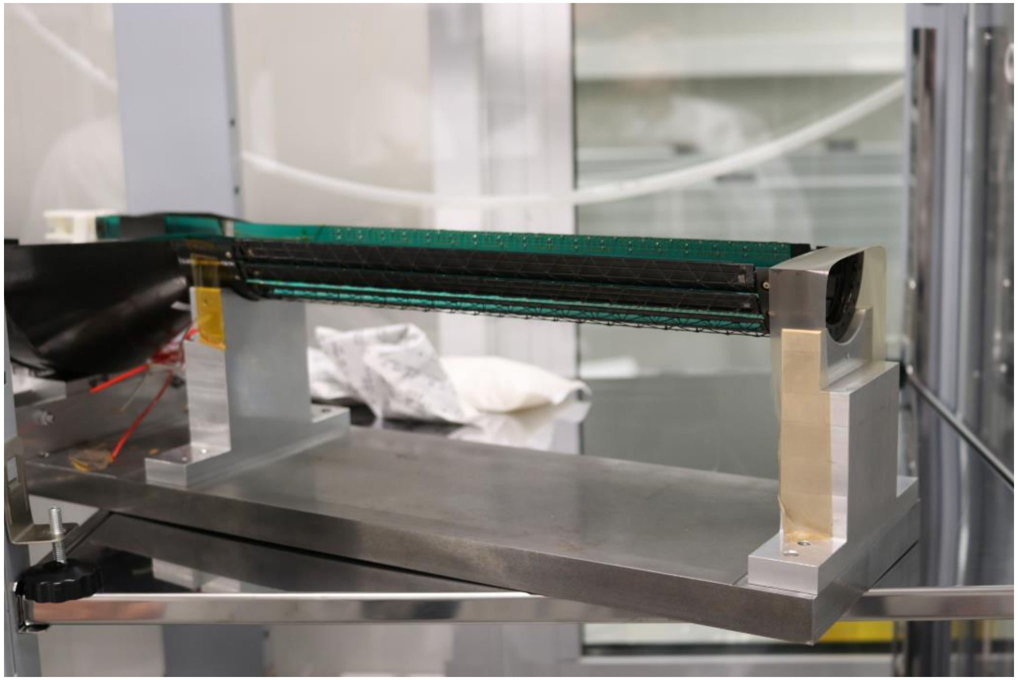
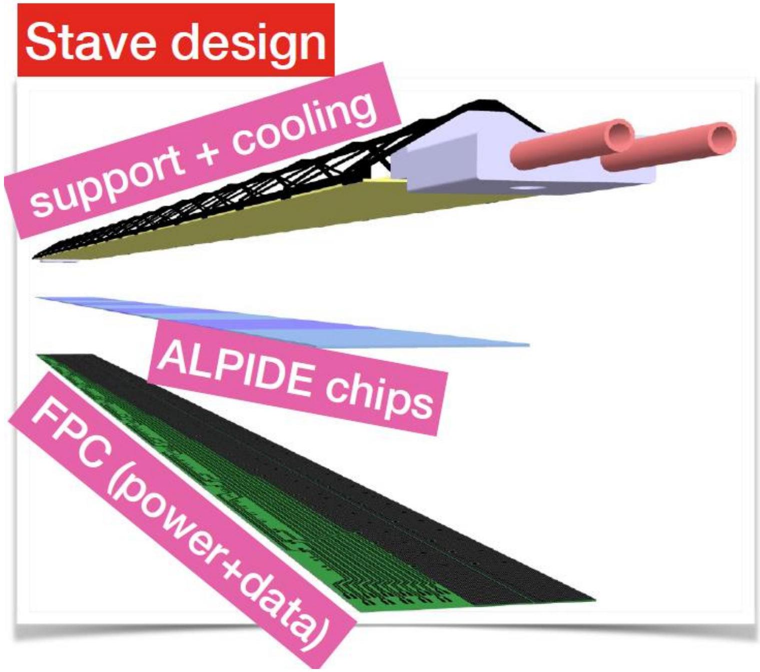
ALPIDE staves

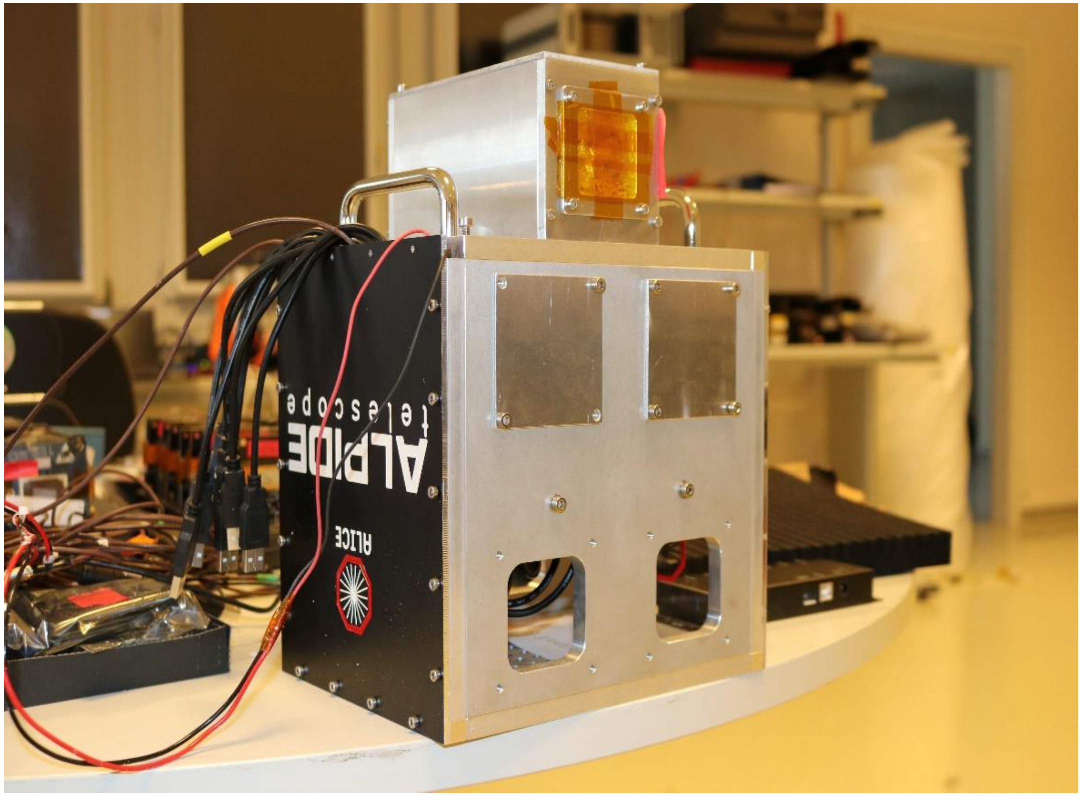




- Inner barrel – 9 sensors (50 μm thick)
- Outer barrel – 2 x 7 sensors (100 μm thick)
- Each stave is connected individually to a concentrator/trigger board

ALPIDE staves

ALPIDE beam telescope

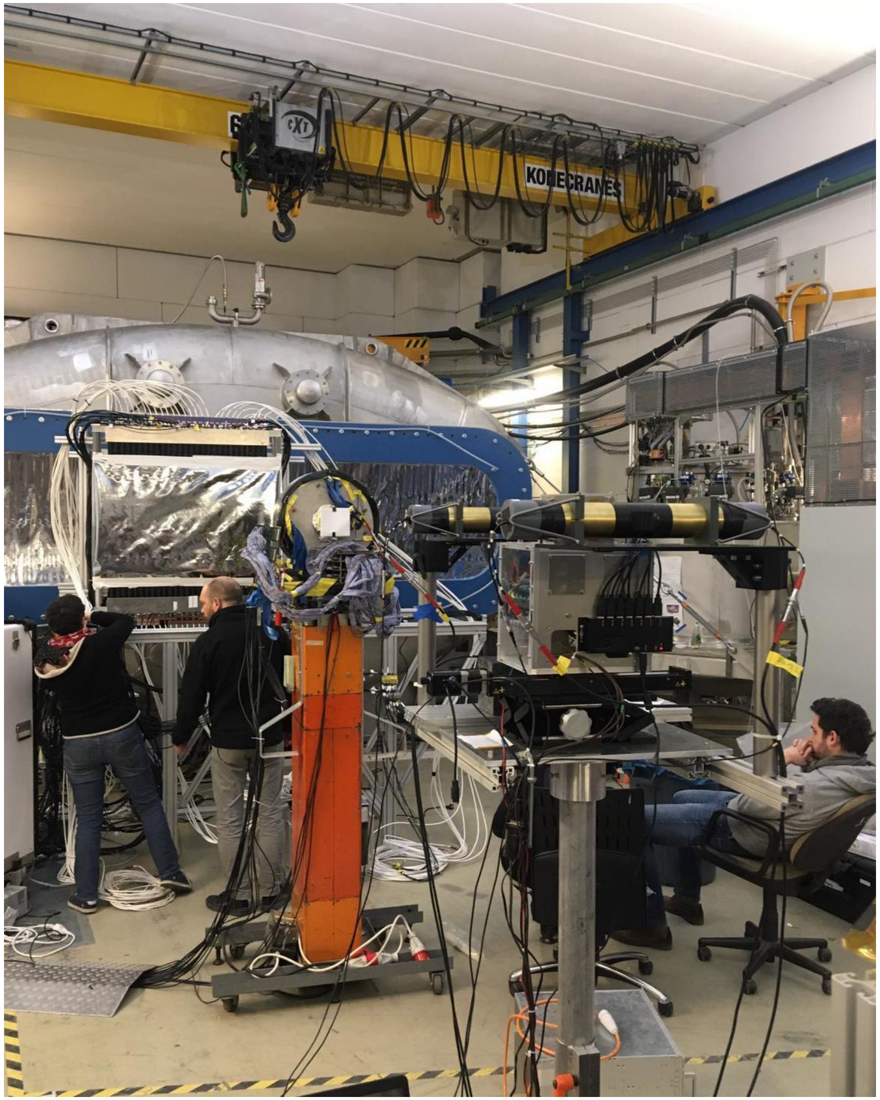


Joined effort with
ALICE GSI/Uni Heidelberg team
(S. Masciocchi, B. Blidaru,
P. Becht)

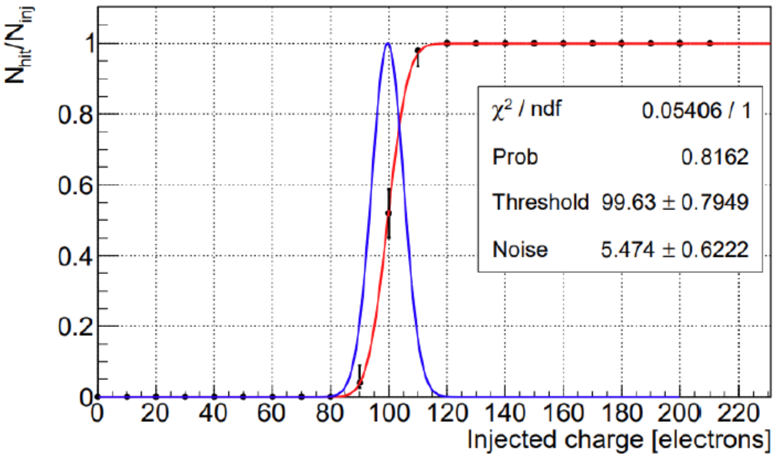
- ALPIDE 7-layer telescope at GSI
- Single sensors readout with dedicated DAQ boards

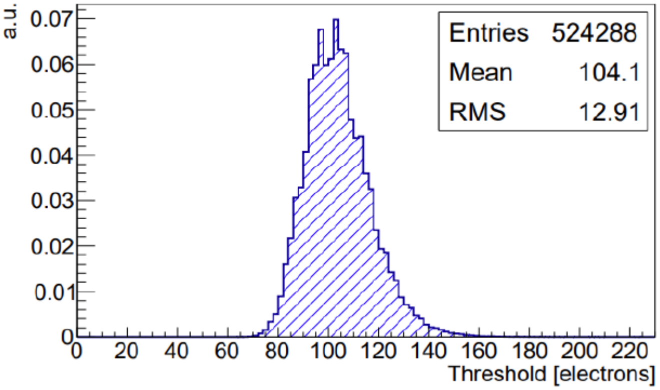
Commissioning of the telescope at Cave C

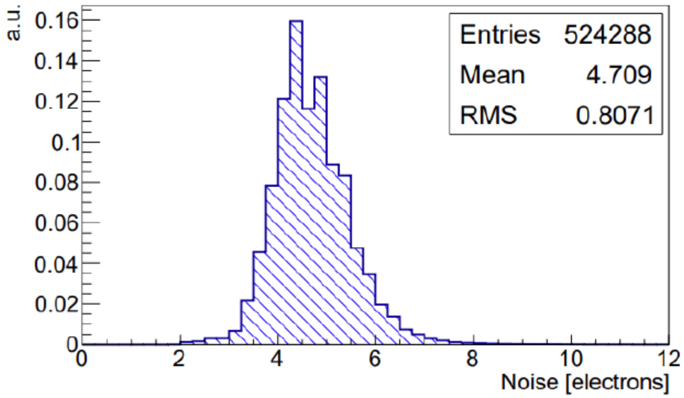
- 21 –22 Nov 2019, primary Ar beam, variable intensity, 550 MeV/u
- •9 –11 Dec 2019, secondary Si (from primary Ar) beam via FRS, ~500 MeV/u
- Cluster size/shape study

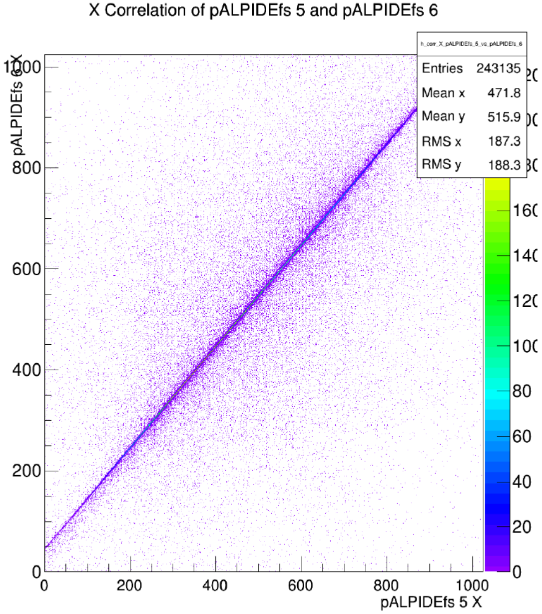


Measurements with ALPIDE









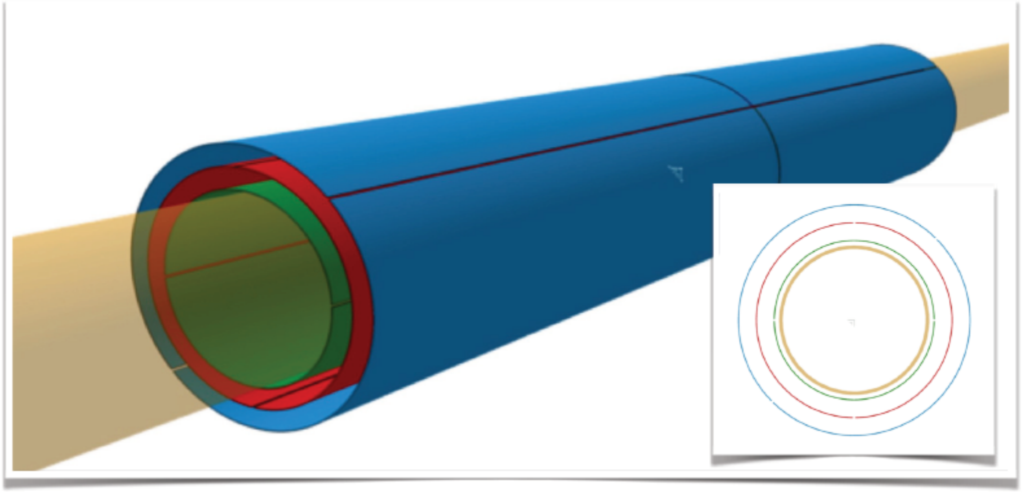
B. Blidaru/P. Becht

- Three runs with the telescope at DESY (e$^-$ beam)
- Very quite detector (noise 5 e$^-$)!
- With thr = 130 e$^-$ practically 100% efficiency for MIPs!

ALICE future ITS

ALICE

Layout



Beam pipe Inner/Outer Radius (mm)	16.0/16.5		
IB Layer Parameters	Layer 0	Layer 1	Layer 2
Radial position (mm)	18.0	24.0	30.0
Length (sensitive area) (mm)	300		
Pseudo-rapidity coverage	±2.5	±2.3	±2.0
Active area (cm^2)	610	816	1016
Pixel sensor dimensions (mm^2)	280 x 56.5	280 x 75.5	280 x 94
Number of sensors per layer	2		
Pixel size (μm^2)	O (10 x 10)		

- New beam pipe:
  - “old” radius/thickness: 18.2/0.8 mm
  - new radius/thickness: 16.0/0.5 mm
- Extremely low material budget:
  - Beam pipe thickness: 500 μm (0.14% X0)
  - Sensor thickness: 20-40 μm (0.02-0.04% X0)
- Material homogeneously distributed:
  - essentially zero systematic error from material distribution

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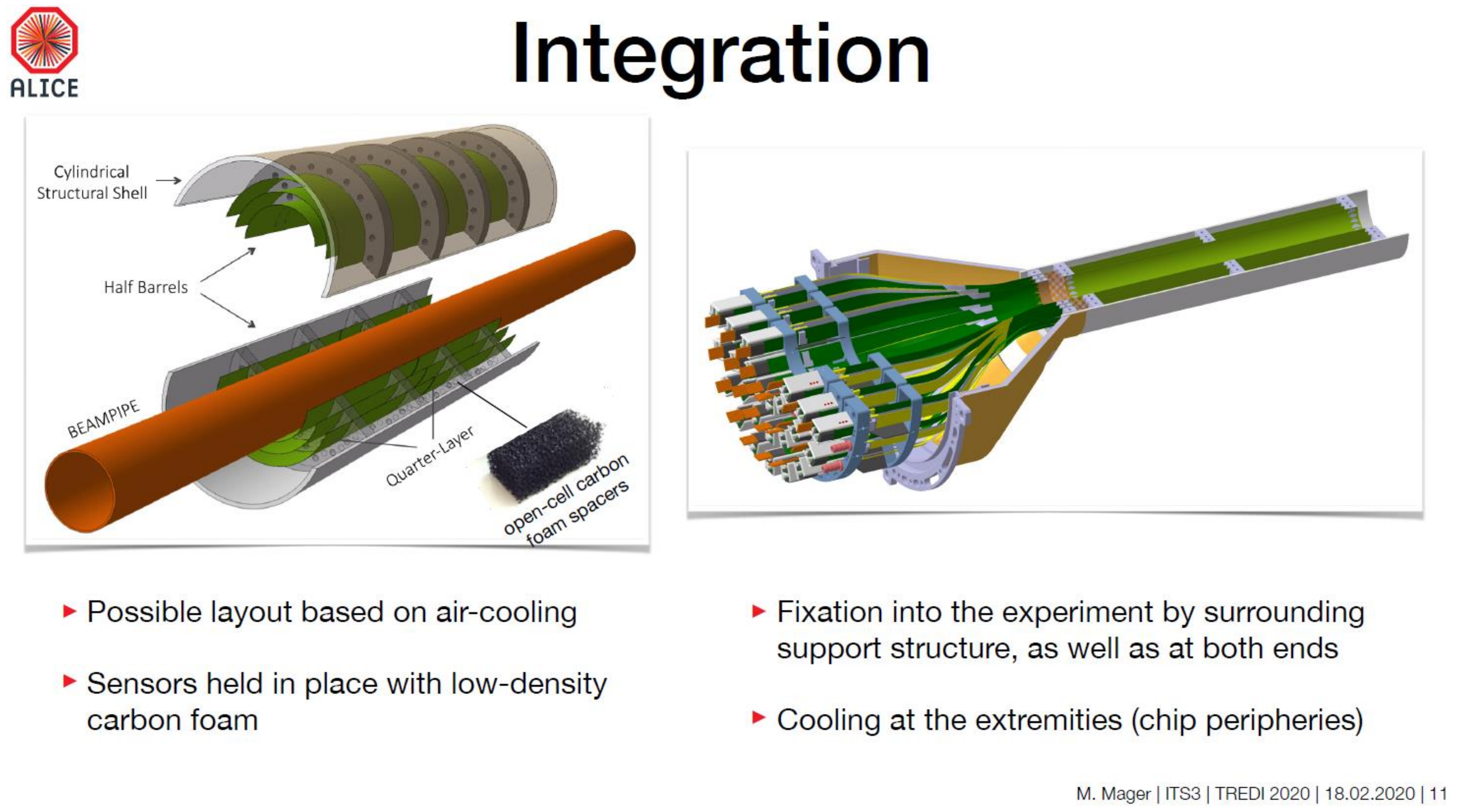
ALICE future ITS



Integration

- Possible layout based on air-cooling
- Sensors held in place with low-density carbon foam

- Fixation into the experiment by surrounding support structure, as well as at both ends
- Cooling at the extremities (chip peripheries)

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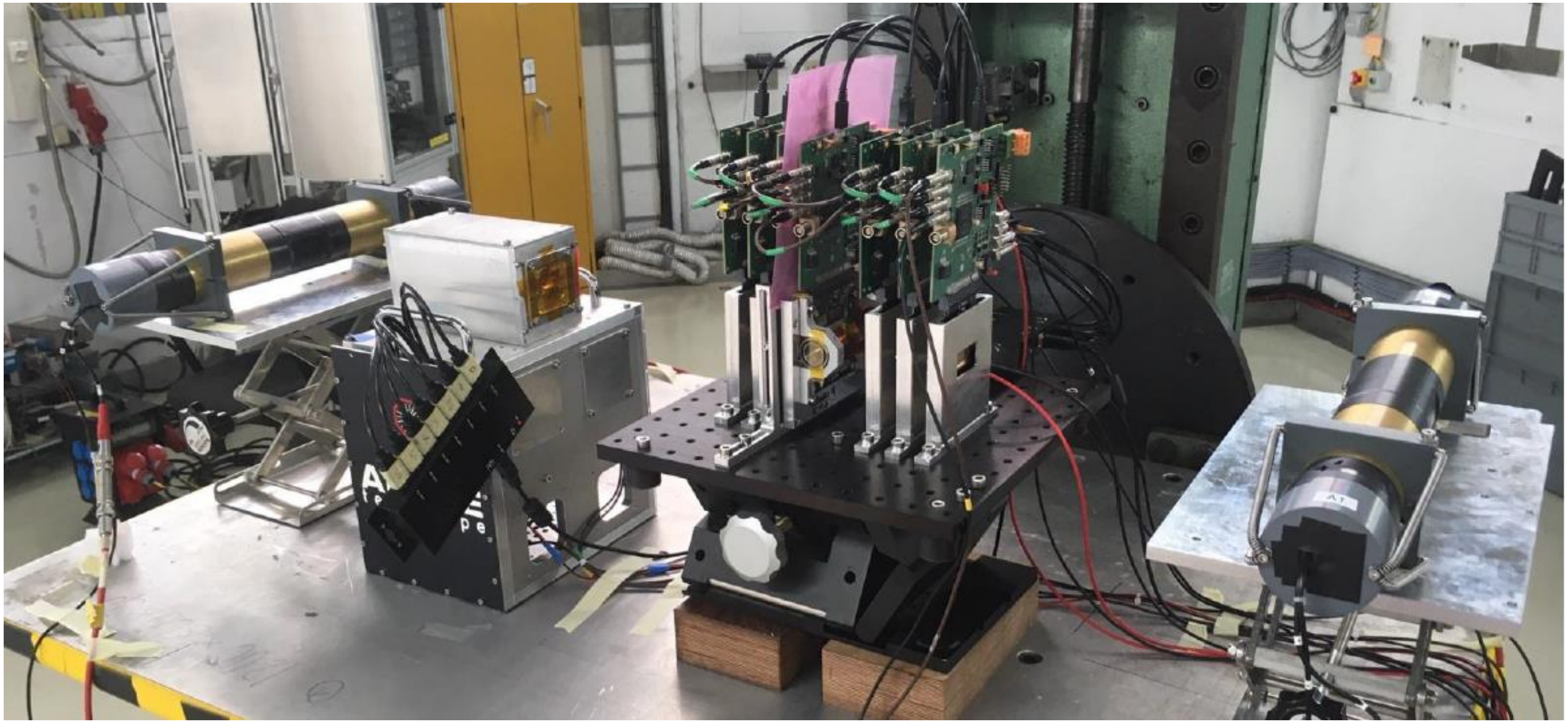
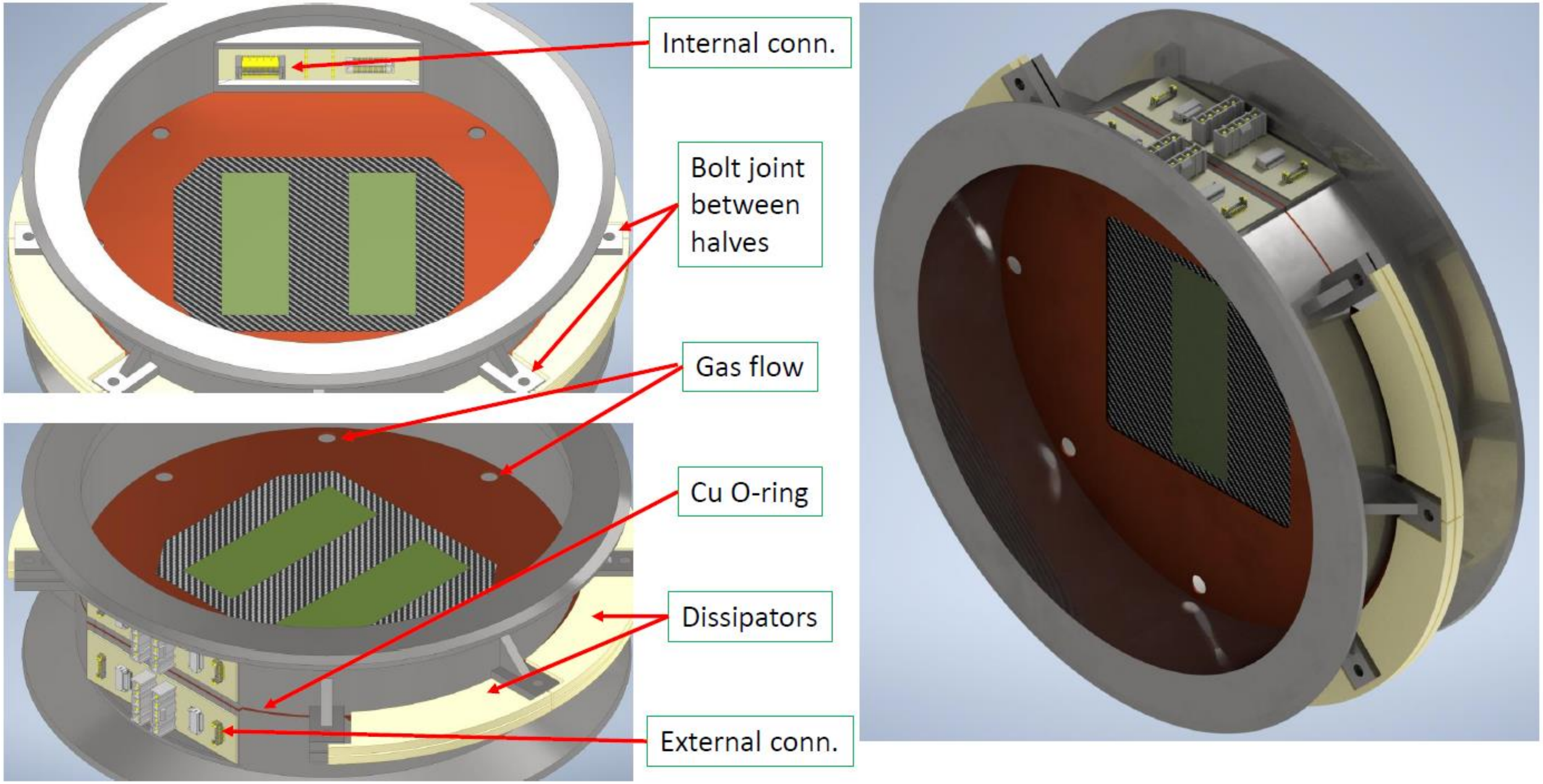
Tests of bended sensors



B. Blidaru/P. Becht

- First tests of bended sensors successful
- Larger samples (eventually with more than 1 sensor) are planned in 2021

First steps towards larger detector



Internal conn.

Bolt joint between halves

Gas flow

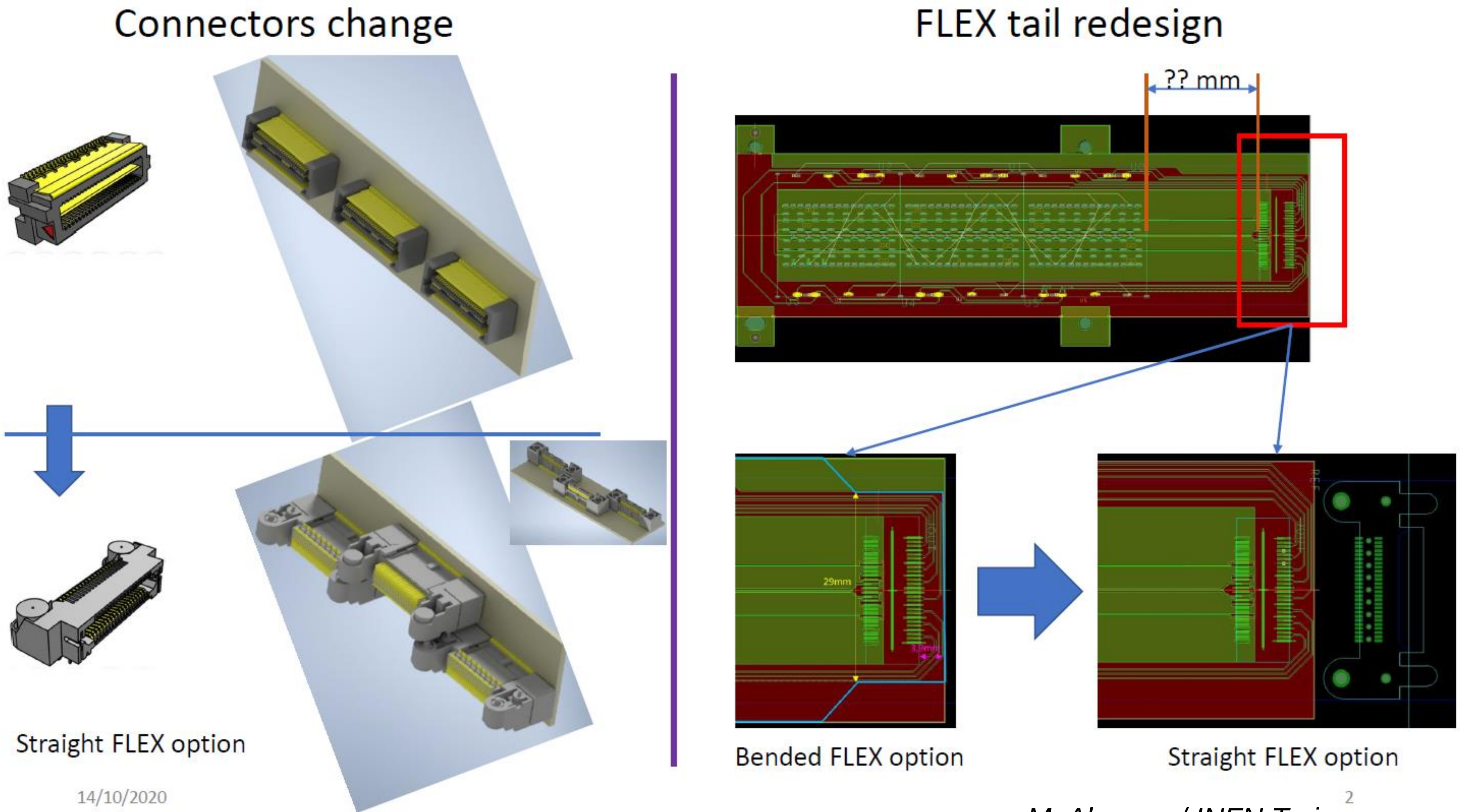
Cu O-ring

Dissipators

External conn.

- Design of M. Alexeev / INFN Torino for the PRM/CERN experiment
- 18 sensors on a 120 μm carbon flex board (~10 x 10 cm active area)
- Active or passive cooling
- Fully suitable for the forward-tracking applications like 2p-radioactivity experiments at FRS

First steps towards larger detector



Connectors change

Straight FLEX option

FLEX tail redesign

Bended FLEX option

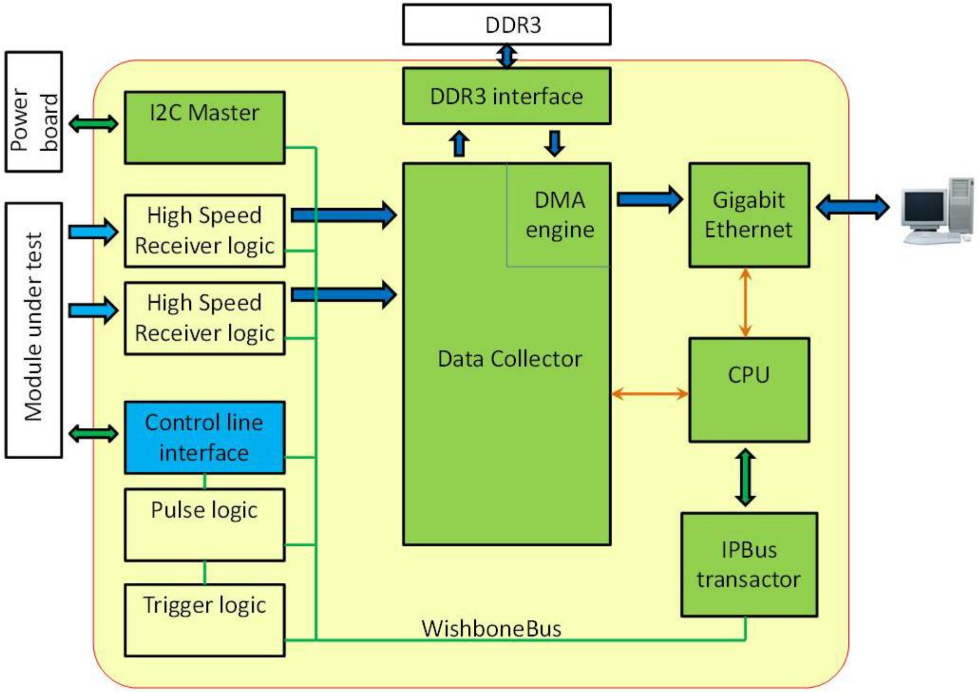
Straight FLEX option

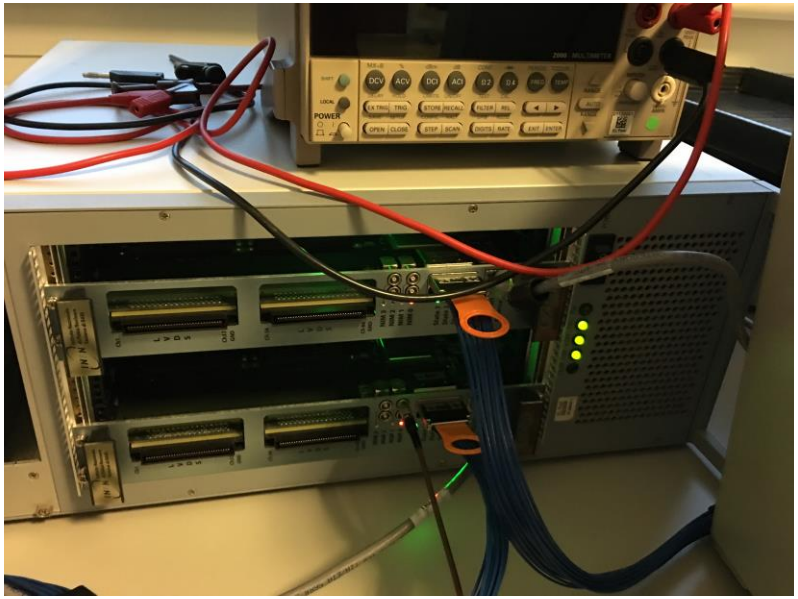
14/10/2020

2

M. Alexeev / INFN Torino

First steps towards larger detector





- MOSAIC readout board (INFN Bari)
- FPGA-based, can read up to 7 ALPIDEs
- Stand-alone time-stamped DAQ

Conclusions

- Recoil tracker is a key instrument of the R3B setup
- Long time ago planned and recently constructed L3T detector unfortunately does not have designed performance
- Intermediate solutions (AMS-like and FOOT-like detectors) allow making (p, 2p), (p, pn) experiments with limited acceptance
- Application of MAPS pixel detectors seems to be very attractive
- First steps (since mid 2019) getting experience are made
- In cooperation with COMPASS++/AMBER collaboration first realistic MAPS-based detector is on the way
- Bended MAPS-based recoil detector is a very promising solution, fully or as am inner layer (2023+)