R&D for R3B/EXL silicon spectrometers, ELISe in-ring instrumentation based on planar Si and CVDD

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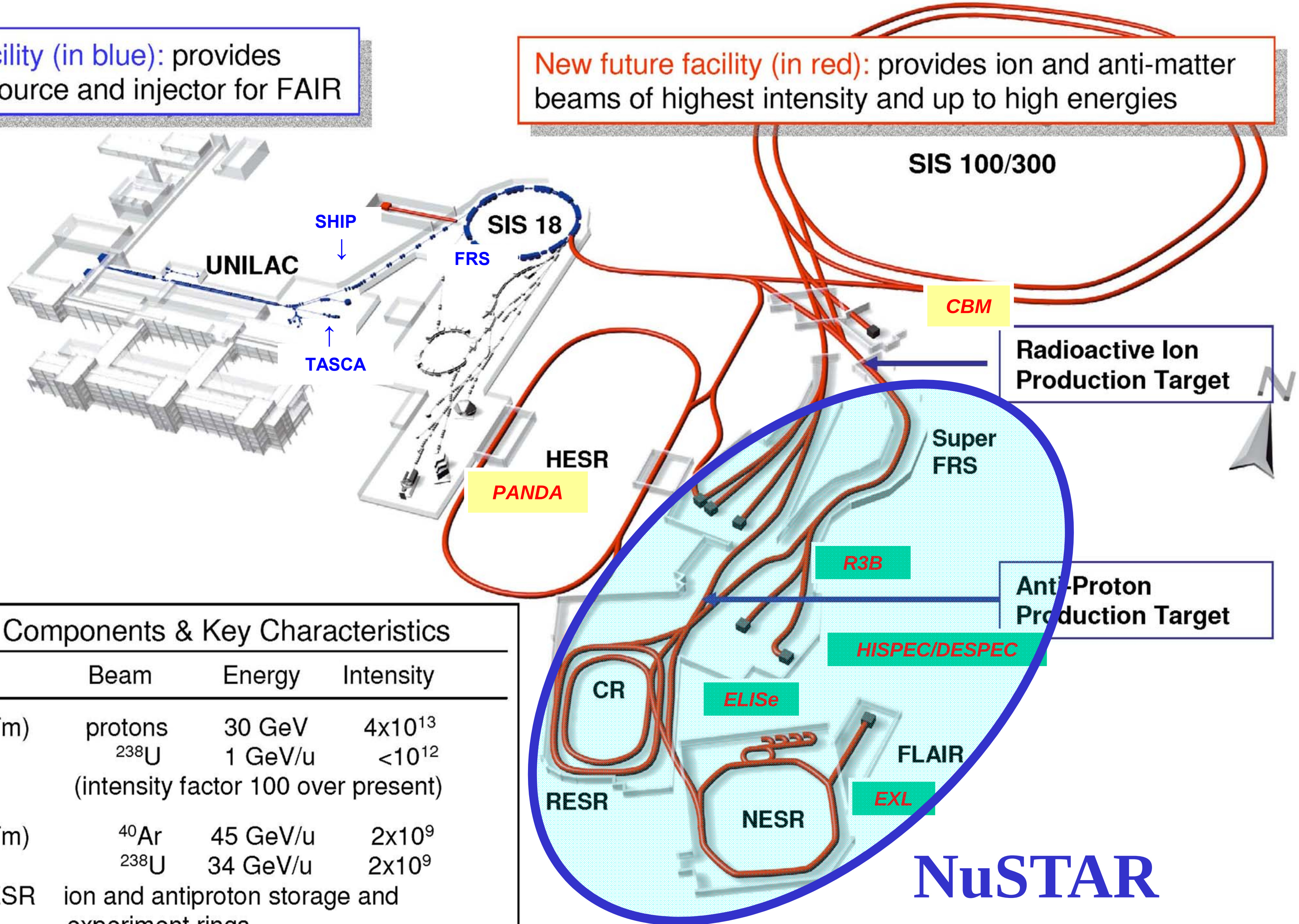
FAIR: Facility for Antiproton and Ion Research

Existing facility (in blue): provides ion-beam source and injector for FAIR

New future facility (in red): provides ion and anti-matter beams of highest intensity and up to high energies



Accelerator Components & Key Characteristics

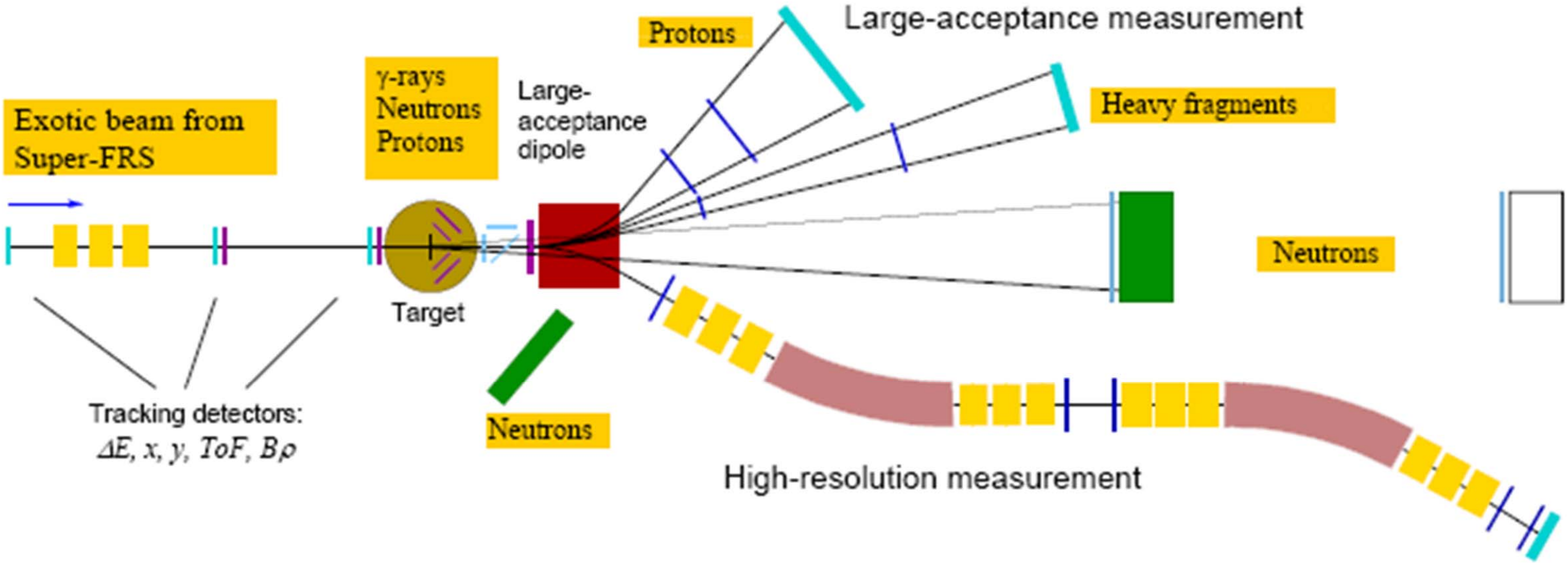
Ring/Device	Beam	Energy	Intensity
SIS100 (100Tm)	protons	30 GeV	4×10^{13}
	^{238}U	1 GeV/u	$<10^{12}$
	(intensity factor 100 over present)		
SIS300 (300Tm)	^{40}Ar	45 GeV/u	2×10^{9}
	^{238}U	34 GeV/u	2×10^{9}
CR/RESR/NESR	ion and antiproton storage and experiment rings		
HESR	antiprotons	14 GeV	$\sim10^{11}$
SuperFRS	rare-isotope beams	1 GeV/u	$<10^{9}$

NuSTAR

Nuclear **St**ructure, **A**strophysics, and **R**eactions

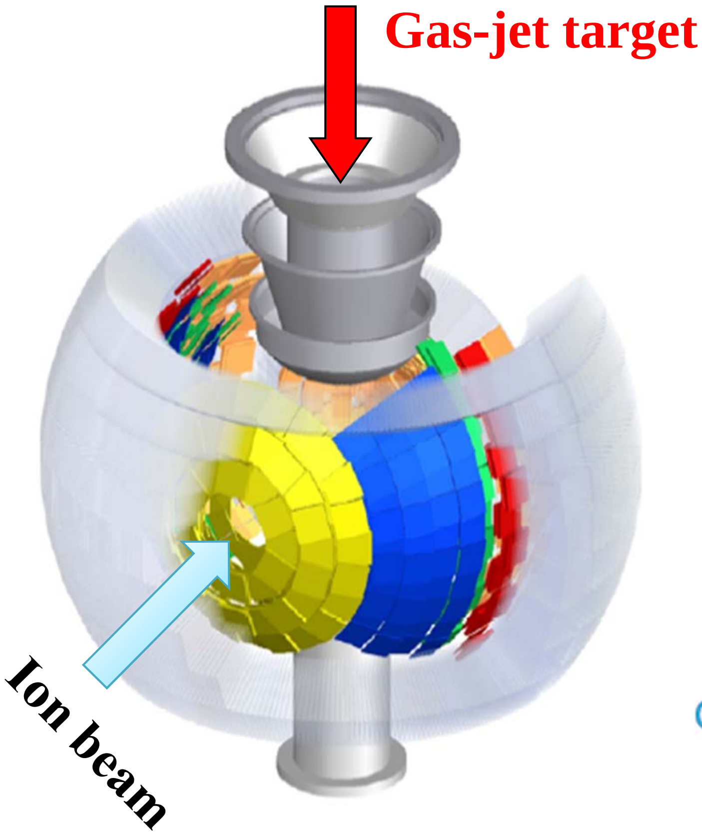
** W. Henning, NuSTAR Meeting*

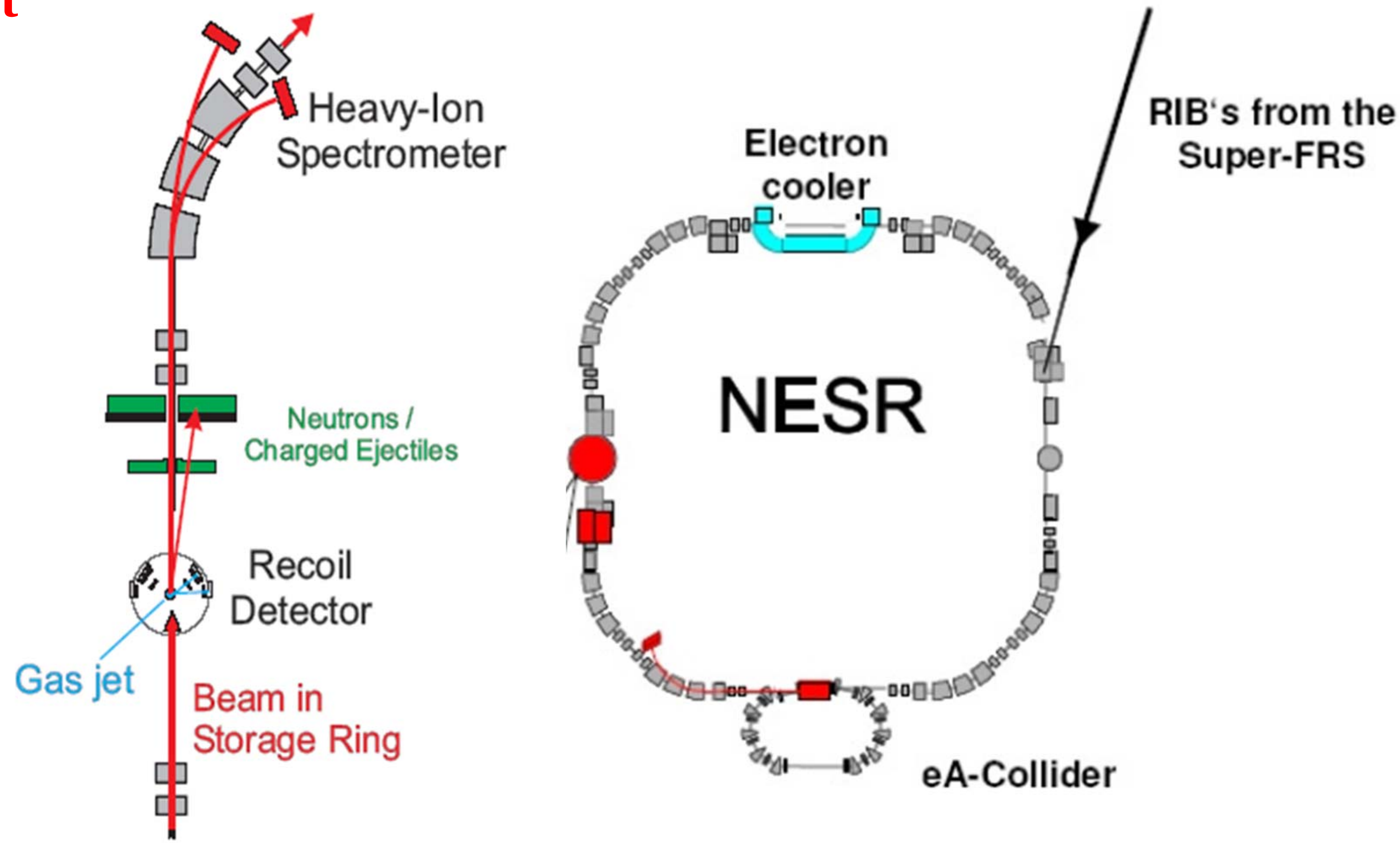
R3B: Reactions with Relativistic Radioactive Beams



Schematic drawing of the experimental setup comprising γ-ray and target recoil detection, a large-acceptance dipole magnet, a high-resolution magnetic spectrometer, neutron and light-charged particle detectors, and a variety of heavy-ion detectors

EXL: EXotic Nuclei Studied in Light-Ion Induced Reaction at the NESR

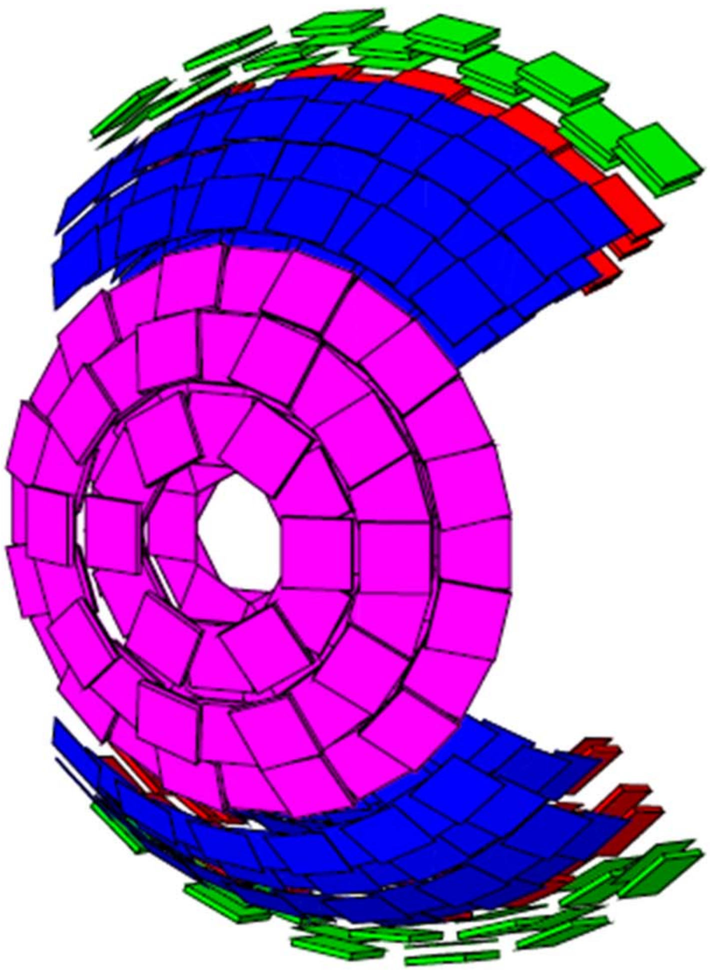




Completely new setup:
Si shell (~ 700 items)
CsI shell (~ 2000 items)

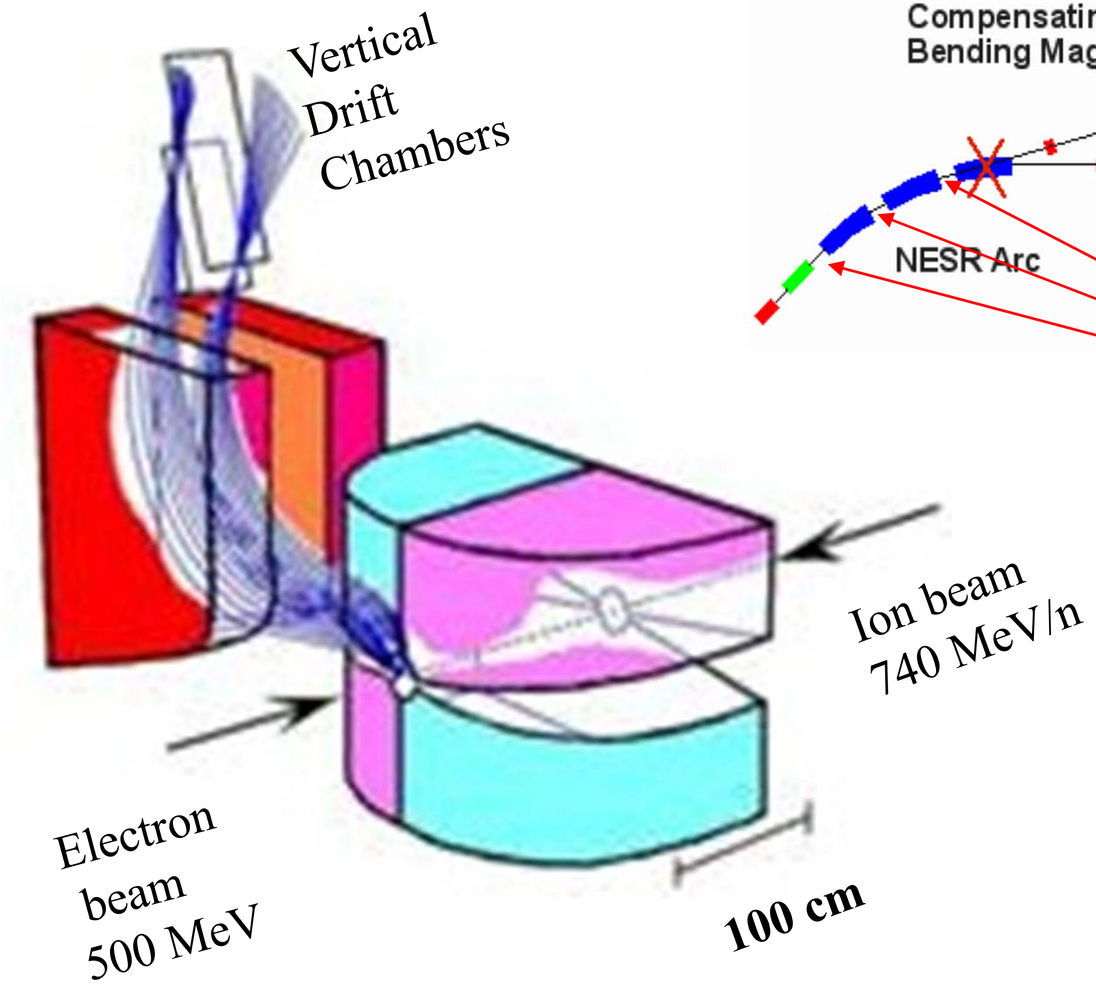
PTI (St.Petersburg) – silicon detectors
VNIIEF (Sarov) – mechanical support & temperature stabilization system
JINR and Kurchatov Institute – CsI shell
JINR – in-ring instrumentation

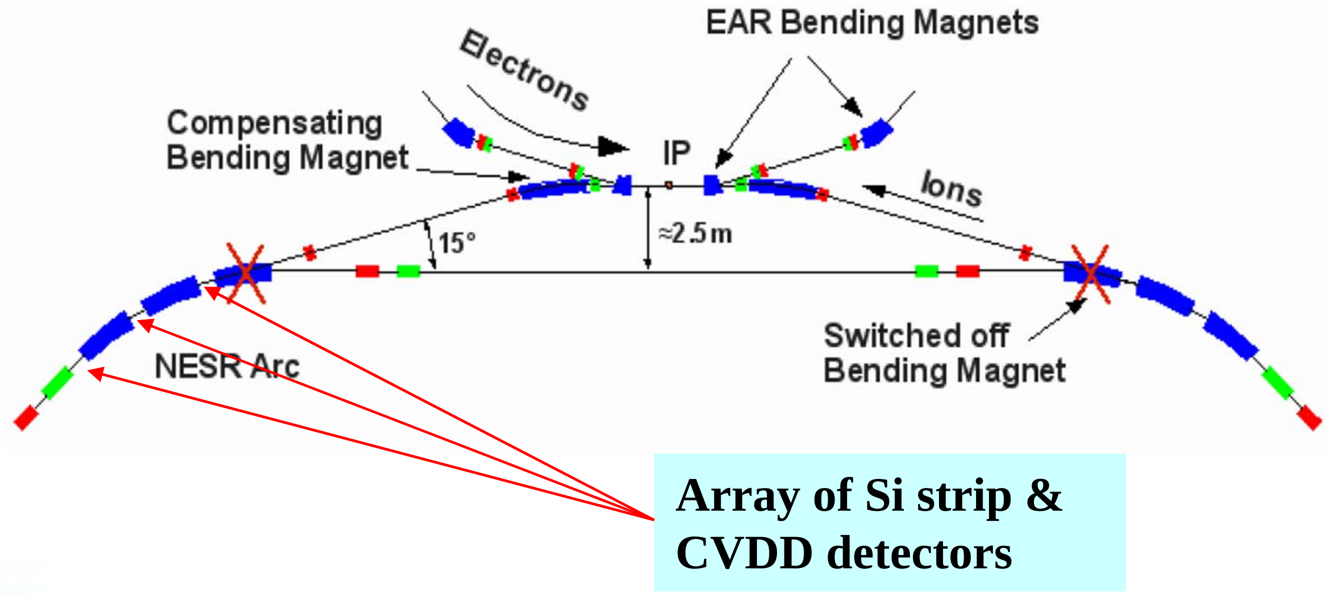
The EXL Recoil and Gamma Array



- **Thin Si DSSD → ΔE, x, y**
  ≤100 μm thick, spatial
  resolution better than 500 μm,
  ΔE ≈30 keV (FWHM)
- **Si DSSD → tracking**
  300 μm thick, double sided, spatial
  resolution better than 100 μm,
  ΔE ≈30 keV (FWHM)
- **Si(Li) → E**
  9 mm thick,
  large area 100*100 mm^2,
  ΔE ≈50 keV (FWHM)
- **CsI crystals → ΔE, γ**
  high efficiency, high resolution,
  20 cm thick

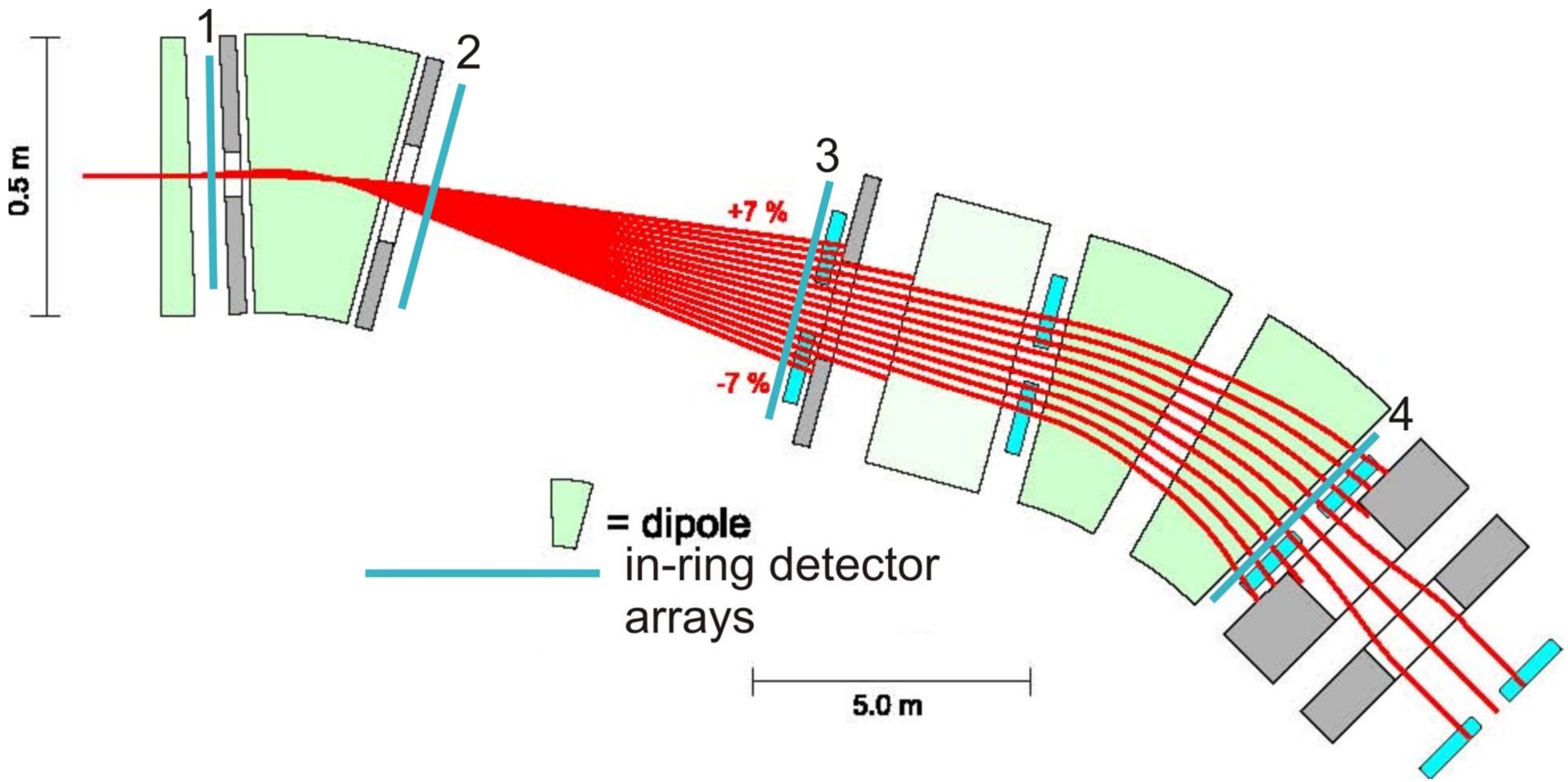
ELISe: ELectron-Ion Scattering experimet





BINP – deflection-separation magnets
INR RAS & KI – electron spectrometer
& luminosity monitor
JINR – in ring instrumentation & simulation

R&D status aimed on in-ring instrumentation for EXL/ELISe



Positions of detector arrays in the first bending section behind interaction zone in the NESR:

☞ detector array (1) in front of the first dipole magnet allowing for 'reaction tagging'

☞ two arrays (2 and 3) placed after the first dipole magnet intended for fragment tracking together with array (1)

☞ detector array (4) placed in front of the quadrupole section to implement the same task for fragments showing $\Delta p/p$ ~ 1-2%

Electron-Ion Interaction Point

Reactions: e(0.5GeV) + ^{132}Sn(0.74 AGeV)

- elastic scattering
- inelastic scattering with excitation of

  ^{132}Sn(E=10MeV, Γ = 1MeV)$\rightarrow^{131}$Sn + n

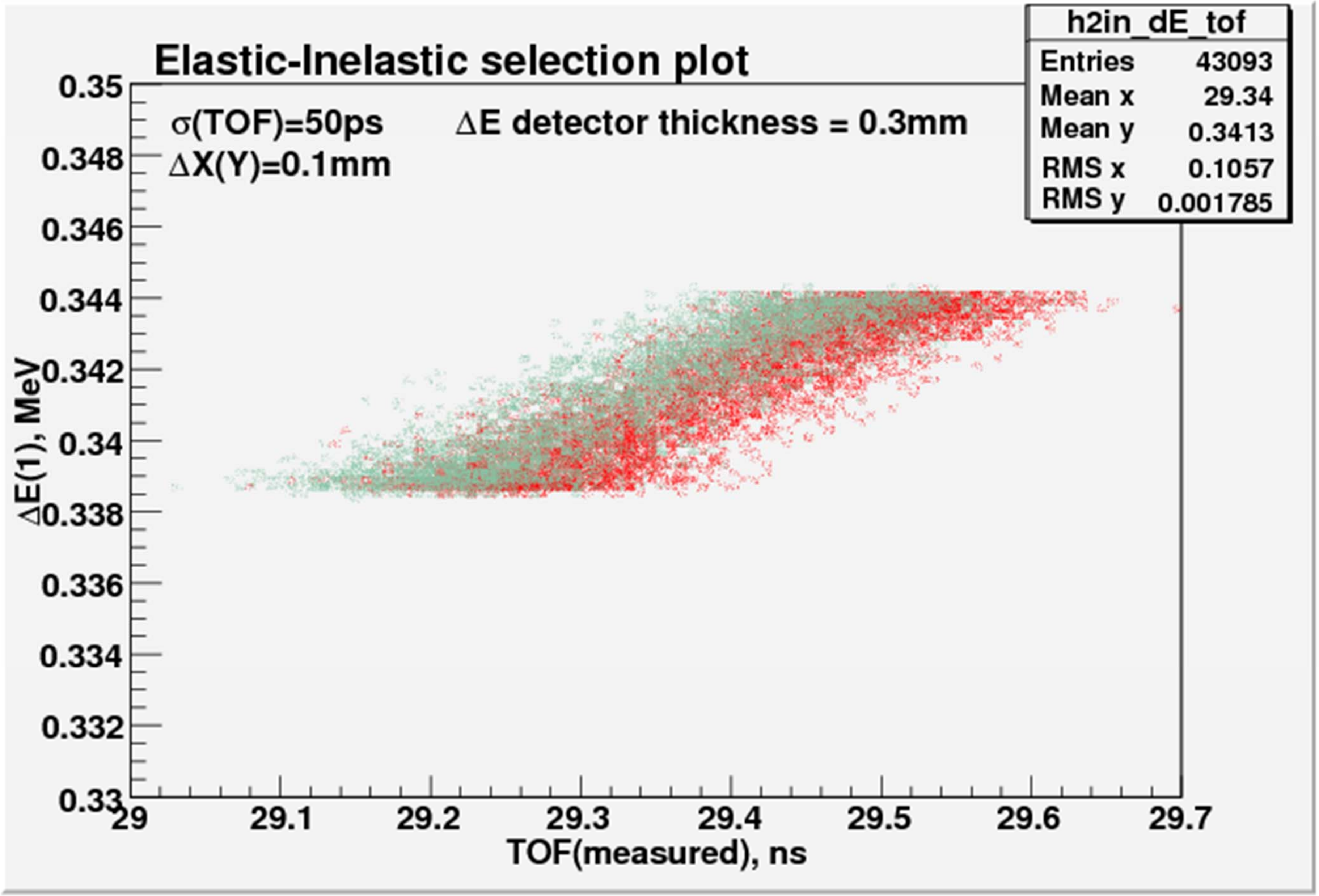
NESR structure: version 65 with bypass:

- beta_X = 1.0m, beta_Y = 0.15m
  - emittance_X(Y) = 0.05π mm mrad, ΔP/P=0.04%
  - σ(x) = 0.22 mm, σ (y) = 0.09 mm
  - $\Delta(\theta x) = \pm 0.22$ mrad, $\Delta(\theta y) = \pm 0.58$ mrad

TOF system parameters:

- TOF path = 7.2 m; σ(TOF) = 50 ps
- ΔX(Y) accuracy of track position = 0.1 mm
- detector thicknesses = 0.3 mm of Silicon

Results of simulation

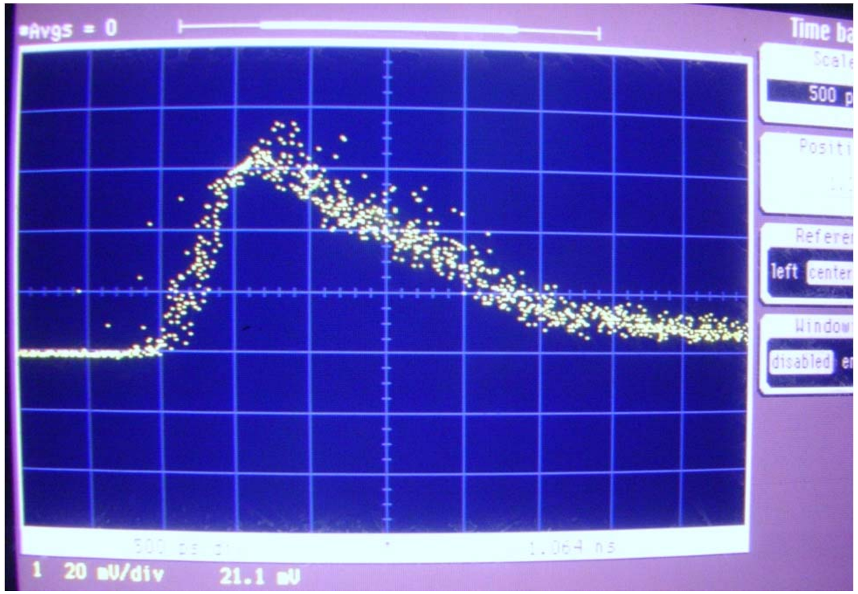


S. Stepantsov, ELISe Meeting 2009, Dubna

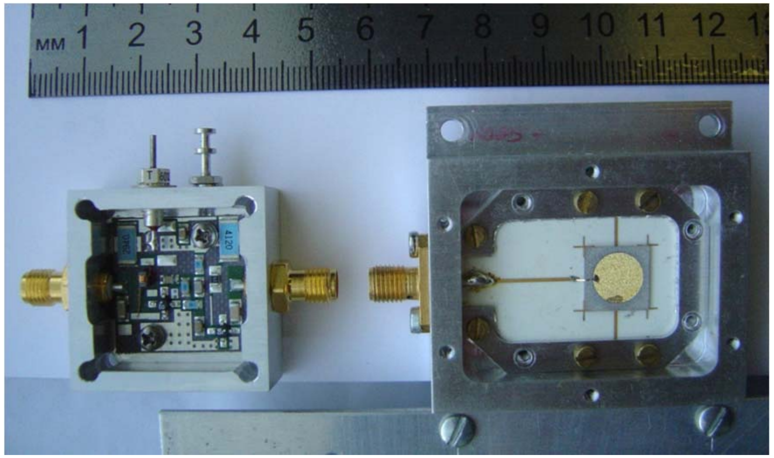
Request to detector system

- Detectors located nearby the circulating beam in the first two planes (arrays 1 and 2) should be thin enough in order to avoid any noticeable distortion caused by multiple scattering in the measured particle trajectories (**100-300 μm @ UHV**).
- High granularity strip detectors providing at least a **0.1 mm** resolution for the ion hit positions.
- Very good timing resolution (**σ ~ 30-50 ps**) and acceptable energy resolution for one planes 1-3 (~0.5%).
- Big enough active area (**X,Y~30x20 cm^2** for arrays 3,4).
- The detector arrays in planes 1–4 should be subdivided into two halves, each one **mounted** on a remotely controlled driving device, since the detector can be positioned only after beam adjustments in the NESR is completed.

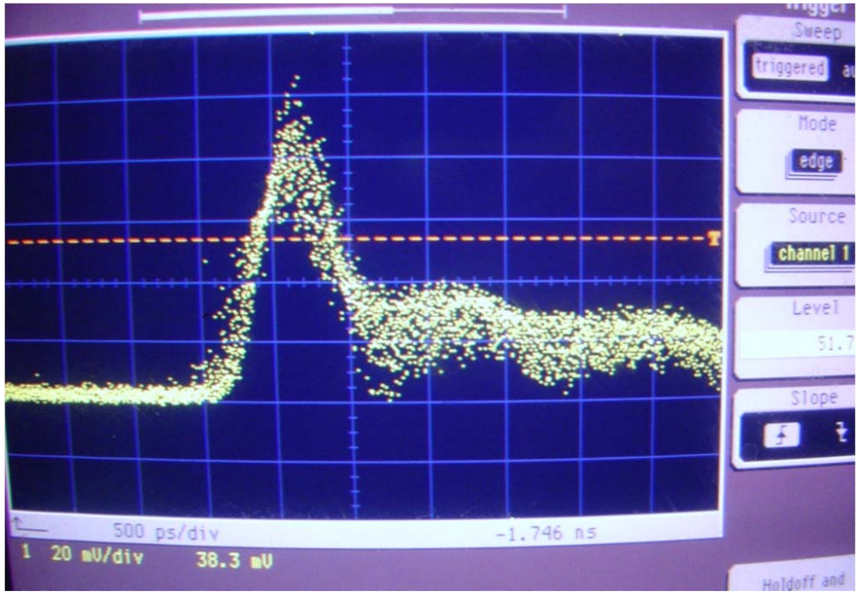
First results for CVDD & Si μ-strip detector



The typical pulses from CVDD in the case of ^{6}Li ions (59 MeV) at the intensities of ~5x10^{7} pps.

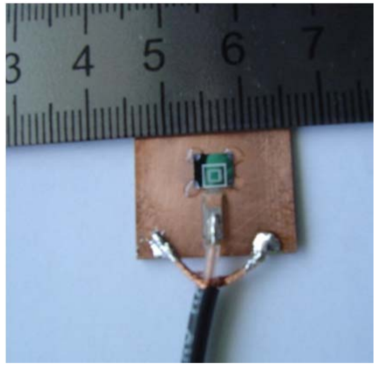


GSI

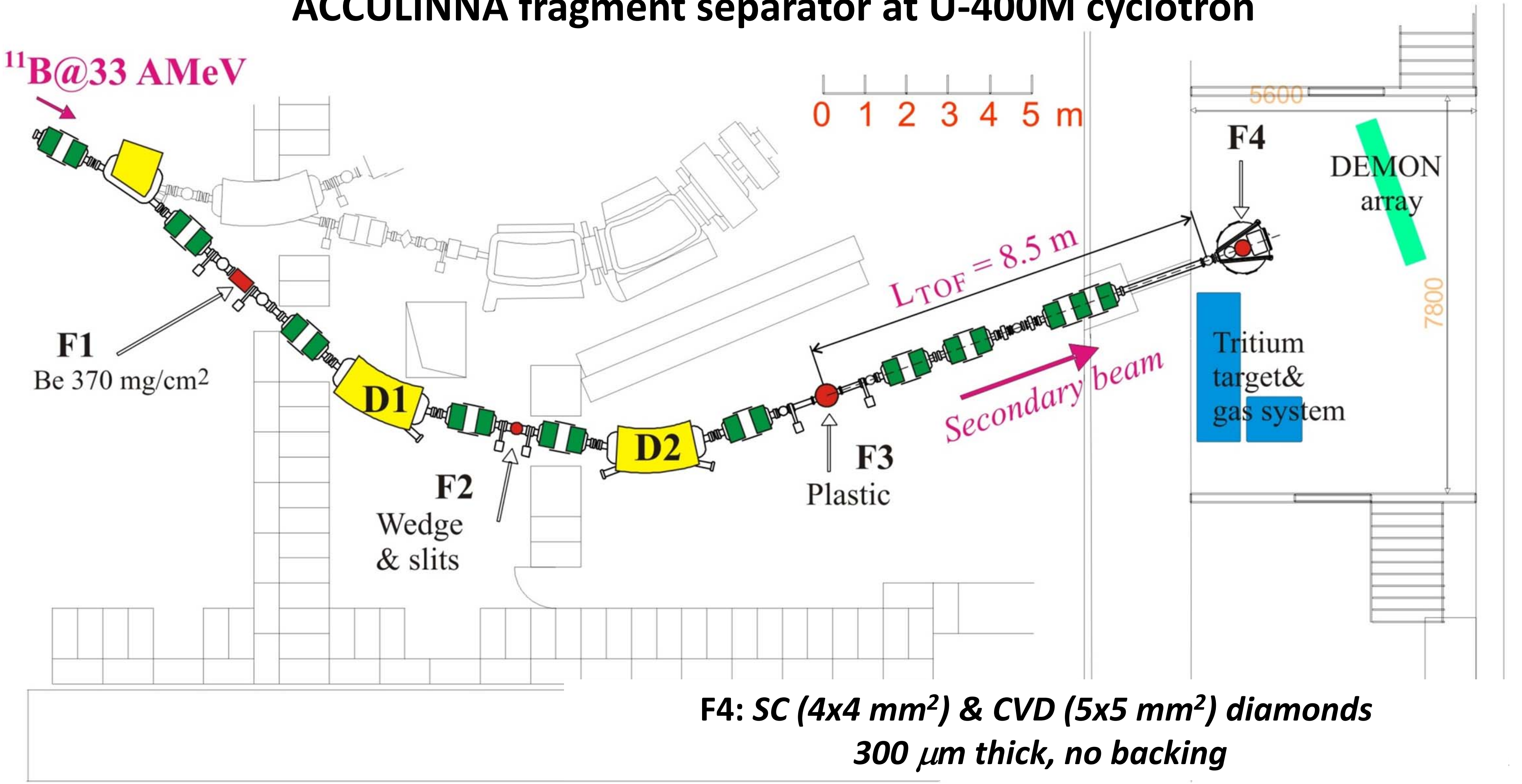


The typical pulses from Si micro-strip detector irradiated by alpha source ^{238}Pu (5.5 MeV).

PTI, St.Petersburg

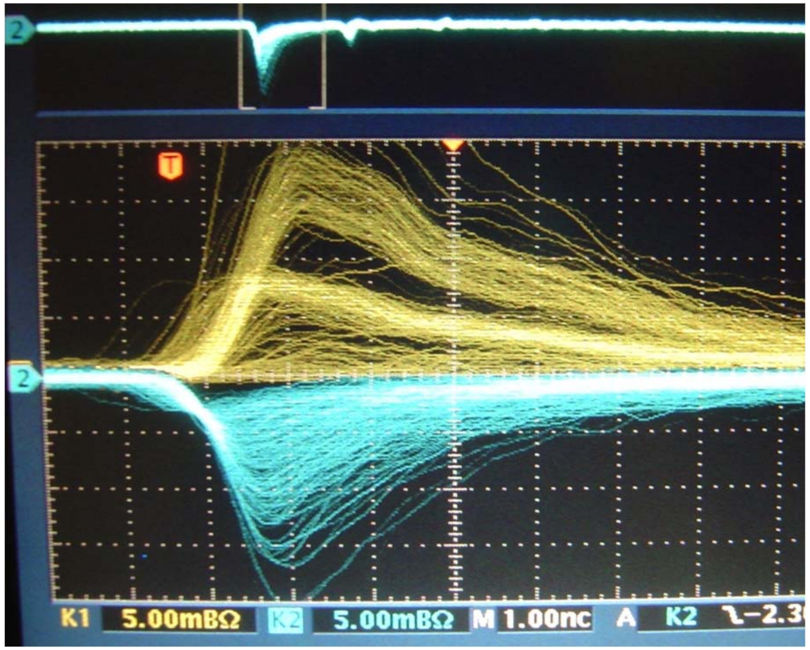


ACCULINNA fragment separator at U-400M cyclotron

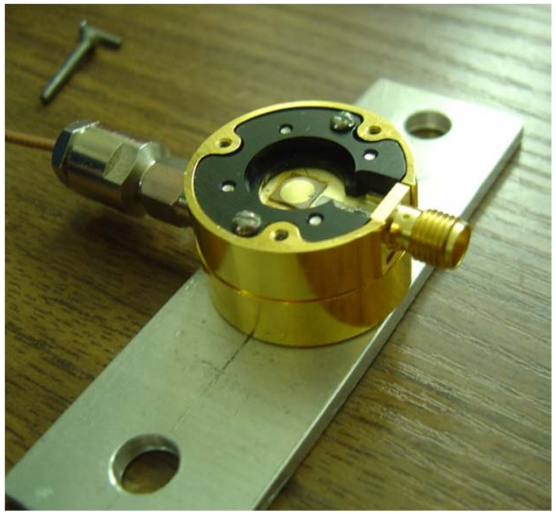


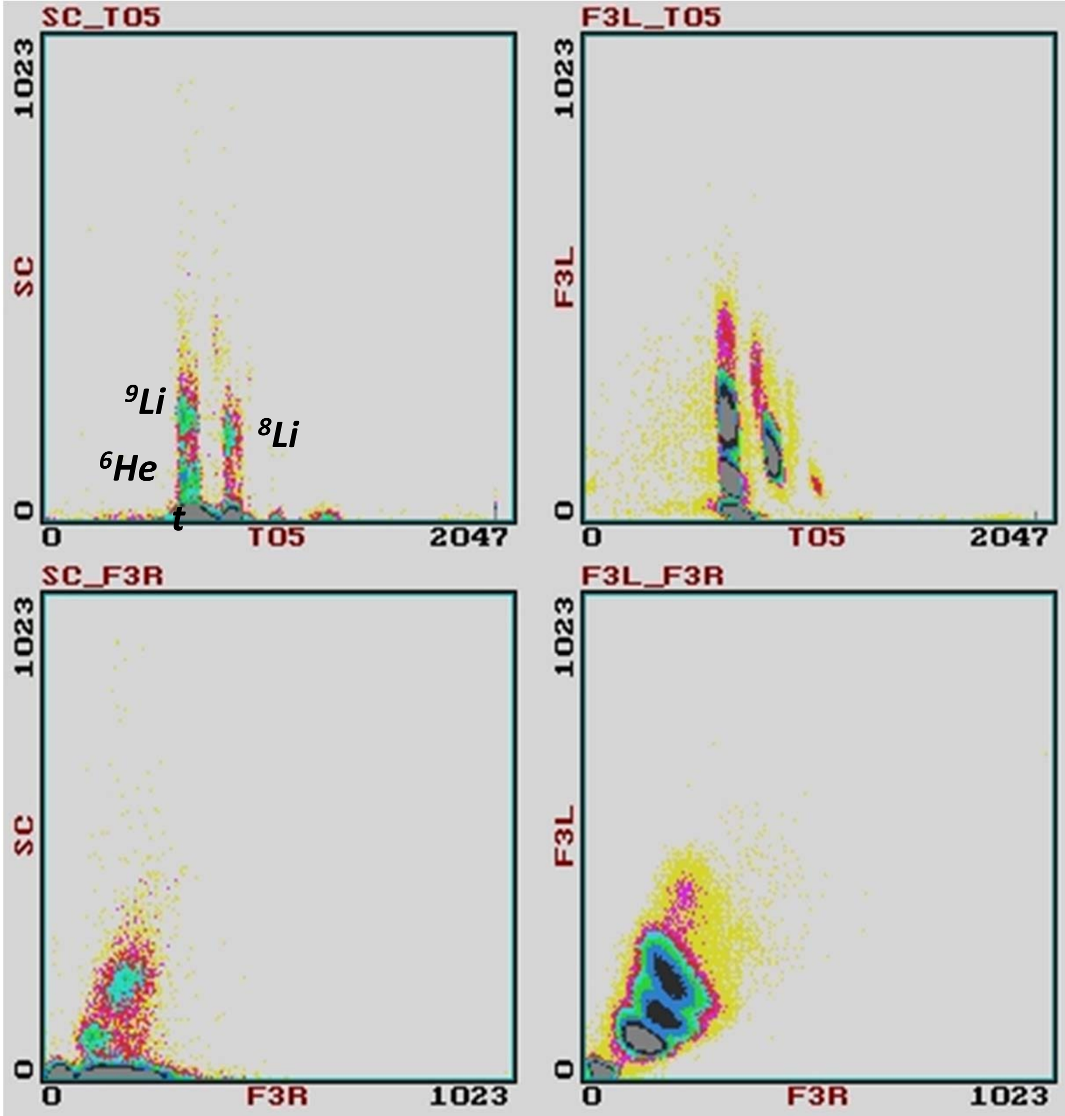
F4: *SC (4x4 mm^2) & CVD (5x5 mm^2) diamonds*
300 μm thick, no backing

First results with RIB's for CVDD and SCD detectors



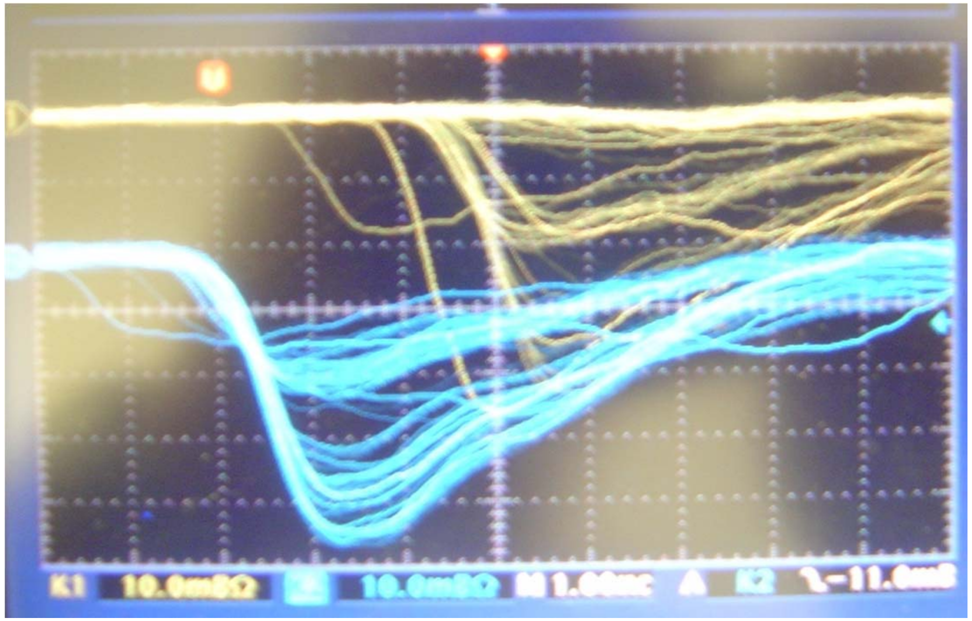
CVDD (blue) , SC (yellow) ⇒ $\delta t \sim 250$ ps

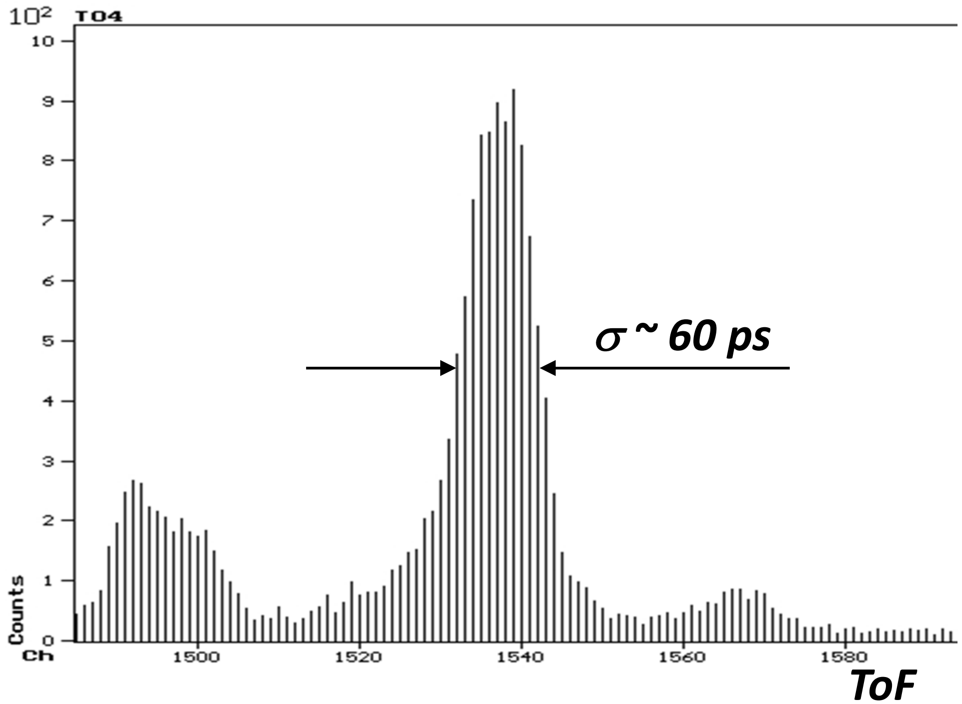




identification plots for the reaction
^{15}N(47 AMeV) + ^{12}C @ E(^{6}He) ~ 40 AMeV

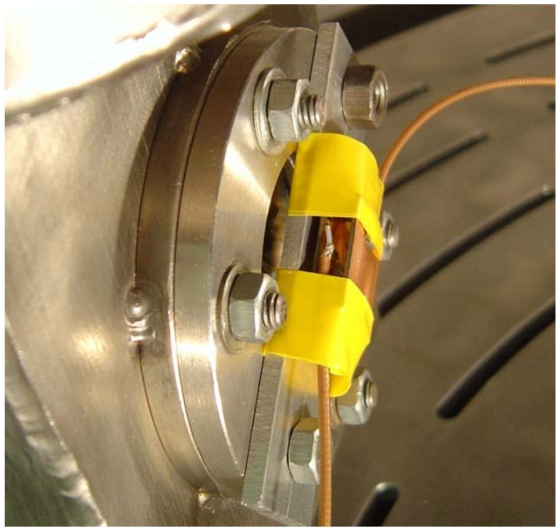
Si µ-strip detector

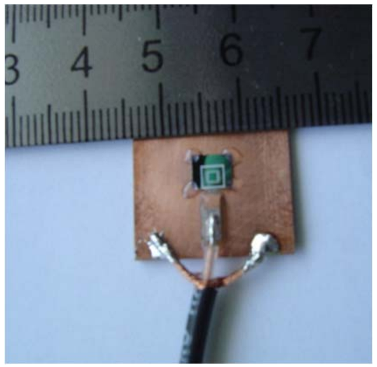




1.5x1.5 mm², 300 µm thick,

backing



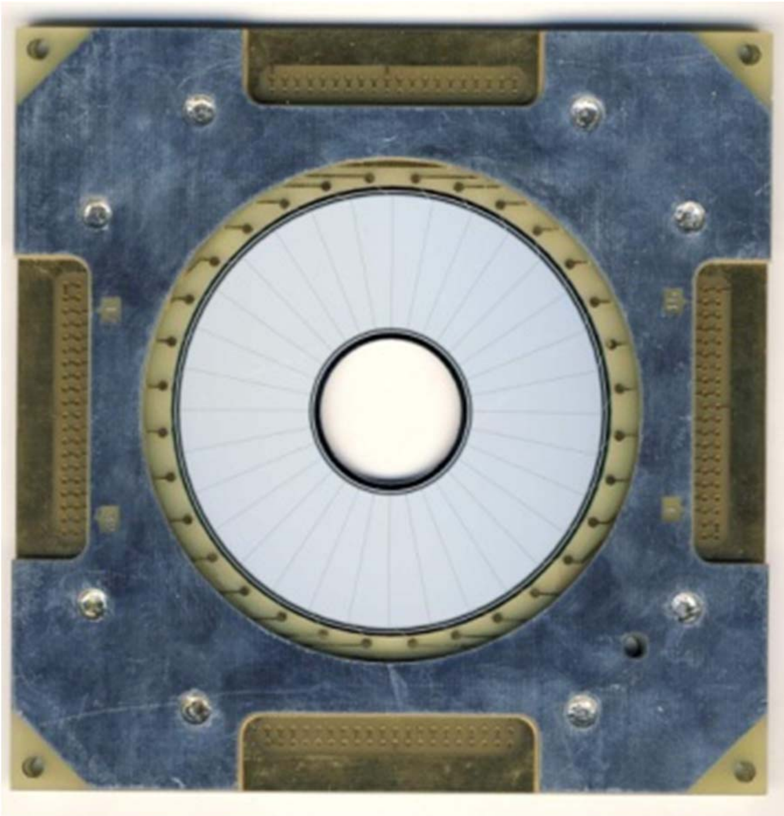


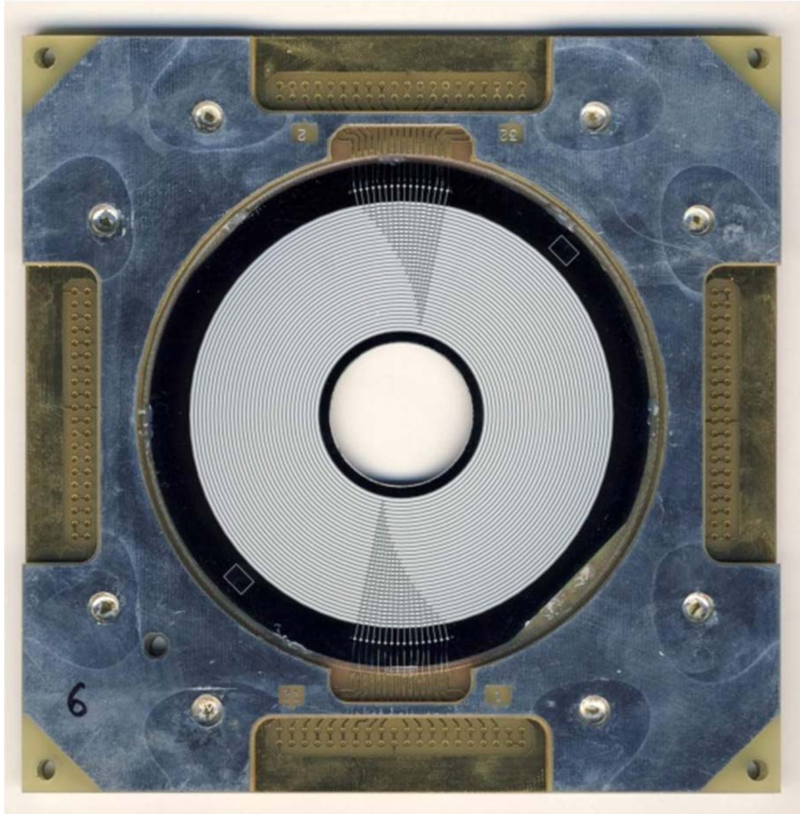
<u>Advantages of Si over diamond:</u>

- the same time resolution
- good amplitude resolution
- simplicity in operation
- not expensive

? radiation hardness

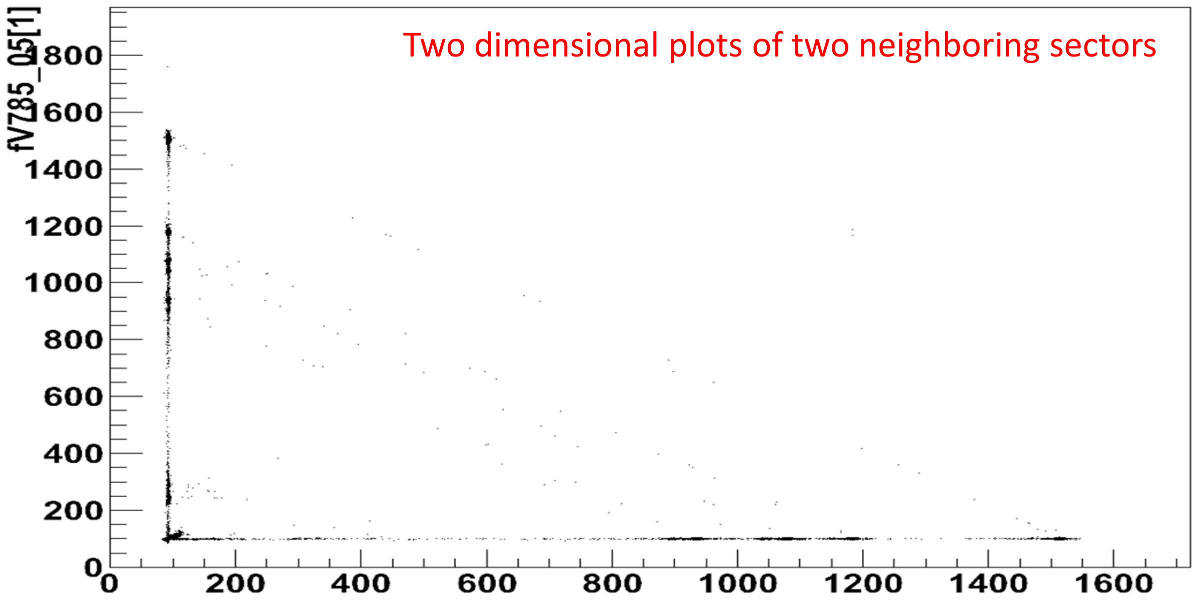
Thick round DSSD detector



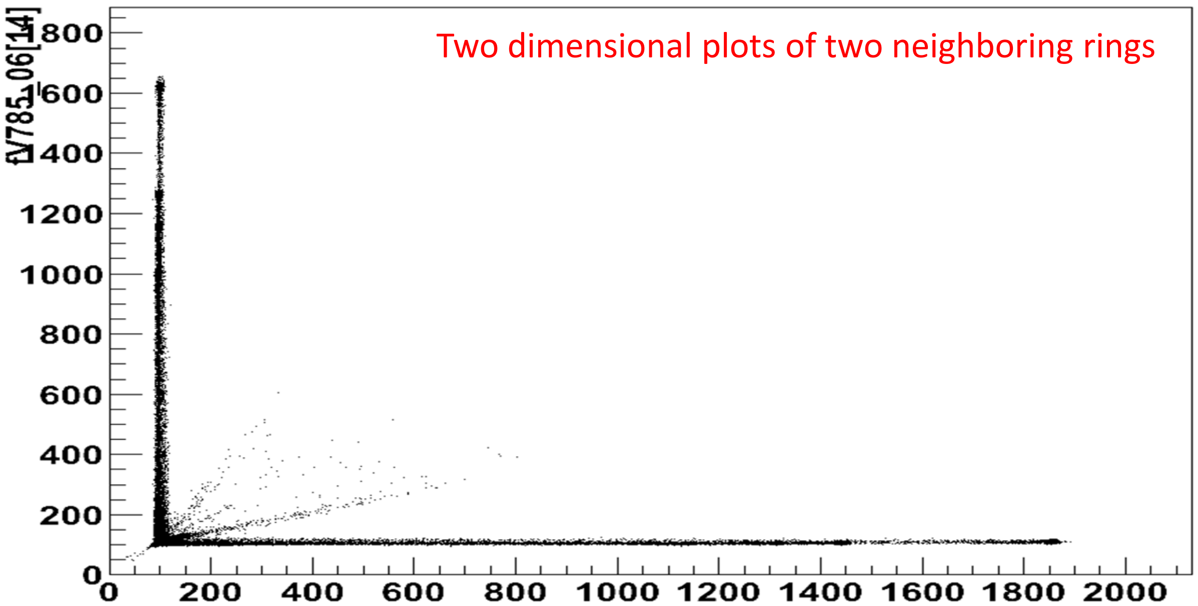


64 sectors from the front side and 32 rings on the back side.
Active zone external diameter - 84 mm, internal diameter - 28 mm.
Distance between two neighboring sectors - 40 µm. Distance between two rings – 170 µm.
Si wafer thickness is 1 mm.
Full depletion voltage U = 200 B, I ≈ 2 µA.

Thick round DSSD detector



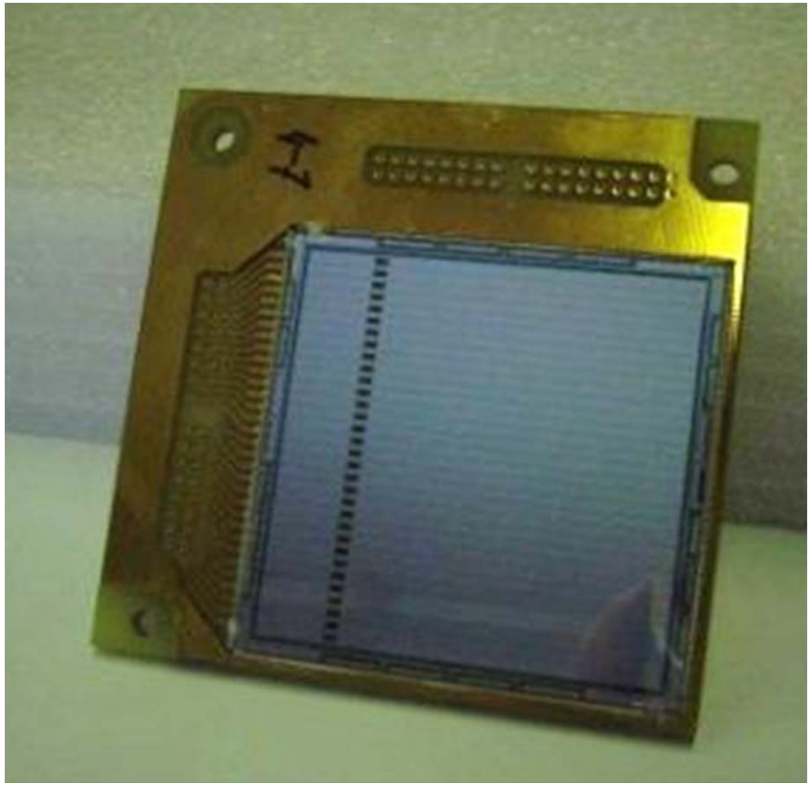
Detection efficiency
98 %

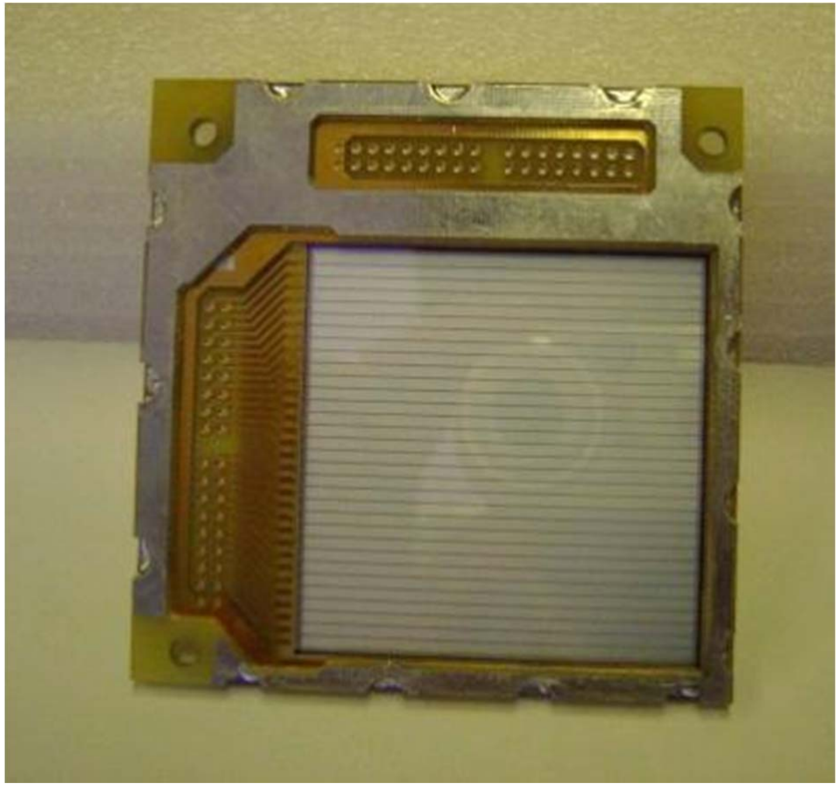


Detection efficiency
85 %

Leading edge of signals have duration about 0.5-0.6 μs
Energy resolution of sectors at room temperature 40 keV

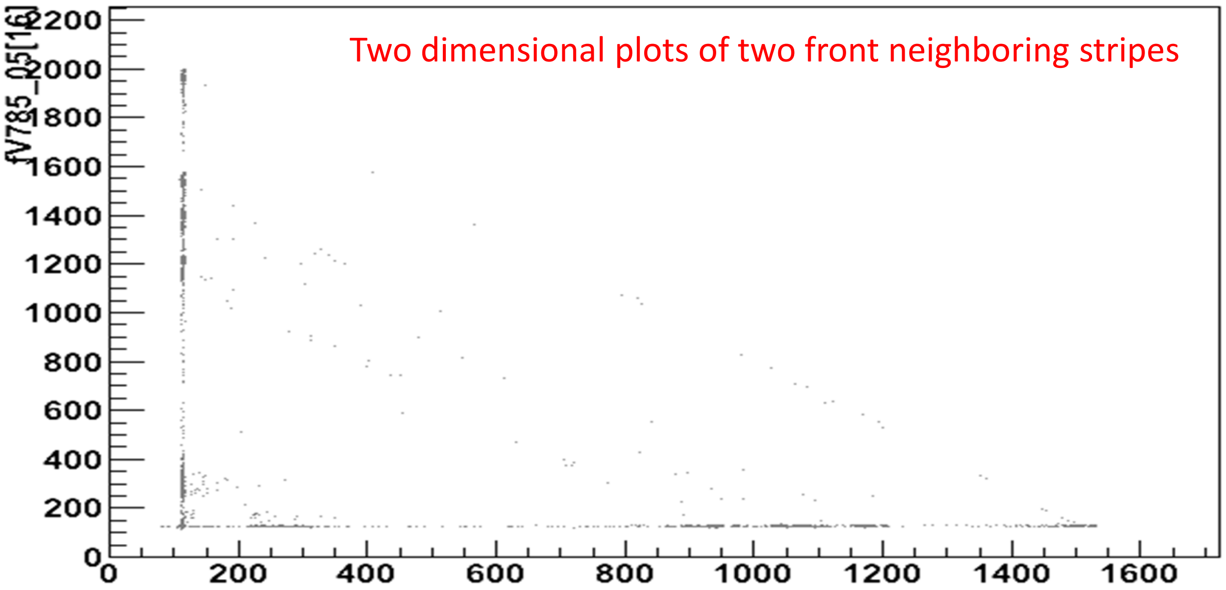
Thick square DSSD detector



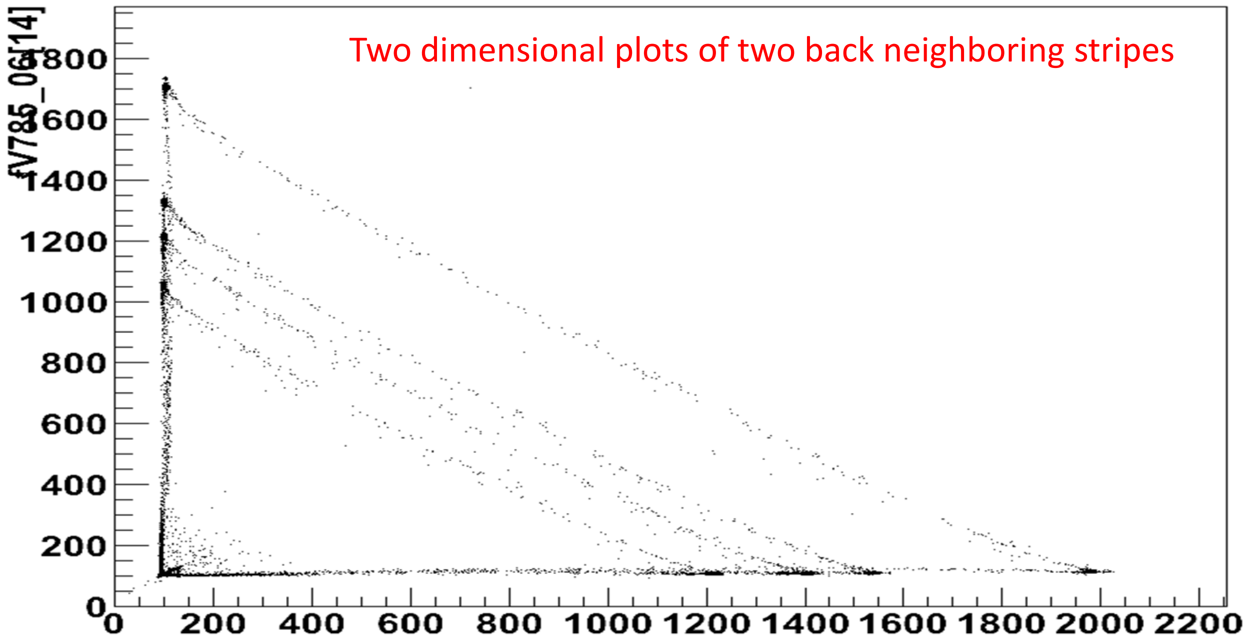


32 strips on the front and back sides.
interstrip distance on the front side - 40 µm, on the back side - 210 µm.
Active area 58×58 мм^2, thickness of silicon wafer - 1 mm,
Full depletion voltage U = 200 V, current I ≈ 1.2 µA.

Thick square DSSD detector



Detection efficiency
96 %



Detection efficiency
87 %

Leading edge of signals have duration about 0.6 μs
Energy resolution of front stripes at room temperature 35 keV

Conclusion

SC diamond detectors:

+ good timing and energy resolutions
+ high radioactive hardness
- can't be big enough
- very expensive

CVD detectors:

+ good timing resolution
+ high radioactive hardness
- low energy resolution
- can't be produced big enough in the nearest some years

Si μ-strip detectors:

+ good timing and energy resolutions
+ low cost

? low radioactive hardness

Thick DSSD detectors:

+ perfect energy resolutions
+ low interstrip charge division
- not so fast, as Si μ-strip and diamond detectors

? low radioactive hardness