Status of diamond sensors for HADES and CBM

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Outline

- FAIR; HADES and CBM experiments
- ToF: requirements for Start detector
- HADES in-beam Start detectors
- mosaic concept for CBM SD
- beam line in CBM cave
- beam monitoring and tracking issues

Facility for Antiproton and Ion Research

Primary Beams

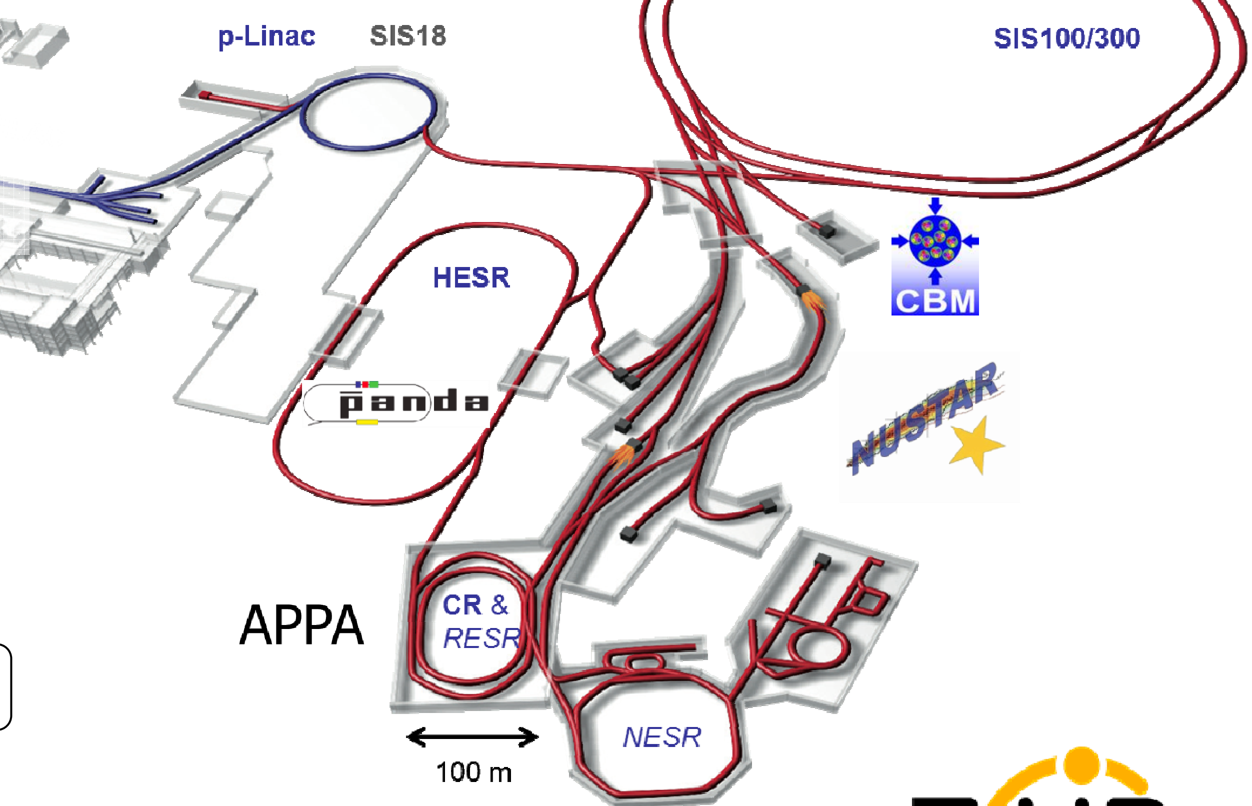
- 10^{12}/s; 1.5 GeV/u; $^{238}U^{28+}$
- 10^{10}/s $^{238}U^{73+}$ up to 35 GeV/u
- 3×10^{13}/s 30 GeV protons

Secondary Beams

- range of radioactive beams up to 1.5 - 2 GeV/u; up to factor 10 000 higher in intensity than presently
- antiprotons 3 - 30 GeV

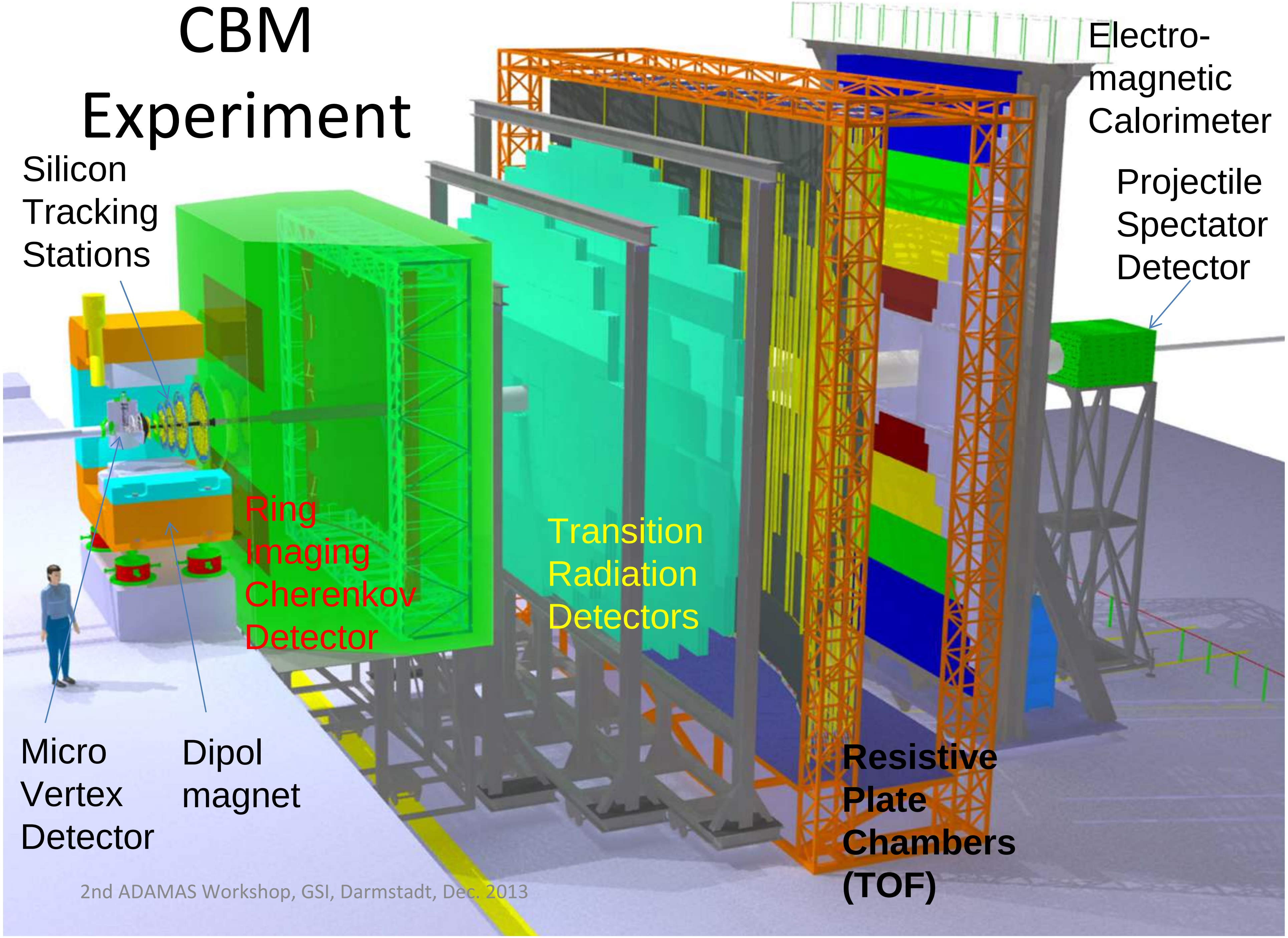
Storage and Cooler Rings

- radioactive beams
- 10^{11} antiprotons 1.5 - 15 GeV/c, stored and cooled



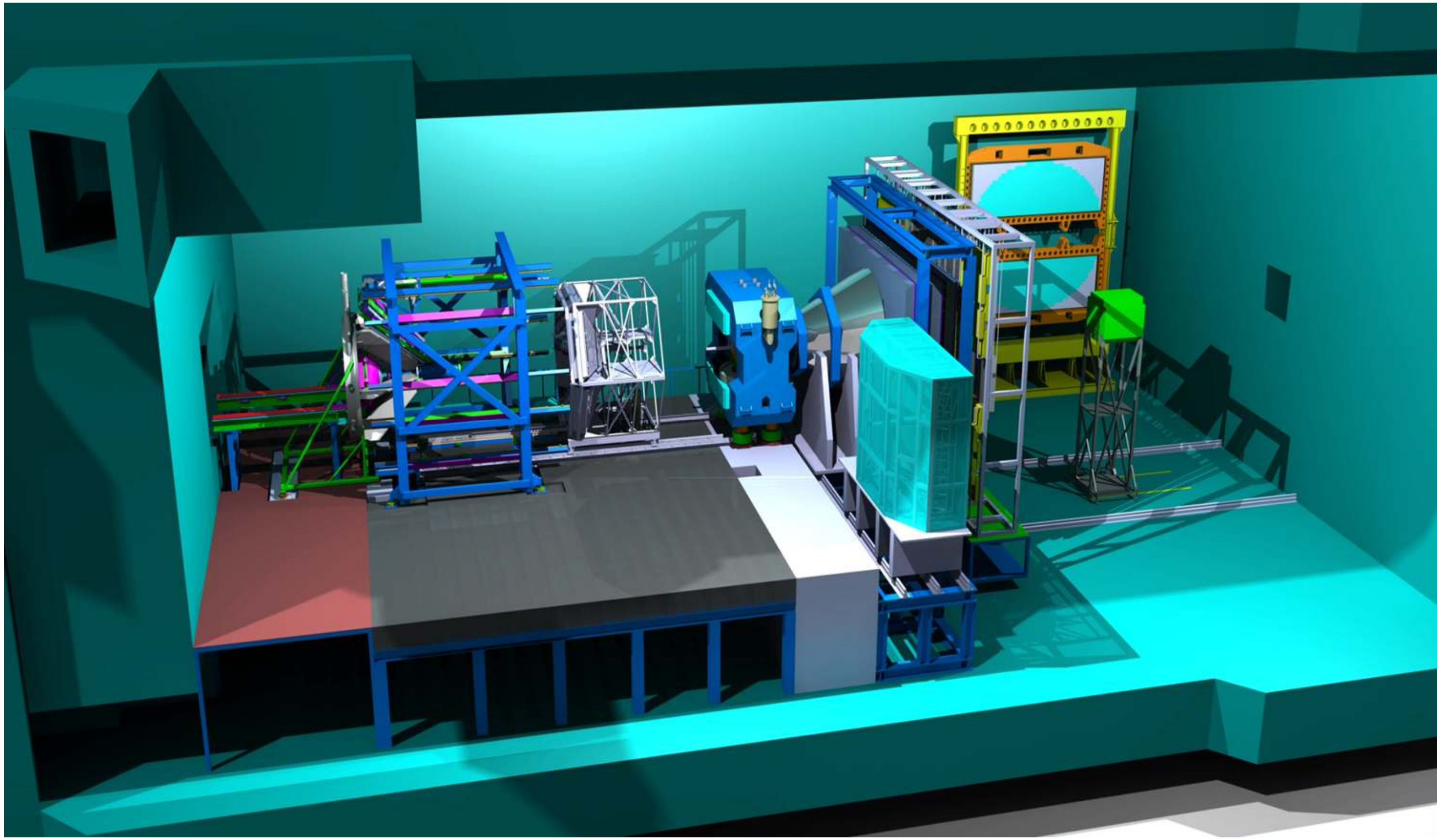
SIS100: Au 11 A GeV
SIS300: Au 35 A GeV

CBM Experiment



CBM Cave for SIS-100

HADES / CBM [STS + MUCH (RICH) + TRD + ToF + (ECAL) + PSD)]



T0 determination

- T0 determination:
  - in-beam dedicated Start Counter
  - dedicated reaction counter
  - dedicated RPC start counter
  - software determination of T0 (ToF wall itself)
- there are particular physics cases where some of above methods would be preferable to others
- software based method can be applied concurrently to any of hardware methods
- proposed detectors are mutually inclusive as long as physics is not affected
- both for HADES and CBM

Requirements for CBM in-beam SD

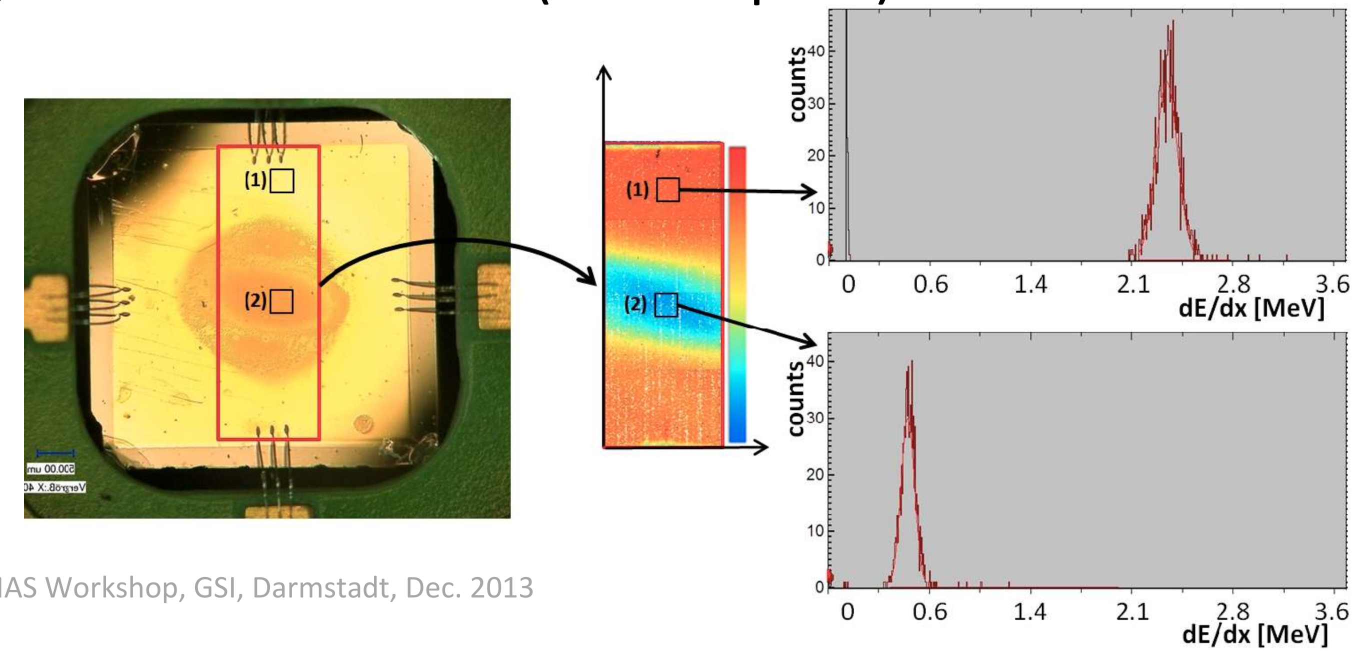
- required time resolution for ToF Wall of system resolution $\sigma_{ToF} < 80$ ps is $\sigma_{T0} < 50$ ps
- efficiency close to 100%
- radiation hard design, vacuum operation
- rate capability: beam requirements, up to 10^9 ions/s, possibly up to 10^{11} p/s
- optional: beam particle tracking
- beam-optimized size of detector
- high-rate high-resolution fast readout electronics
- version for HIs and for MIPs (protons)
- to be used by HADES and CBM

Radiation hardness requirement

- for HIs (Au) 50 µm (pc/scCVD), 0.4 % inter. rate
- for MIPs (p) 300 µm scCVD, 0.4 % inter. rate
- should not be obstacle for downstream detectors
- dose for MI proton beam of 10^9 1/s is about 10 Gy/day
- dose for 4x4 cm^2 pcCVD diamond exposed to 10 AGeV Au ions at same intensity is 600 Gy/day
- we should be able to operate detectors for months

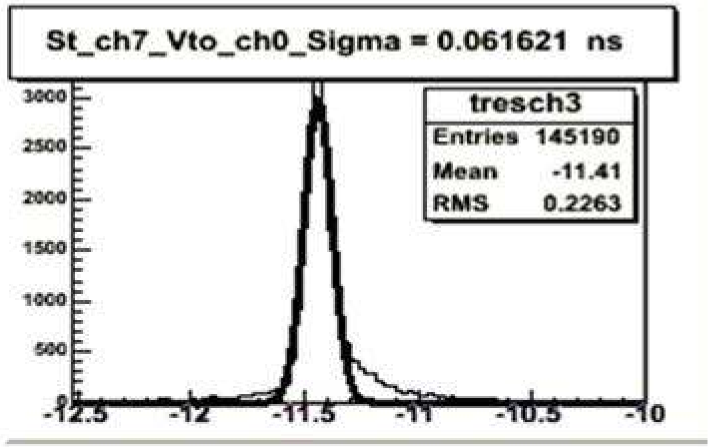
Radiation hardness

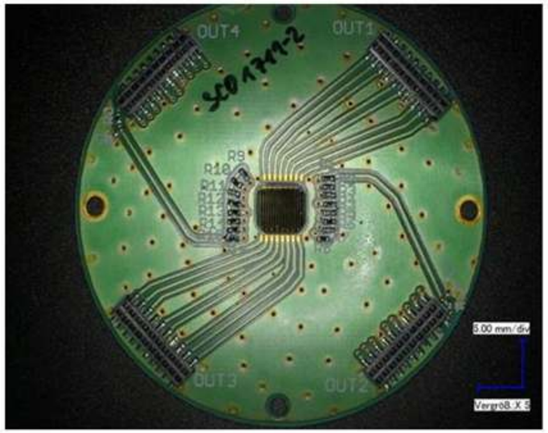
- 70 µm thick scCVD irradiated with 1.25 AGeV Au beam, $3x10^{11}$ particles/mm^2, about 80 MGy
- equivalent to 10^{12} protons/mm^2 (reported limit about 10^{14})
- deterioration of signal observed, timing 42 ps to 54 ps
- IBIC method to characterize damage
- signals are still usable (HV adopted)

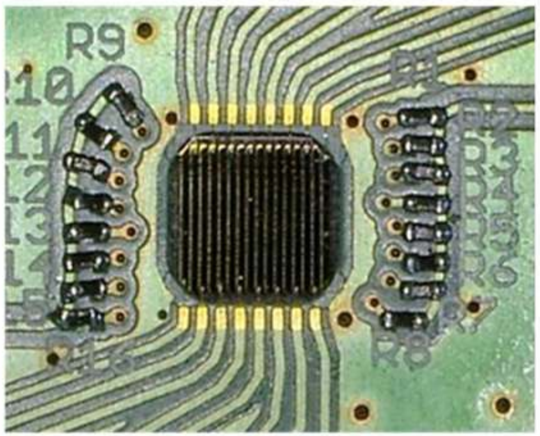


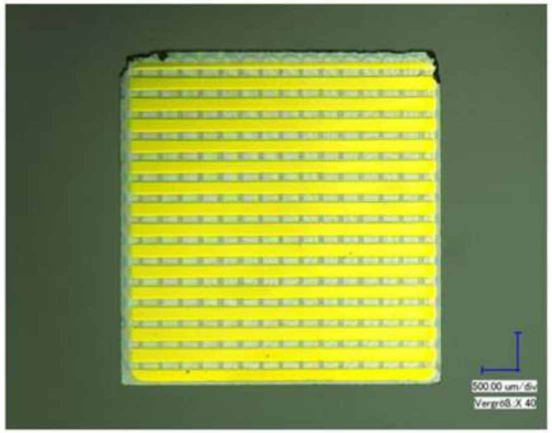
HADES strip detector prototype

- 4.7x4.7 cm^2, 60 µm thick scCVD
- 16 x 16 strips (front and back)
- timing + x,y position (tracking)
- timing better than 55 ps



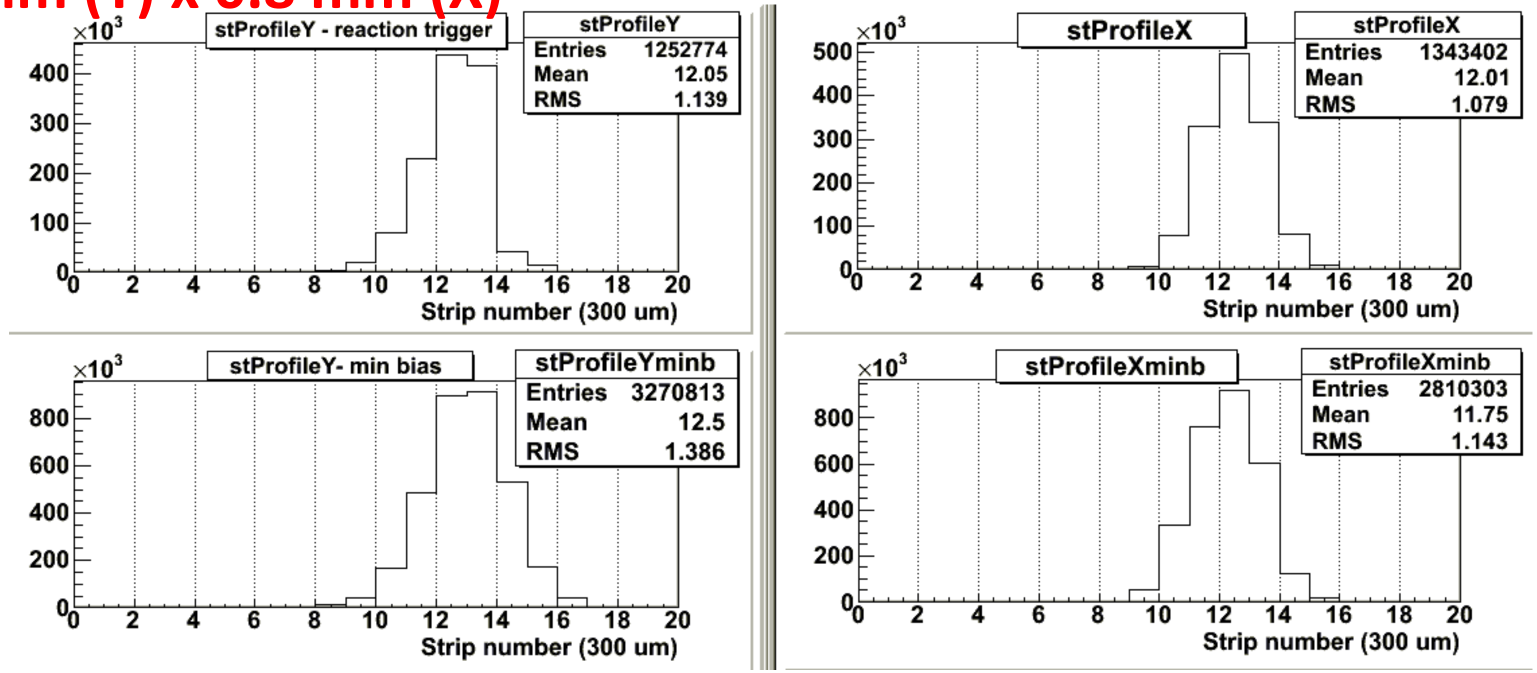




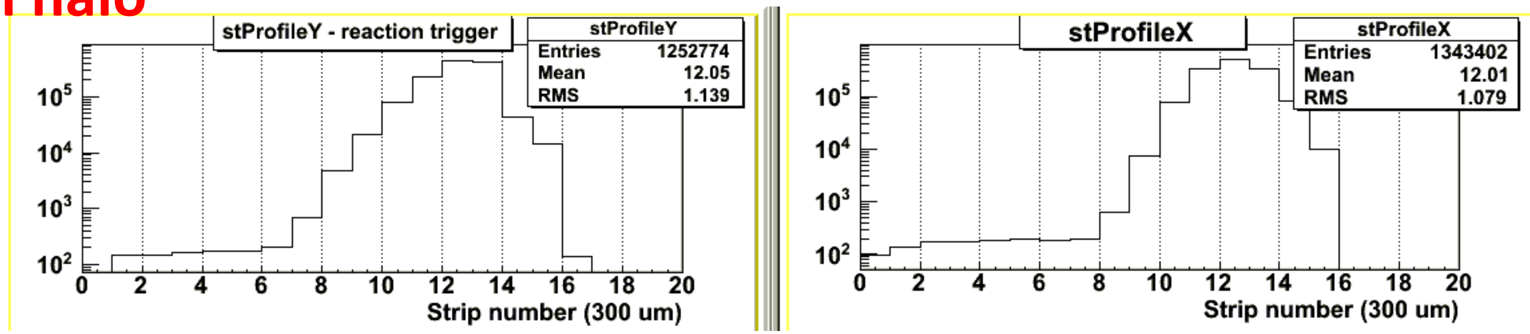


Beam profile

1.2 mm (Y) x 0.8 mm (X)



beam halo



Concept for CBM detector

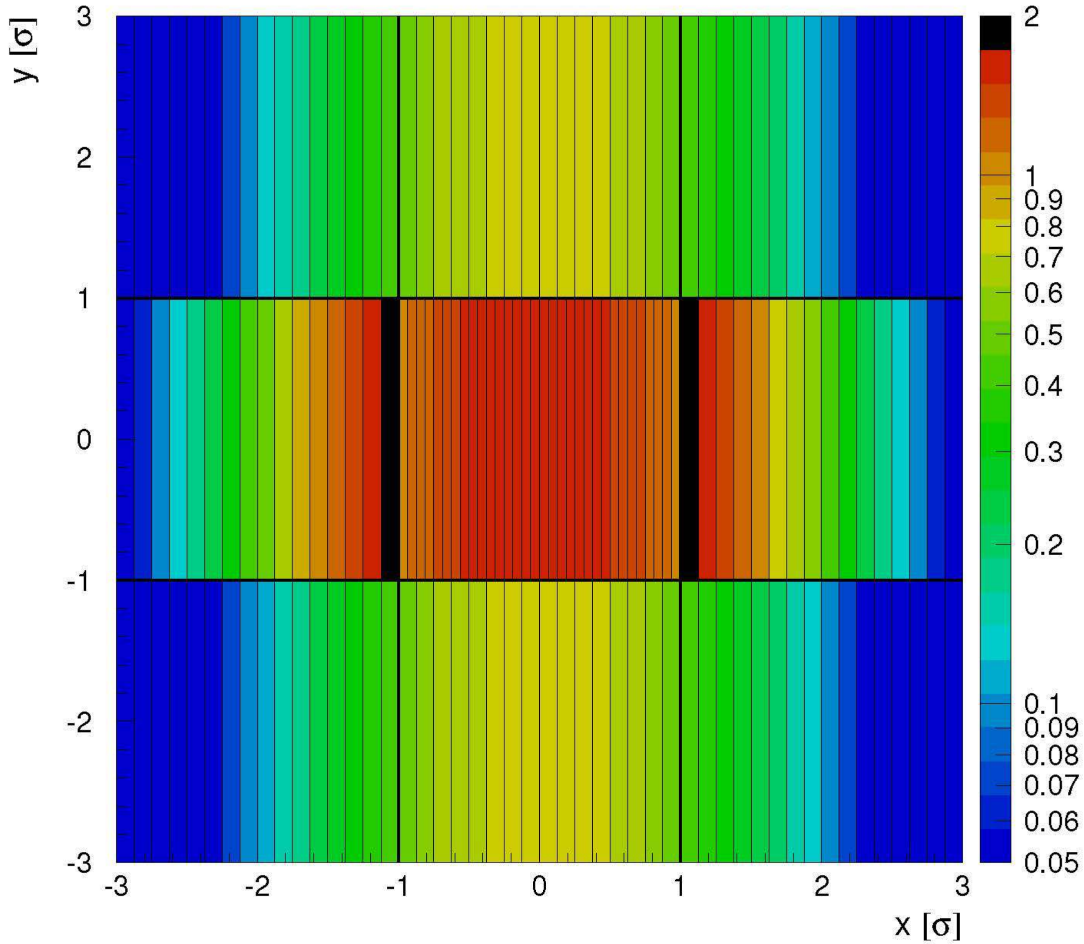
- first possibility: large area pcCVD diamond
  - large area, good radiation hardness (+)
  - large signal variation, low CCE (-)
  - can be used for HI
- second possibility: scCVD
  - 4.5x4.5 cm^2 standard size, max. 1 cm^2 (rare) (-)
  - around 100% CCE, excellent signal stability (+)
  - only viable solution for MIPs
- DOI?

Concept for in-beam detector: occupancy adjustment

- by proper segmentation of the detector we can come up to a rate that can be tolerated by each electronics channel detector
- using readily available scCVD of 4.5 x 4.5 mm^2
- mosaic detector: using a 2x2 or 3x3 matrix
- vertex detector: using two widely spaced detectors helps vertex detection
- beam monitoring: precise beam position and intensity variation determination

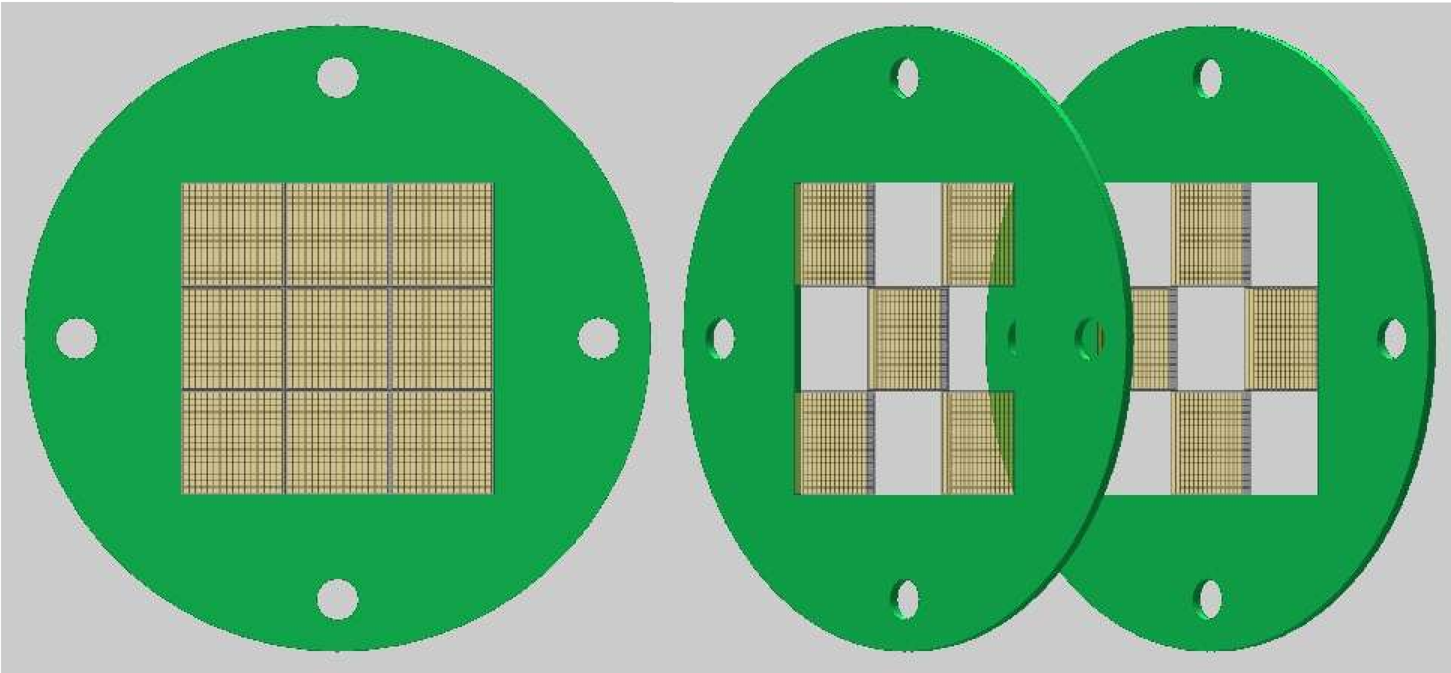
Mosaic concept

- beam 10^9 part/s
- assumed Gaussian shape (+-3 σ)
- 3x3 diamond plates, strip segmented in x, y (both sides)
- 16 strips (32 in centre), 320 channels
- maximum intensity ~ $1/(2\pi\sigma^2)$



Mosaic 3x3 diamond SD

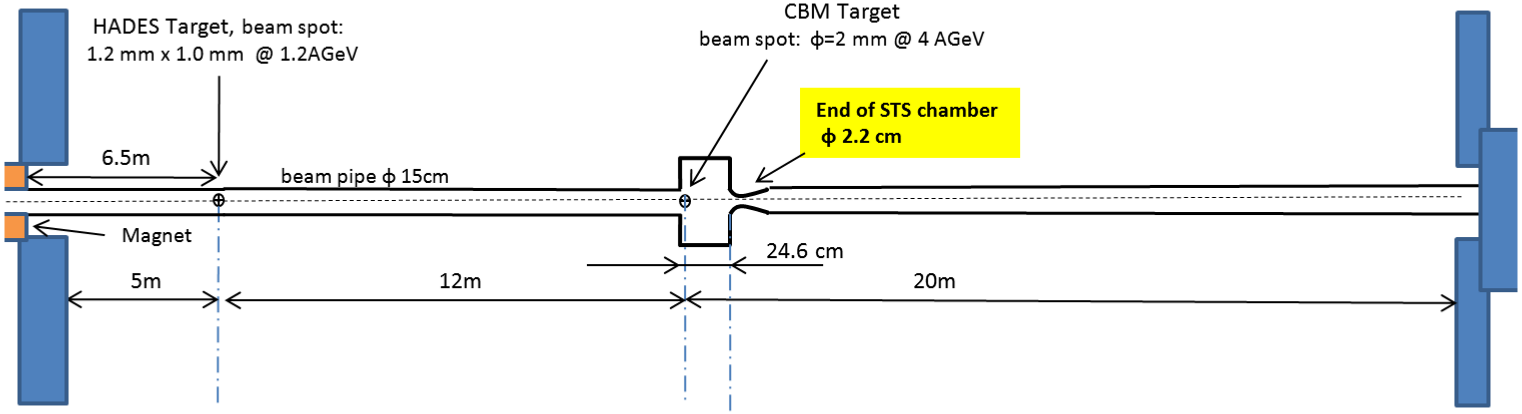
- diamond sensor placement in a mosaic structure
- signal extraction 2x2 simple, 3x3 complicated



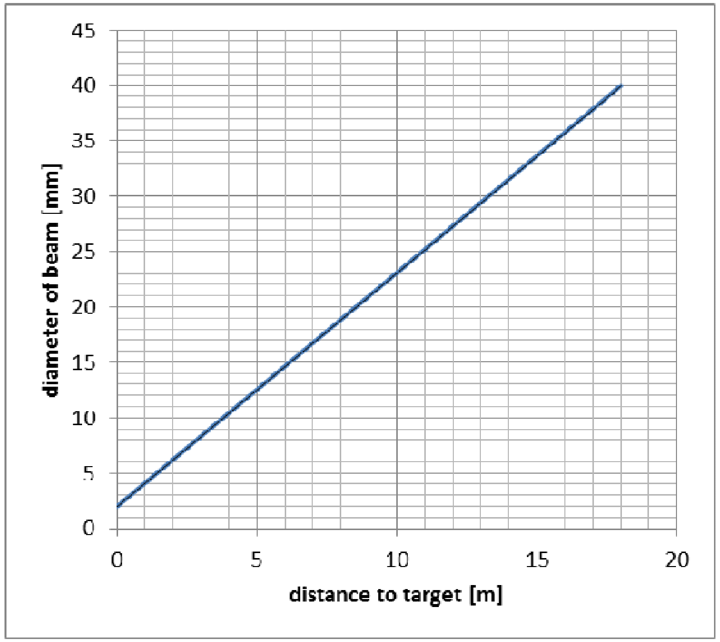
Readout electronics

- large difference in intrinsic signal in diamond
- HIs: for Au beam of 10 AGeV 4 MeV/µm
- MIPs: for protons of 10 GeV 0.6 keV/µm
- presently obtainable resolution with MIPs is better than 100 ps, needs improvement
- FEE: (HADES) NINO (+ booster stage)
- under development: PADI-8d
- digitizer: TRB3, FPGA, runs with HADES and CBM protocol

CBM Cave beam line



- beam size expected at target position d=2 mm
- focusing quadruples 18,5 m upstream
- upstream beam-pipe diameter 15 cm (bore of quadruplets 17 cm)
- maximum beam size d = 4 cm after quadruple
- based on "old" magnetooptics calculations

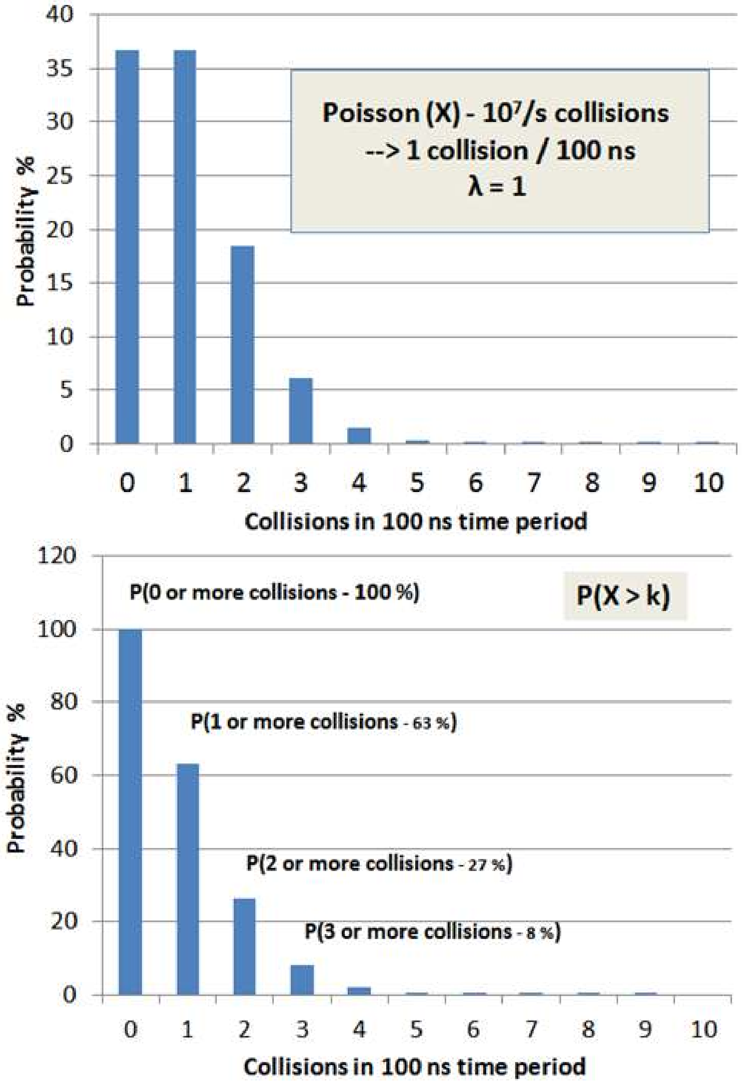


Target and beam monitoring

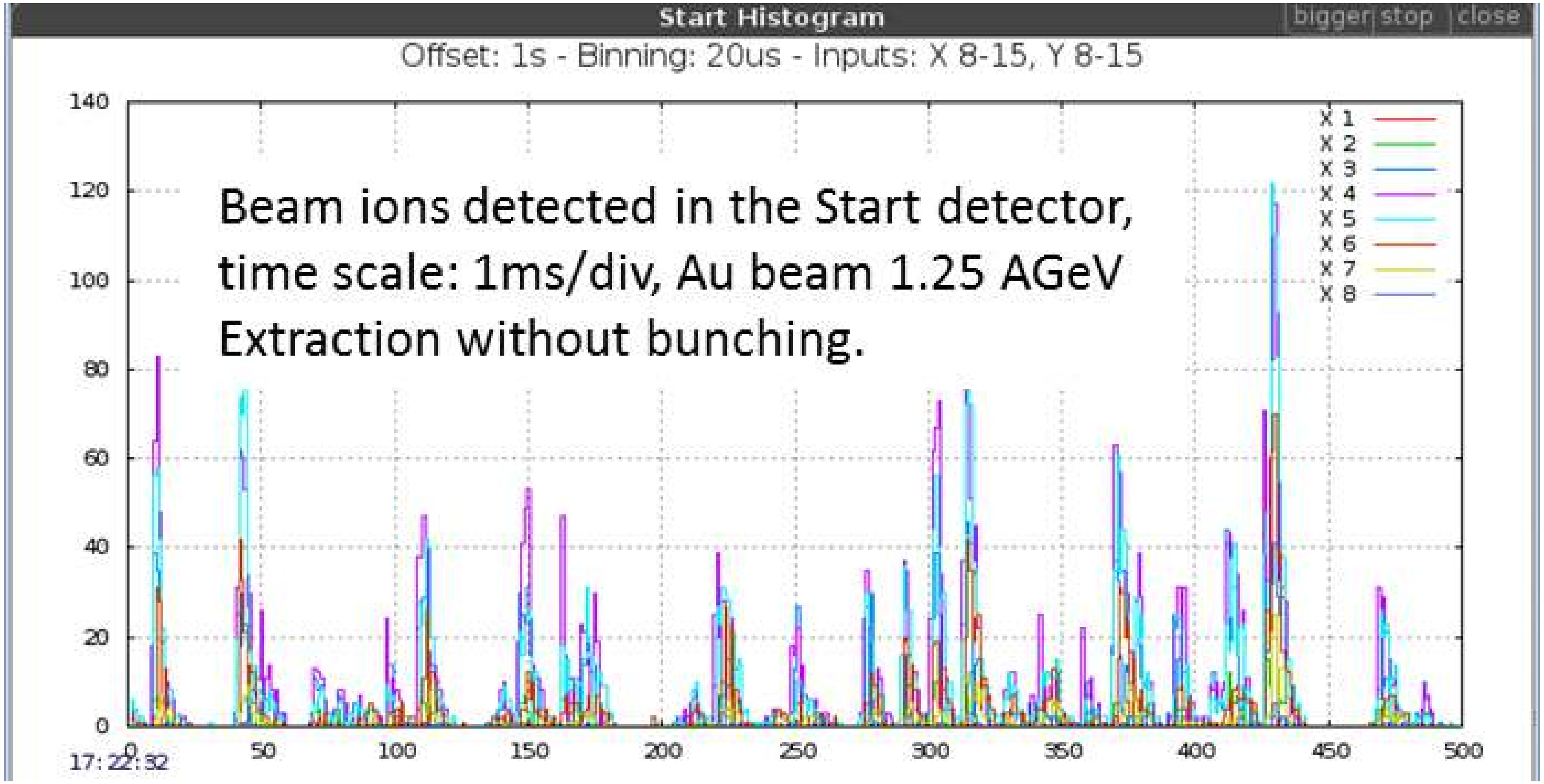
- interaction rate 10^7 s^{-1} (every 100 ns)
- beam structure in SIS-100 need excellent time structure (μs scale)
- reduction of reaction pile-up
- beam spot size focusing, target size
- additional beam position determination (X-Y) by means of the beam detectors
- background from target: δ-electrons, bremsstrahlung, γ-conversion

Beam

- collision every 100 ns (300 tracks for minbias) -> 3000 tracks within 1 µs
- ideal case: Poisson
- 3 or more collisions - 8 %
- consequences:
  - significant background for rare probes (10^{-8})
  - very good timing needed, better than 1 ns
  - STS resolution < 10 ns



Beam structure at SIS-18



Summary

- in-beam SD for HADES/CBM experiment can be realized by using diamond as detector material
- in-beam SD is only detector that should actually give time reference signal for each beam particle
- main function: timing; in addition: beam profile and structure monitoring, tracking
- measurements combined with other detectors
- beam tracking needs to be studied thoroughly and in close connection with target design