



Development of Trigger and Start Detectors for Experiments with High-Energy Heavy Ions at JINR

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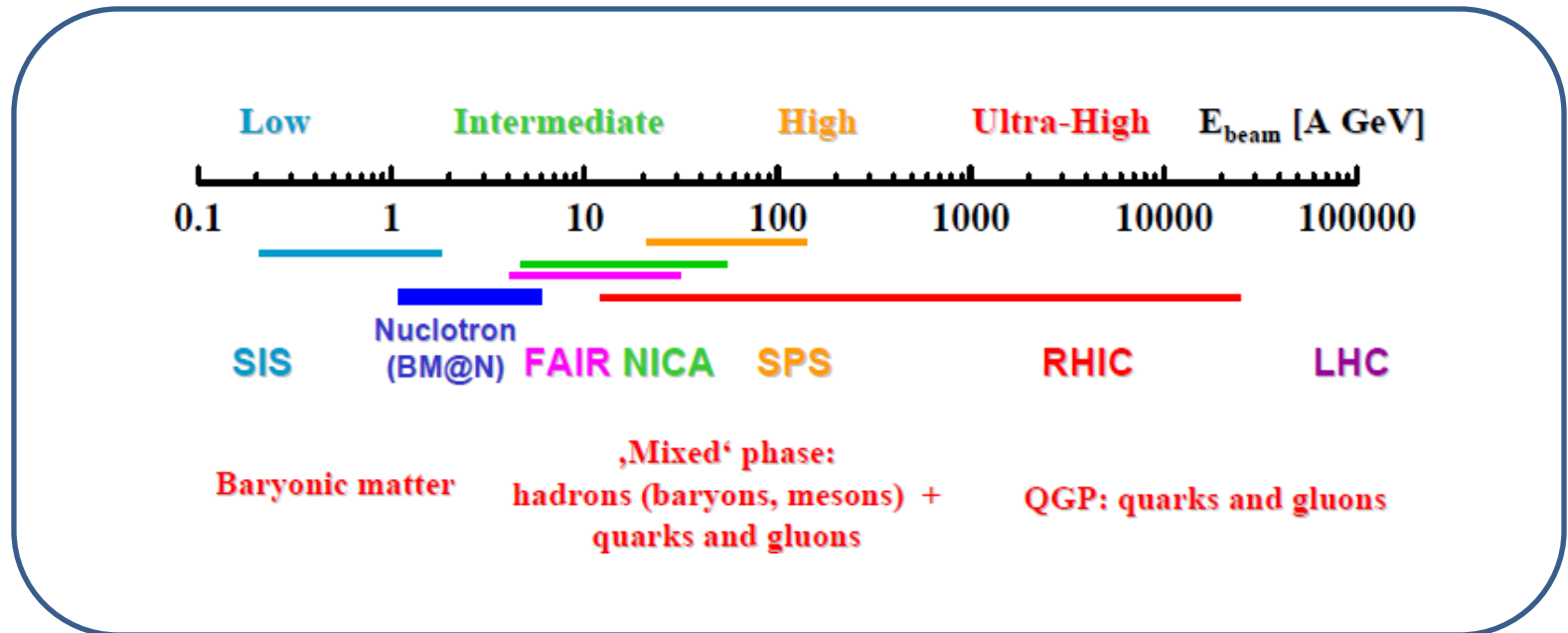
Content

- NICA project at JINR
- Fast Forward Detector for Multi Purpose Detector project
- Trigger and T0 system for Baryonic Matter at Nuclotron project
- Conclusion

High Energy Heavy Ion Experiments to Study Properties of Nuclear Matter at Extreme Conditions in AA- collisions

Two types of HI experiments: **Fixed target experiments** (long history)
Collider experiments (beginning of XXI c)

Experiments in Dubna: **Baryonic Matter at Nuclotron (BM@N)** [active]
Multi Purpose Detector (MPD) [in preparation]



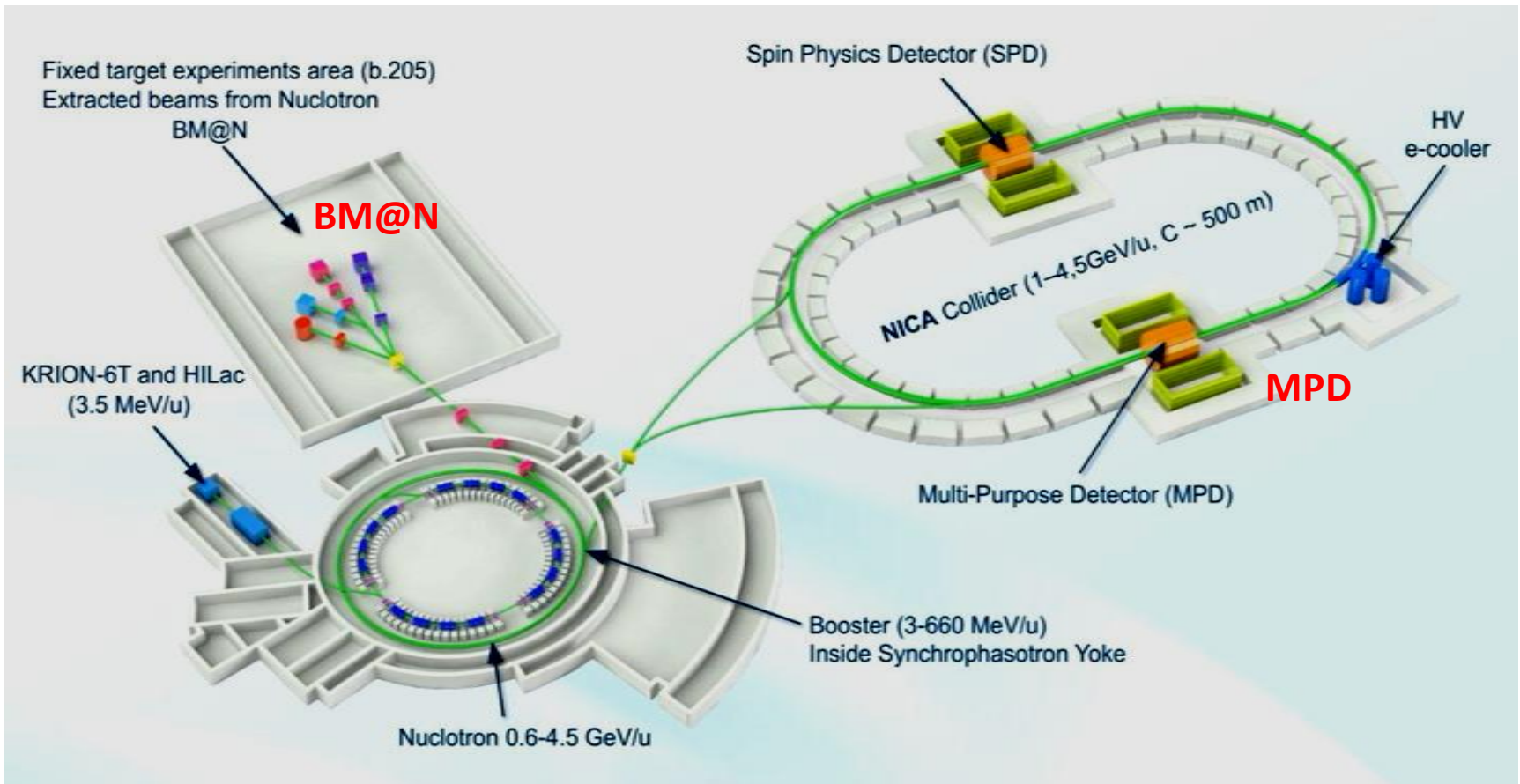


The NICA Complex



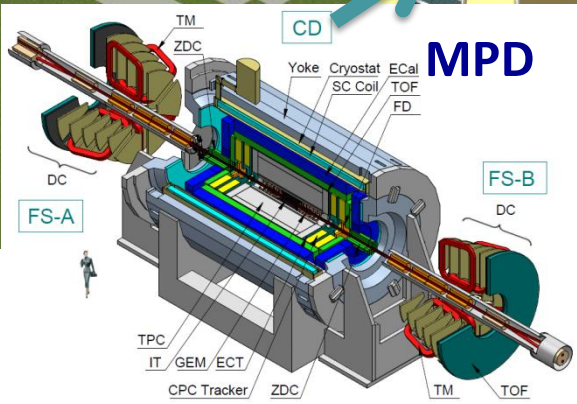
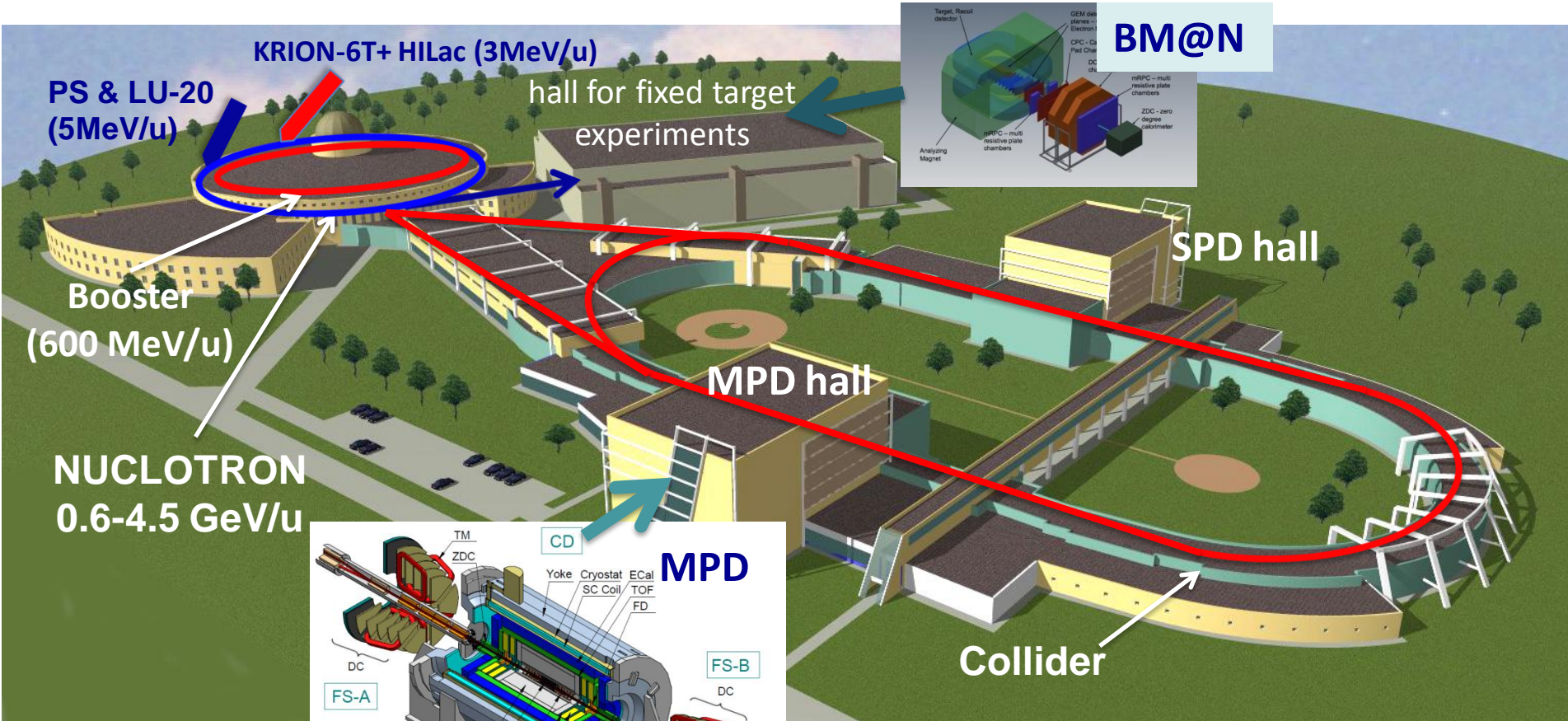
Nuclotron based Ion Collider facility

Beams from p to Au





The NICA Complex



The aim of fast trigger and T0 detectors

- fast triggering of nucleus–nucleus collisions with high efficiency
- generation of the start signal T0 for TOF detectors with picosecond time resolution

Requirements

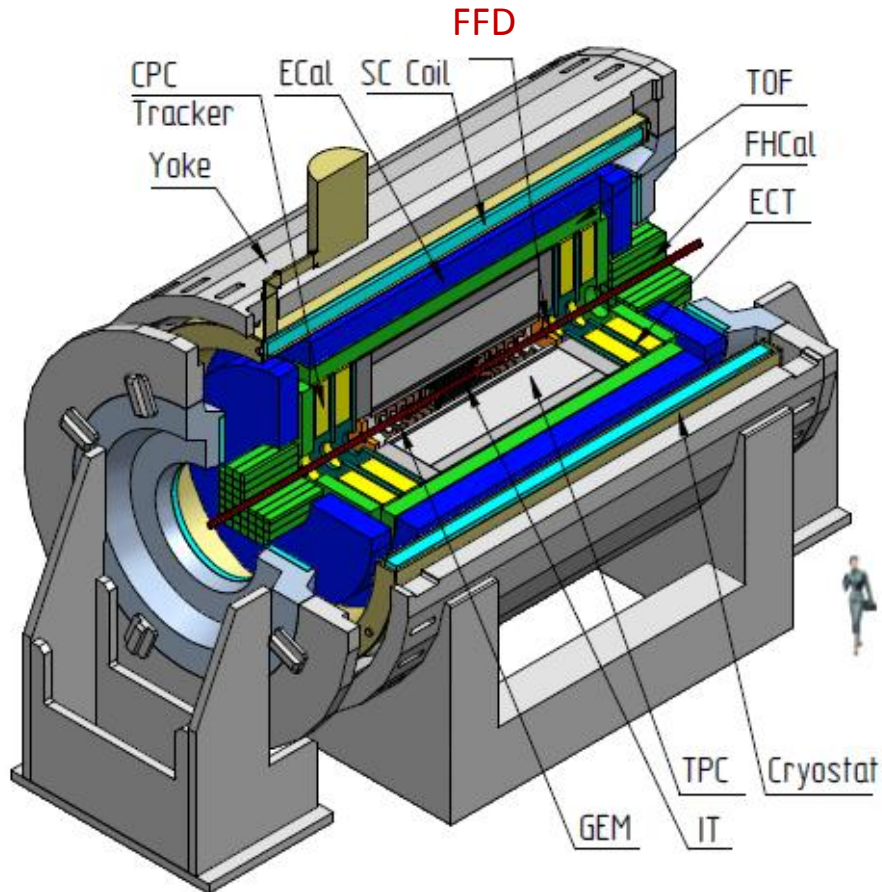
- time resolution of T0 pulse with $\sigma_t \leq 50$ ps for TOF detectors based on RPCs
- operation in strong magnetic fields of MPD ($B = 0.5$ T) and BM@N ($B \leq 0.9$ T)

Importance of picosecond timing

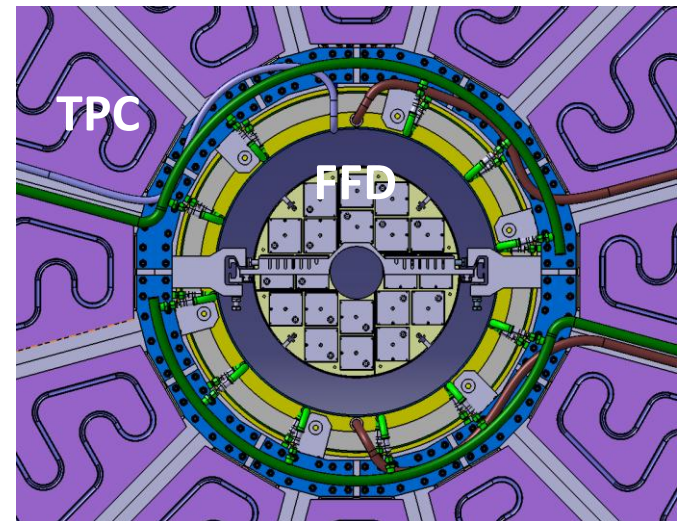
- TOF measurement of energy spectra of particles
- Charged particle identification by TOF - momentum analysis
- triggering AA- collisions in center of MPD setup by fast Vertex

Multi Purpose Detector (MPD)

2021 – Beginning of MPD/NICA operation



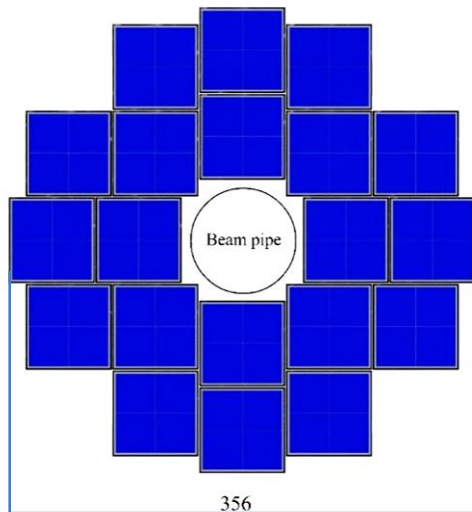
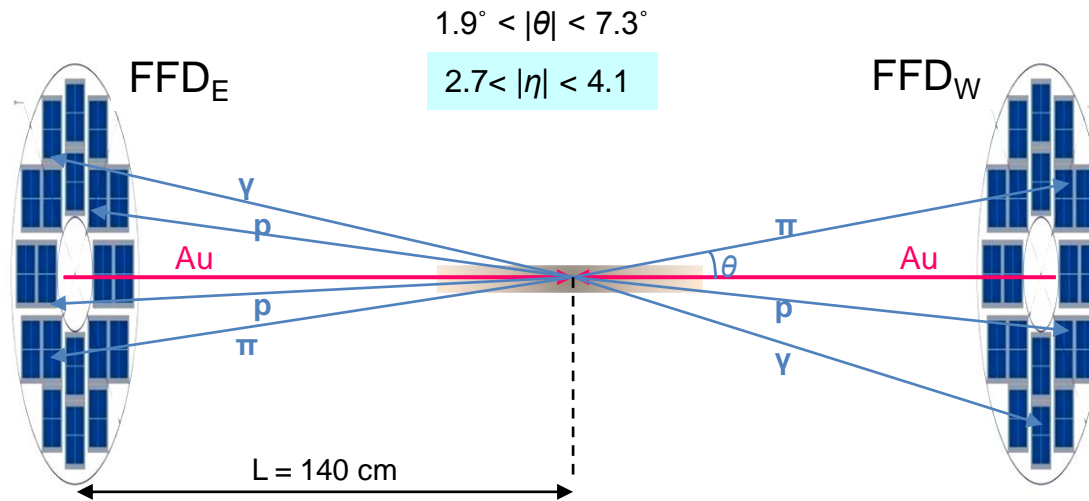
MPD is 4π experiment for study of nuclear matter properties at the highest baryon density.



A view of installed FFD

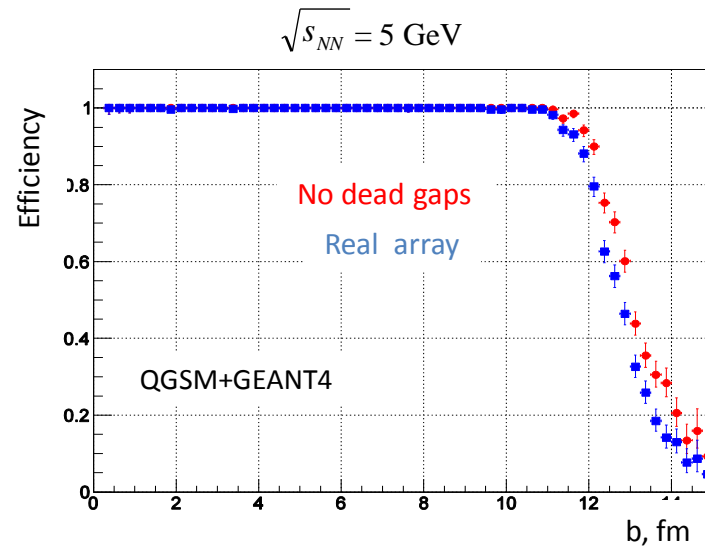
The Fast Forward Detector (FFD) provides Fast Vertex trigger and T0 pulse for TOF detector

Fast Forward Detector (FFD)



FFD modular array
 20 modules
 80 + 20 channels

MC simulation of trigger efficiency for Au + Au collisions



Two problems at NICA energies

1. Small multiplicity of produced particles
2. Small velocity of charged particles

Solution used in FFD

- Large active area of FFD
- Detection of high-energy photons

Fast interaction trigger by Vertex FFD_E - FFD_W

(~50 ns on-line processing of FFD pulses)

Requirement: good timing signals from modules of both sub-detectors

Start signal production for TOF

(off-line analysis of FFD pulses)

Requirement: at least one pulse with good timing from all FFD channels

TOF time resolution: $\sigma_t^2 = \sigma_{T0}^2 + \sigma_{TOF}^2$

Start signal T0 resolution: $\sigma_{T0} = \sigma_0 / N^{1/2}$

where N – the number of fired channels of FFD

Recent progress in pico-second timing with time resolution < 50 ps

➤ New photodetectors

- MCP-PMTs
- SiPMs

➤ Large TOF detectors based on RPCs

➤ New readout electronics

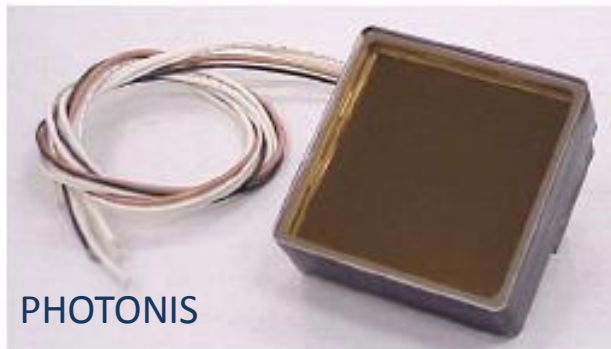
- TDCs (HPTDC, ...)
- GHz digitizers

Contributions to time resolution of detector with MCP-PMT

- Timing of Cherenkov / scintillation process
- Time spread of photon arrival on photocathode
- Transition time spread
- Photoelectron statistics
- FEE and method of signal processing
- Cables and connectors
- Readout electronics
- Method of data processing

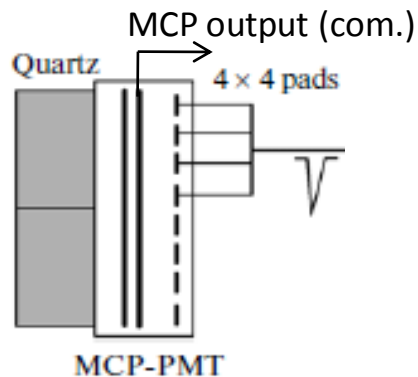
Photodetector

Type: Planacon MCP-PMT XP85012/A1-Q



- Photocathode of $53 \times 53 \text{ mm}^2$ occupies 81% of front surface
- Sensitive in visible and ultraviolet region
- 8×8 multianode topology
- Chevron assembly of two MCPs (25- μm)
- Typical gain factor of $10^5 - 10^6$
- Rise time 0.6 ns
- Transit time spread $\sigma_{\text{TTS}} \sim 37 \text{ ps}$
- High immunity to magnetic field

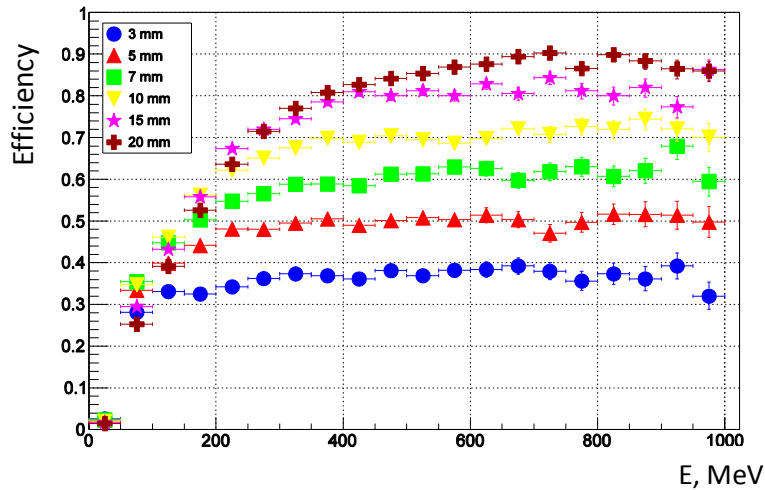
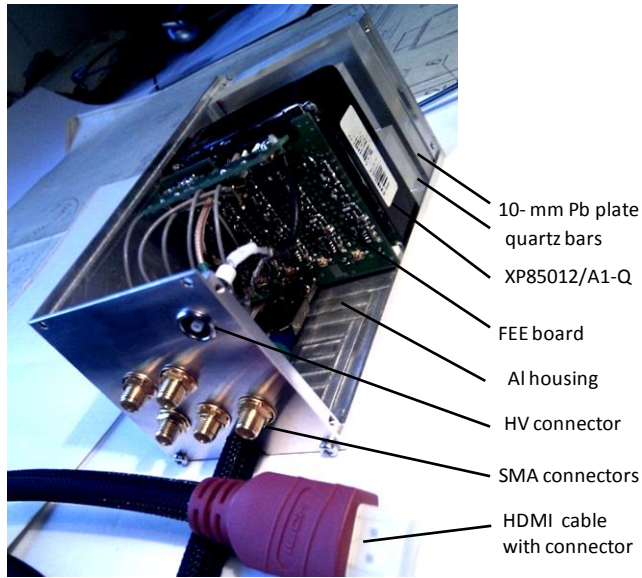
Planacon in Cherenkov modules of FFD with quartz radiators



64 anode pads is transformed into the 4- channel photodetector by merging 16 pads (4×4) of each cell into a single channel

Quartz radiator dimension: $56 \times 56 \times 15 \text{ mm}^3$
consists of 4 quartz bars: $28 \times 28 \times 15 \text{ mm}^3$

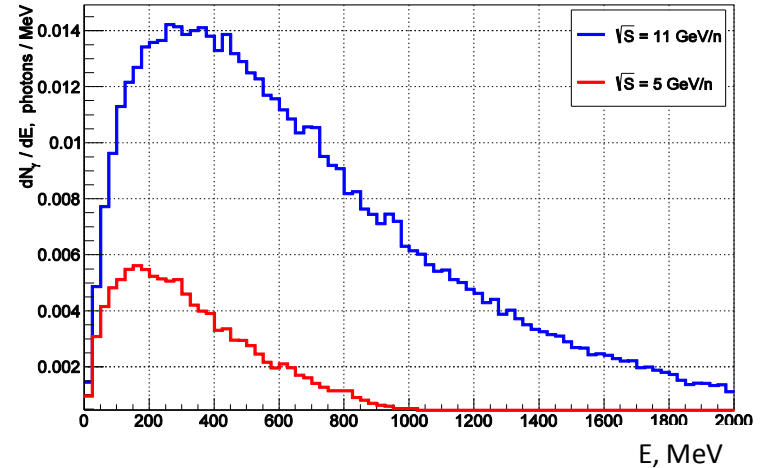
FFD module



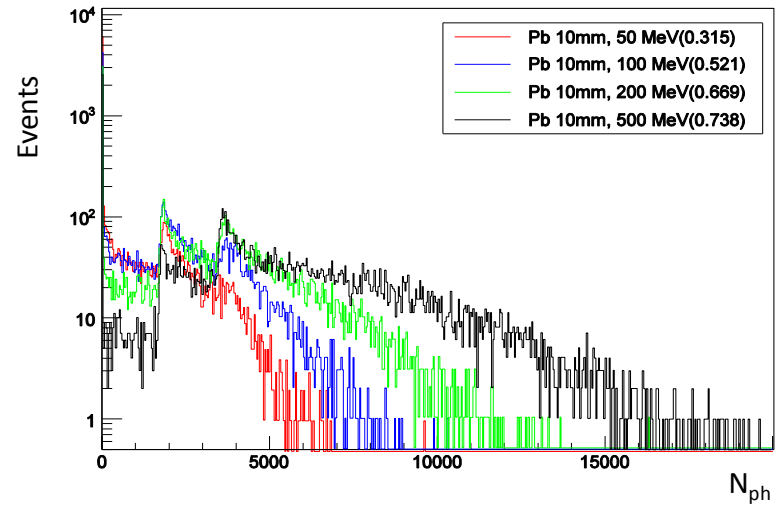
The efficiency of photon detection as a function of the photon energy for six different thicknesses of the lead converter from 3 to 20 mm.

Detection of high-energy photons

Energy spectra of photons in Au+Au collisions

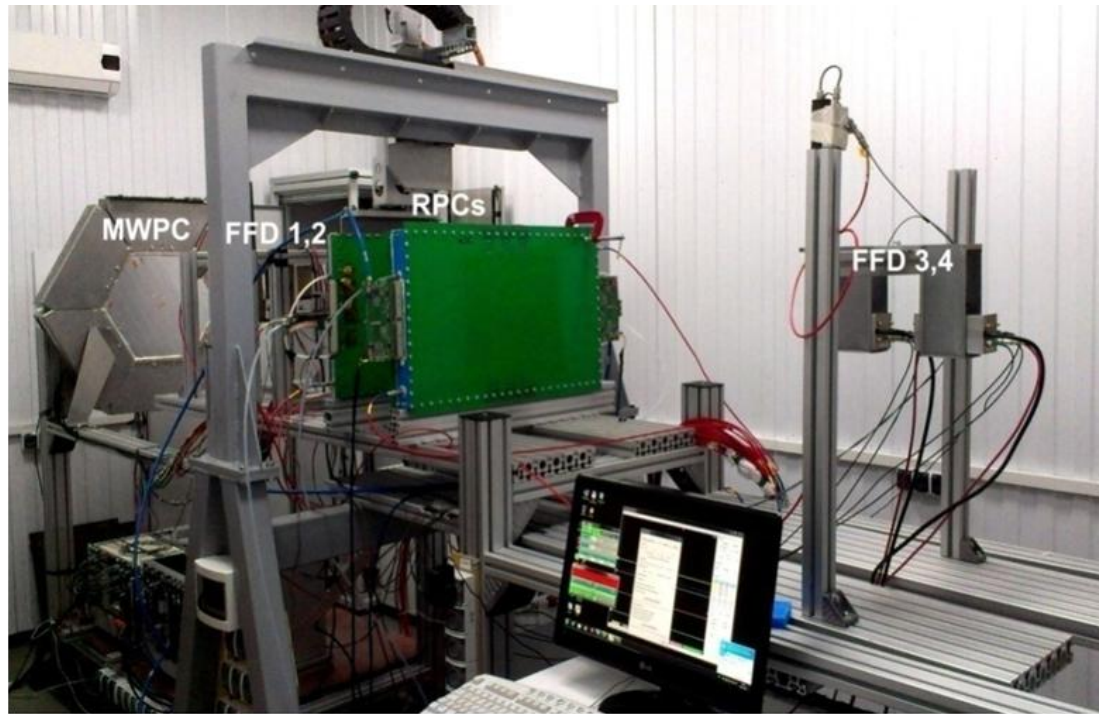


Detector response



Distributions of Cherenkov photon number for different energies of incoming photons 50, 100, 200, and 500 MeV.

Tests with module prototypes and beam of 3.5- GeV deuterons



FFD modules on the beam line of MPD-test area.

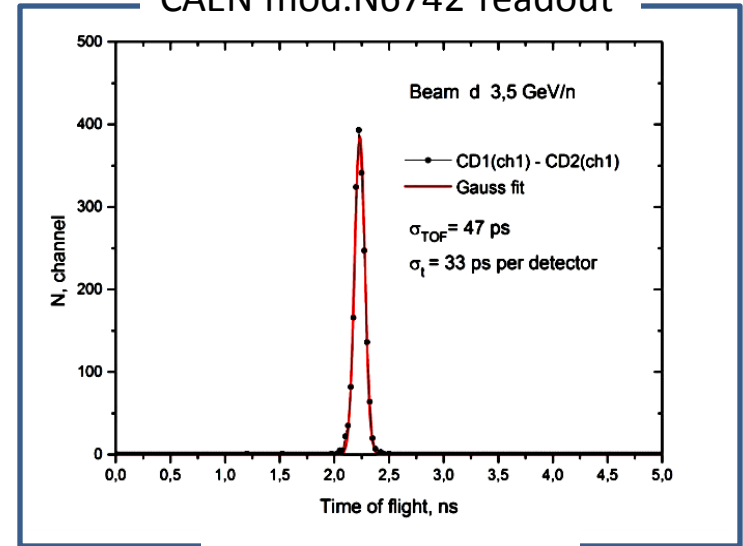
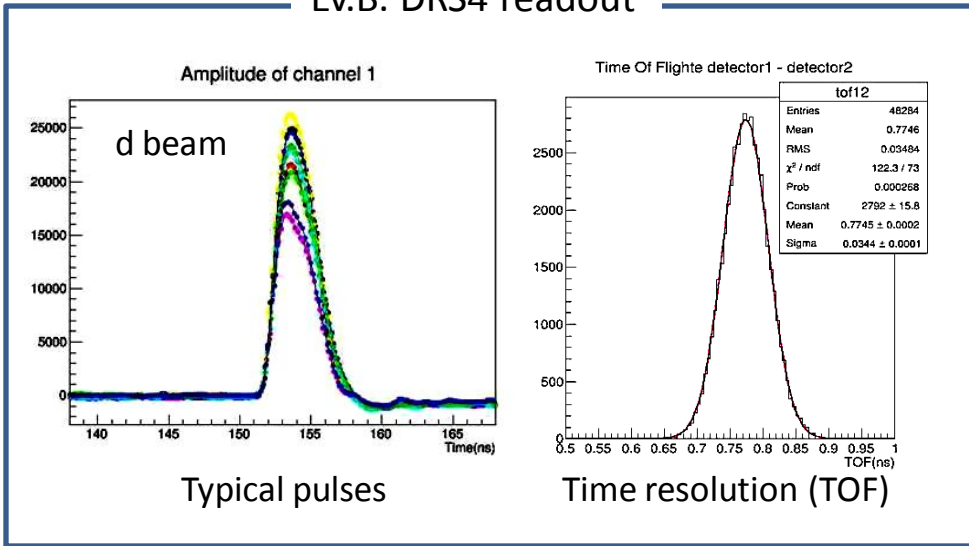
Three types of readout electronics were used in the tests:

1. Evaluation Board DRS4 v5 (time jitter ~ 4 ps)
 2. Digitizer CAEN mod.N6742 based on DRS4 chip (time jitter ~ 20 ps)
 3. TDC72VHL based on HPTDC chip and produced at JINR (time jitter ~ 25 ps)
- } Analog pulses
- LVDS pulses

Study of time resolution

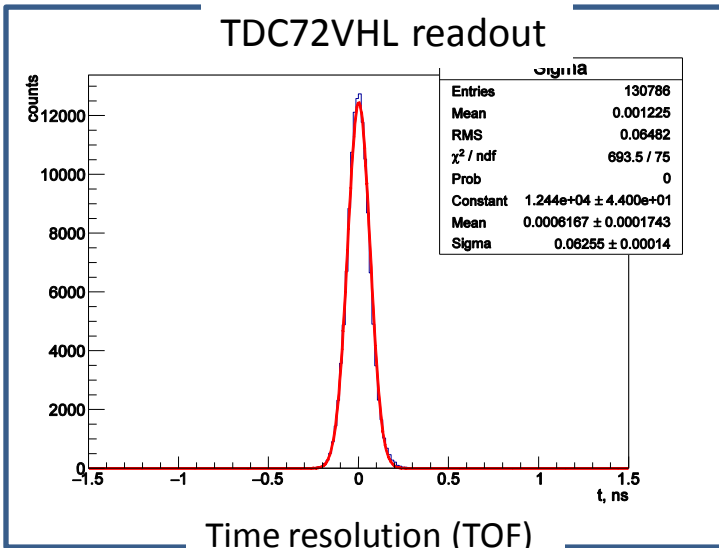
Ev.B. DRS4 readout

CAEN mod.N6742 readout



Time resolution (TOF)

TDC72VHL readout



Time resolution (TOF)

Conclusions

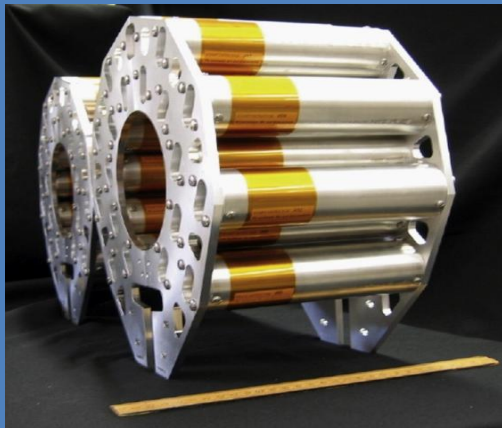
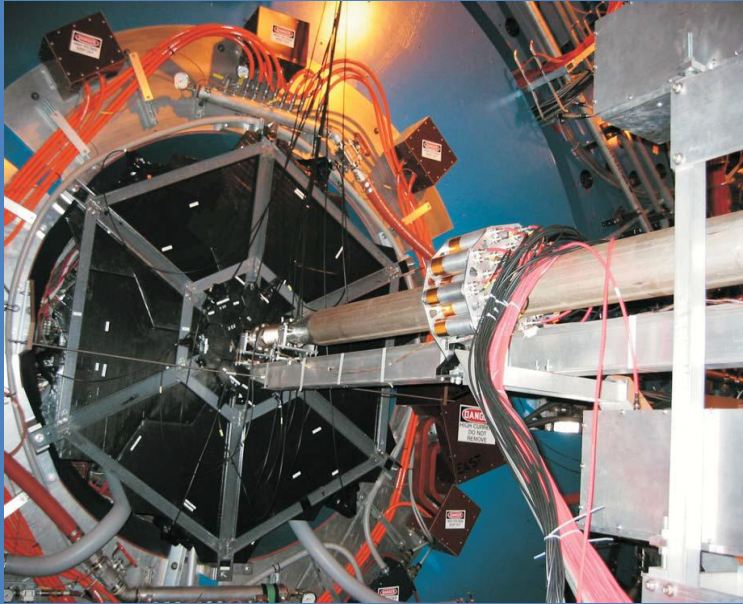
- Time resolution of FFD module itself - 21.5 ps
- with readout by E.B. DRS4 digitizer - 24 ps
- with readout by digitizer CAEN mod.N6742 - 34 ps
- real chain with readout by TDC72VHL - 44 ps

Realistic chain of cables and electronics.

View of T0 & Vertex detectors of STAR and ALICE

STAR / RHIC

VPD detector



ALICE / LHC

T0 detector



FIT detector  Upgrade 2019



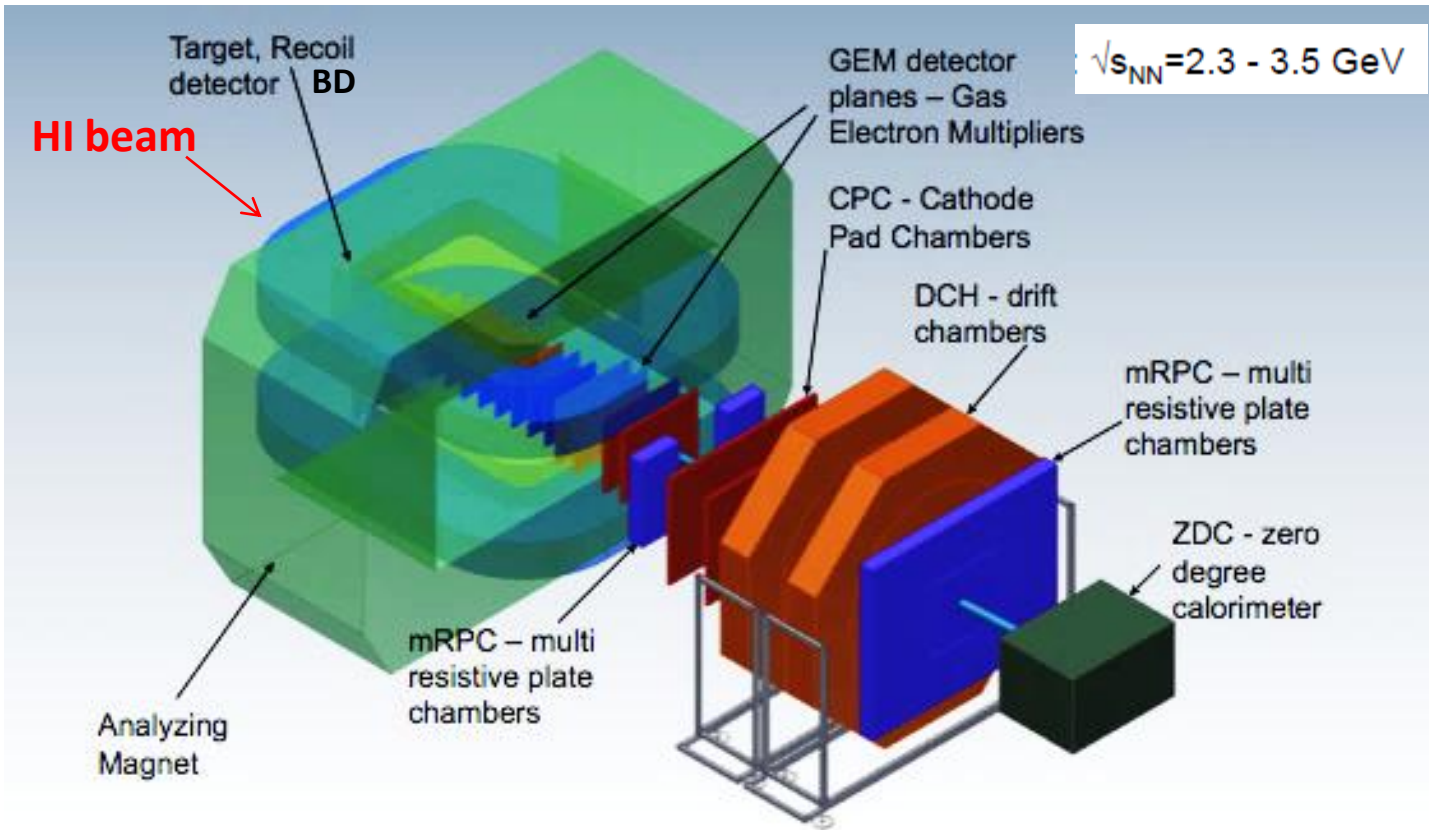
Vertex trigger and T0 detectors of HI collider experiments

Experiment	Detector	Active area* (cm ²)	Number of channels	Photodetector	Operation in MF	Time resolution** (ps)
STAR/RHIC	VPD scintillation	215	19	Hamamatsu mesh dynode PMTs R5946	Yes	150
PHENIX/RHIC	BBC Cherenkov	314	64	Hamamatsu mesh dynode PMTs R3432	Yes	52
PHOBOS/RHIC	Cherenkov counters	79	16	Hamamatsu PMTs R1924	No	60
ALICE/LHC	T0 Cherenkov	38	12	Electron mesh dynode PMTs FEU187 Upgrade: Photonis MCP-PMTs	Yes	28
MPD/NICA	FFD Cherenkov	625	80	Photonis MCP-PMTs XP85012/A1	Yes	~40

* sub-detector

** single channel time resolution

Baryonic Matter at Nuclotron (BM@N)



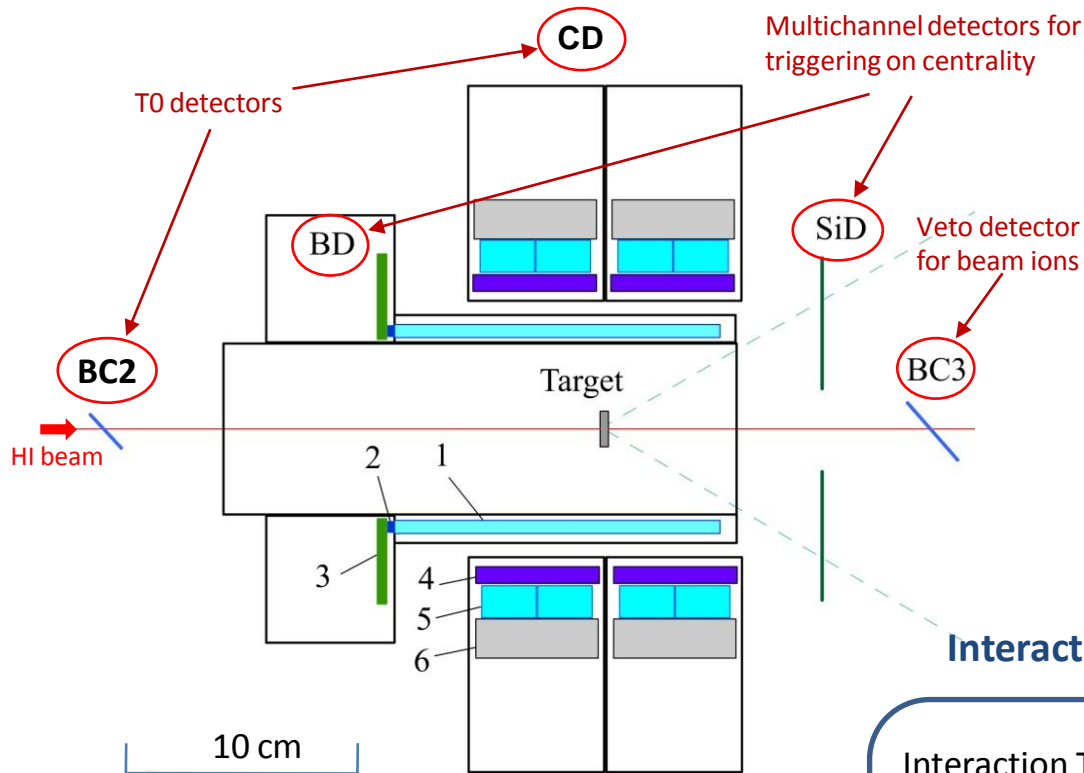
General scheme of setup

BM@N technical runs with beams of deuterons and C ions with energy of 3.5 – 5.2 A GeV



View of BM@N experimental area

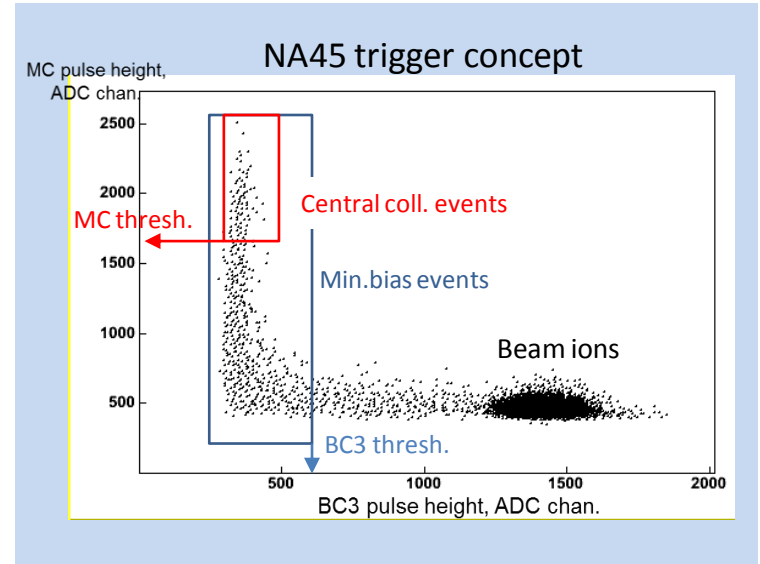
Active target area and trigger concept



A scheme of the target area

- 1 – BD strip scintillator, 2 – SiPM, 3 – FEE board,
- 4 – lead converter, 5 – quartz bars,
- 6 – MCP-PMT XP85012/A1-Q.

BC2 (T0 det.) and BC3 – plastic scintillator & MCP-PMT
 BD – Barrel Detector, scintillation strips & SiPMs (40 ch.)



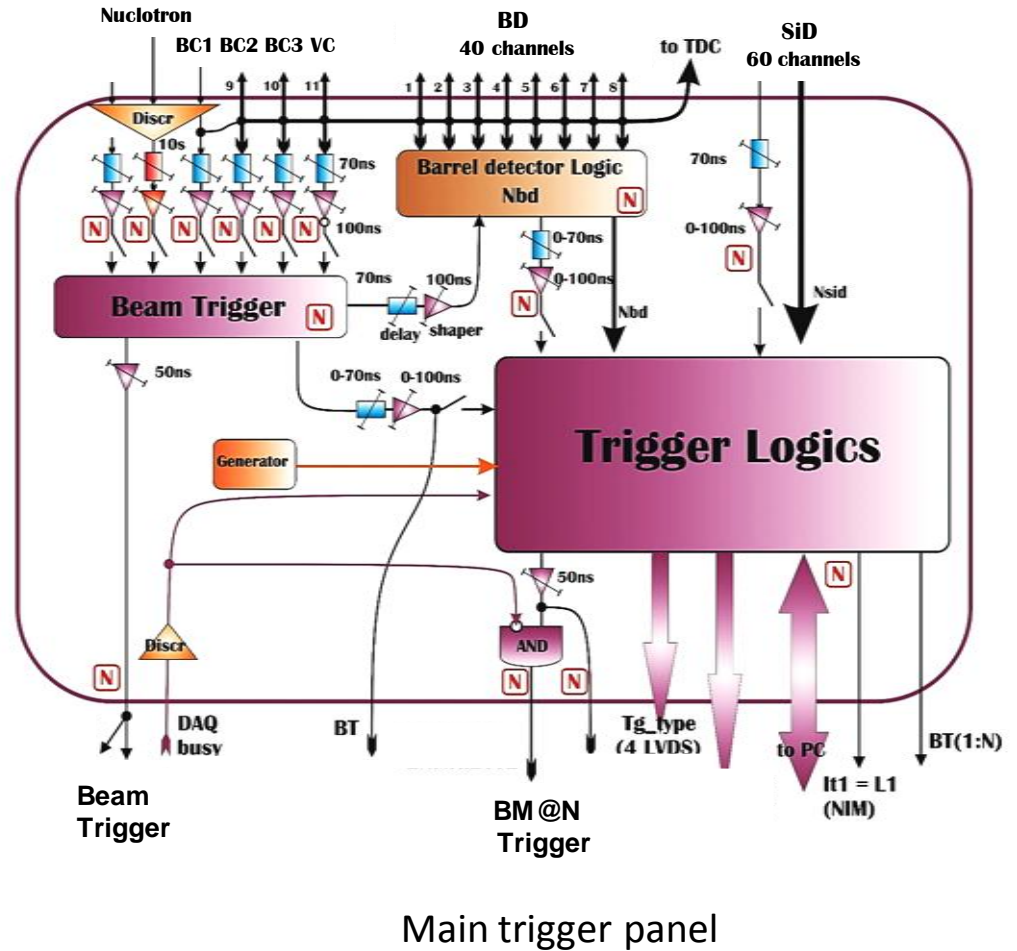
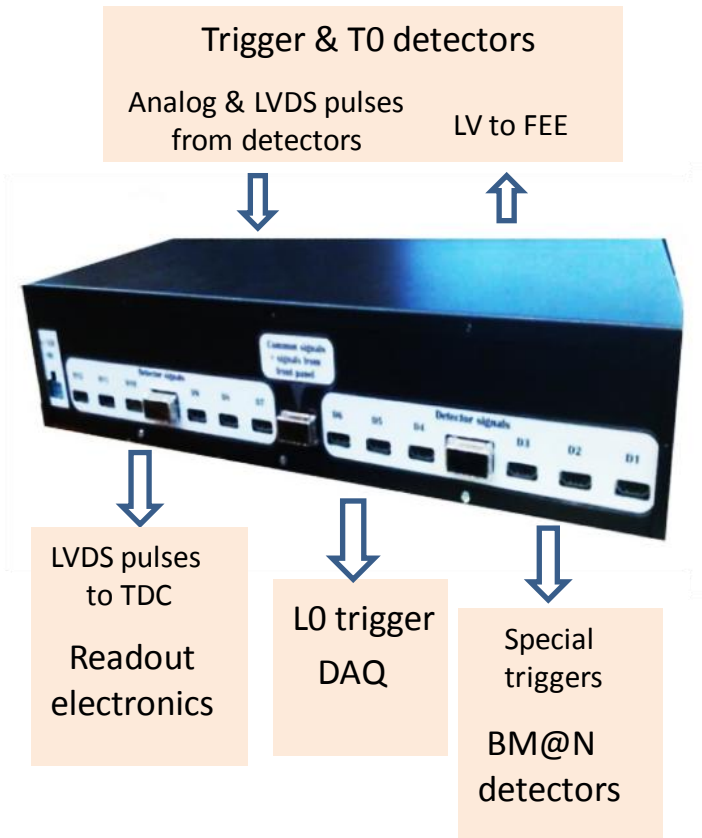
Interaction trigger detectors and trigger logic

$$\text{Interaction Trigger} = \underbrace{\text{BC1} * \text{BC2} * \text{VC}_{\text{veto}}}_{\text{Valid beam}} * \underbrace{\text{BC3}_{\text{veto}} * \text{BD} + \text{SiD}(N > N_{\text{th}})}_{\text{Min.bias}}$$

Semi-central & central collision

Trigger electronics

TOU module with programmable trigger logic based on FPGA



Barrel Detector (BD)

Barrel Detector is used for selection of AA- collisions on centrality by fast determination of a number of fired scintillation strips

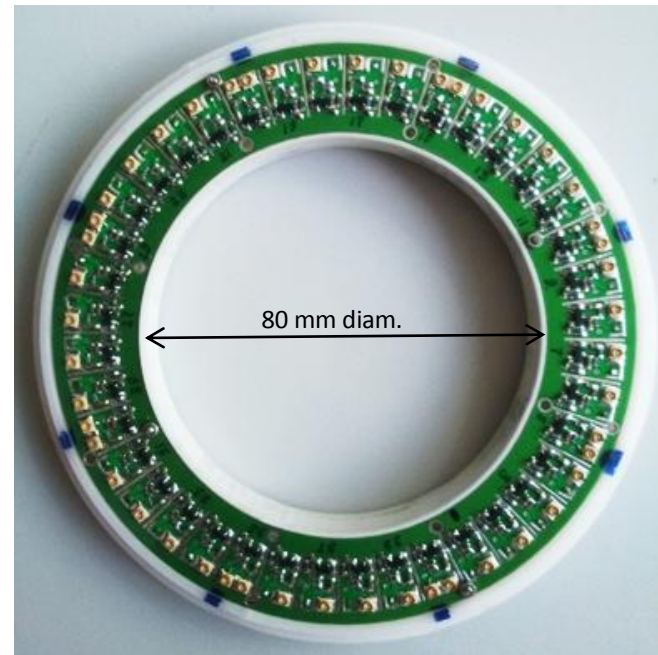
The scintillation light is detected by SiPMs directly connected with the strips.

Strips: scintillator BC-418, $150 \times 7 \times 7 \text{ mm}^3$

SiPM type: Sensl Micro FC-60035-SMT, $6 \times 6 \text{ mm}^2$



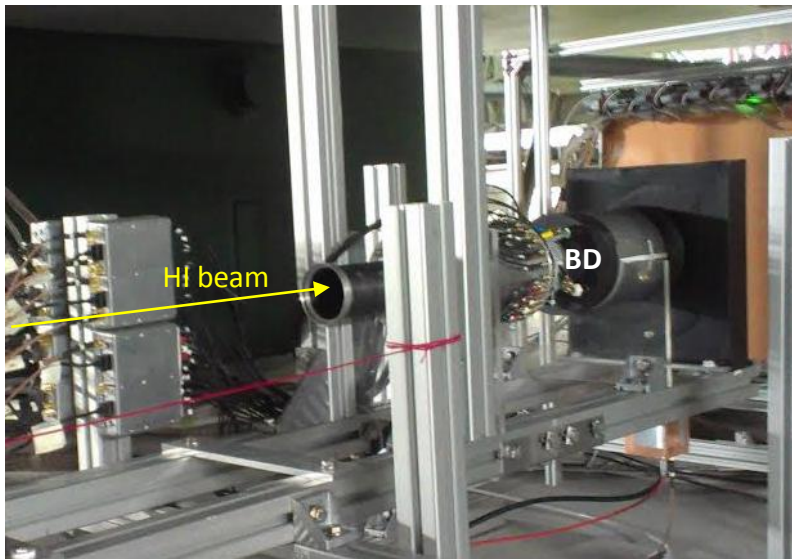
A view of strip assembly with SiPMs board



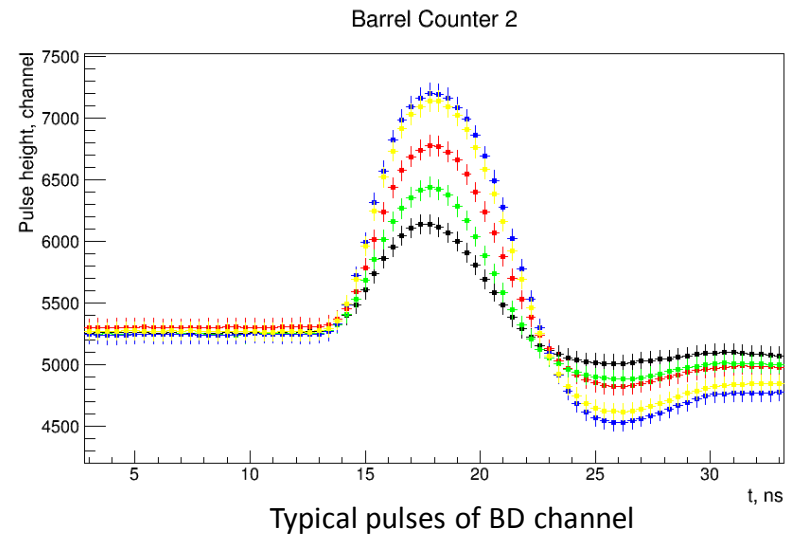
A view of SiPMs board

Barrel Detector in March 2017

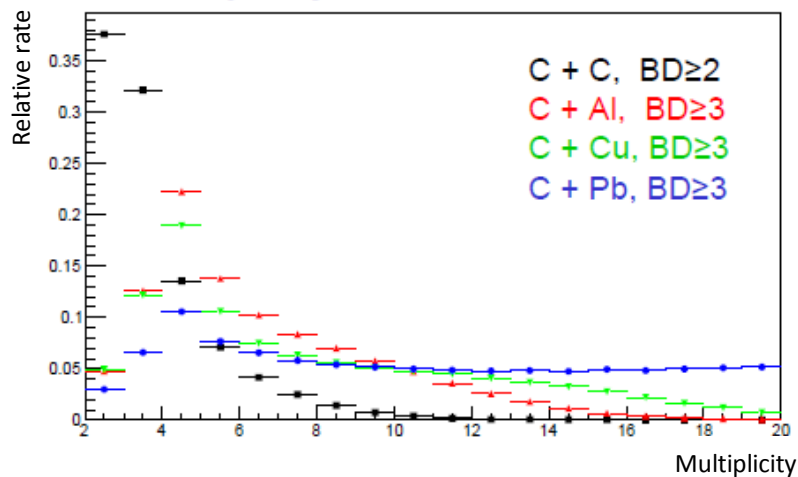
Run with 4.5 A GeV C ions



A view of Barrel Detector layout on beam line

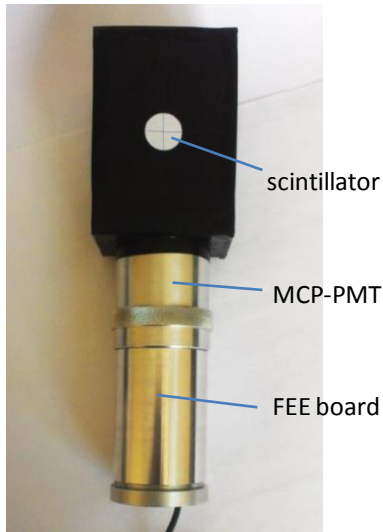


BD multiplicity in carbon beam interactions



BD provides effective interaction trigger for all types of targets even operating alone (without SiD)

T0 detector (BC2)



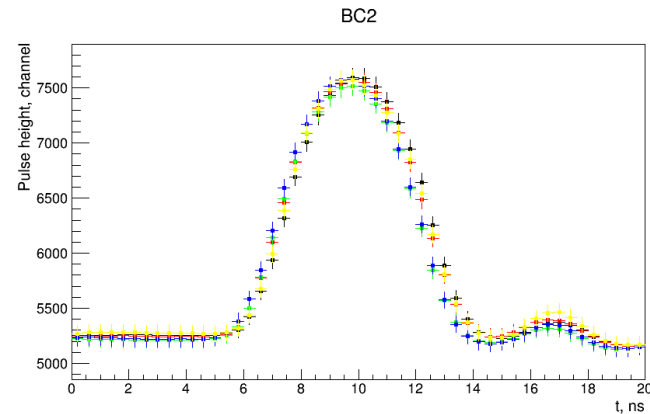
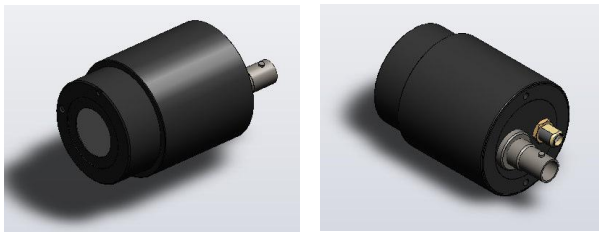
Two beam detectors were equipped with this photodetector and were used in Run 2017 with C ion beam:

1. CC - Cherenkov counter with 4- mm quartz (46° to beam axis)
2. BC2 – beam counter with 0.8- mm scintillator (45° to beam axis)

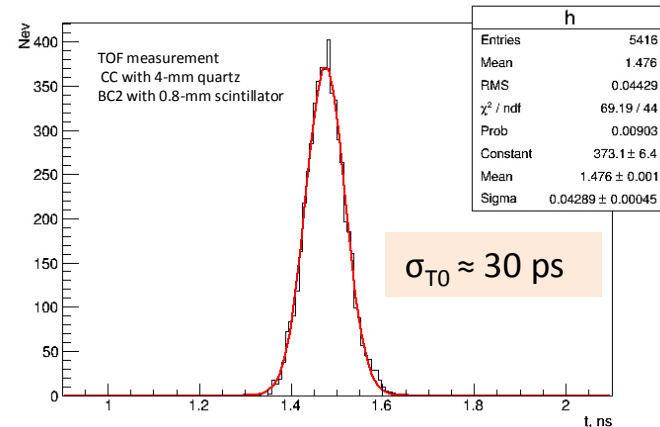
Photodetector TYPE PP0365G

18mm double-MCP based MCP-PMT

Input window: Quartz
 Photocathode type: S20
 MCP double, chevron: 6 μ m pore size, 50:1 L:D
 Output single anode: SMA connector
 HV Supply HV: BNC connector



Typical pulses of BC2 measured with CAEN digitizer

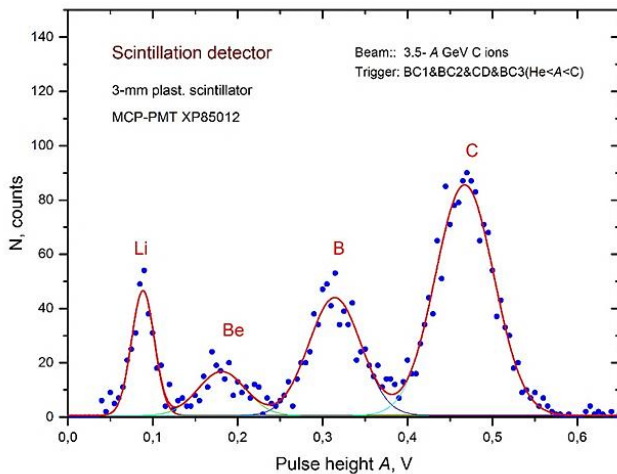
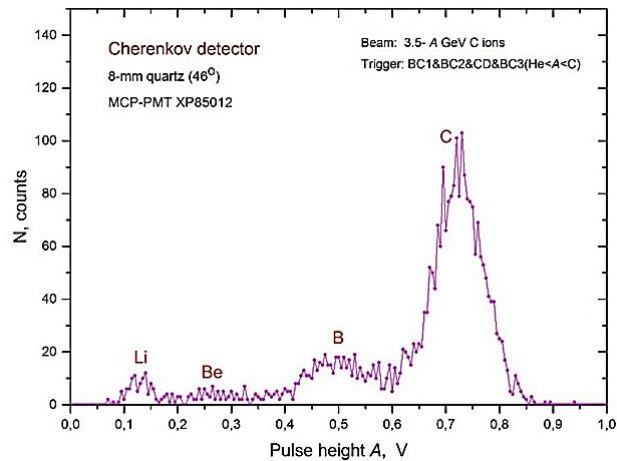


Measurements with prototypes of BC2 and BC3

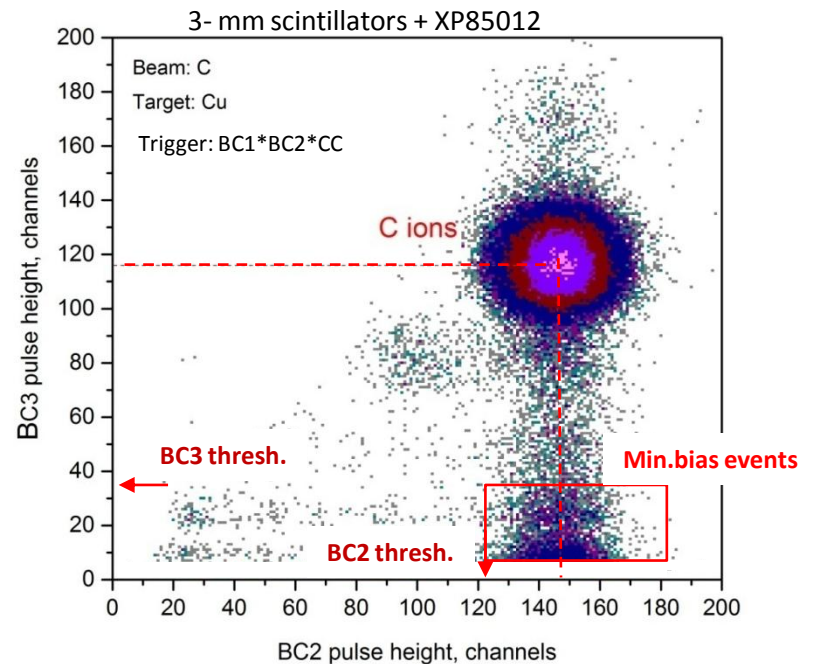
4.5 A GeV C ion beam

Photodetectors: MCP-PMTs XP85012/A1

Ion selection with BC3



Selection of events by min. bias trigger with 3-mm scintillators of BC2 & BC3



Conclusion

The developed fast interaction trigger and T0 detectors for MPD and BM@N experiments produce

- the efficient trigger of nucleus - nucleus collisions,
 - the T0 pulses for TOF detectors with $\sim 30 - 40$ ps resolution,
- that corresponds to requirements to these systems.

In plan for next two years

2017 – the preparation of trigger and T0 system for BM@N run with Kr or Xe beam
– continue MC simulation of trigger and detector performance

2018 – production of FFD modules
– R&D on Vertex-Trigger electronics for MPD experiment
– Laser system for calibration of FFD channels
– Development of trigger and detectors for BM@N runs with Au beam