Development of L0 trigger for study of *AA*- collisions in BM@N/Nuclotron and MPD/NICA experiments

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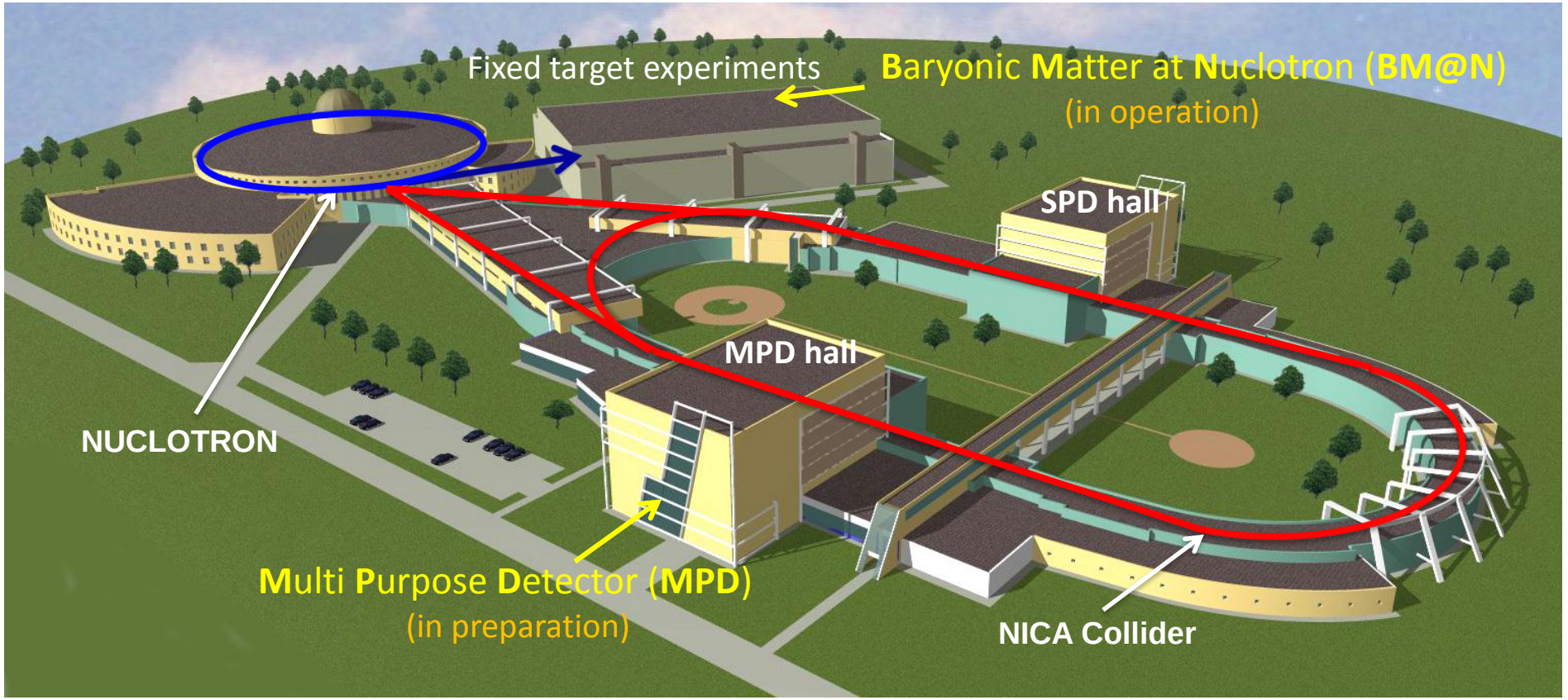
HI experiments at NICA Complex



Fast interaction trigger and T0 system

Aim

- fast triggering of nucleus–nucleus collisions with high efficiency
- generation of the start signal T0 for TOF detectors with $\sigma_t \leq 50$ ps

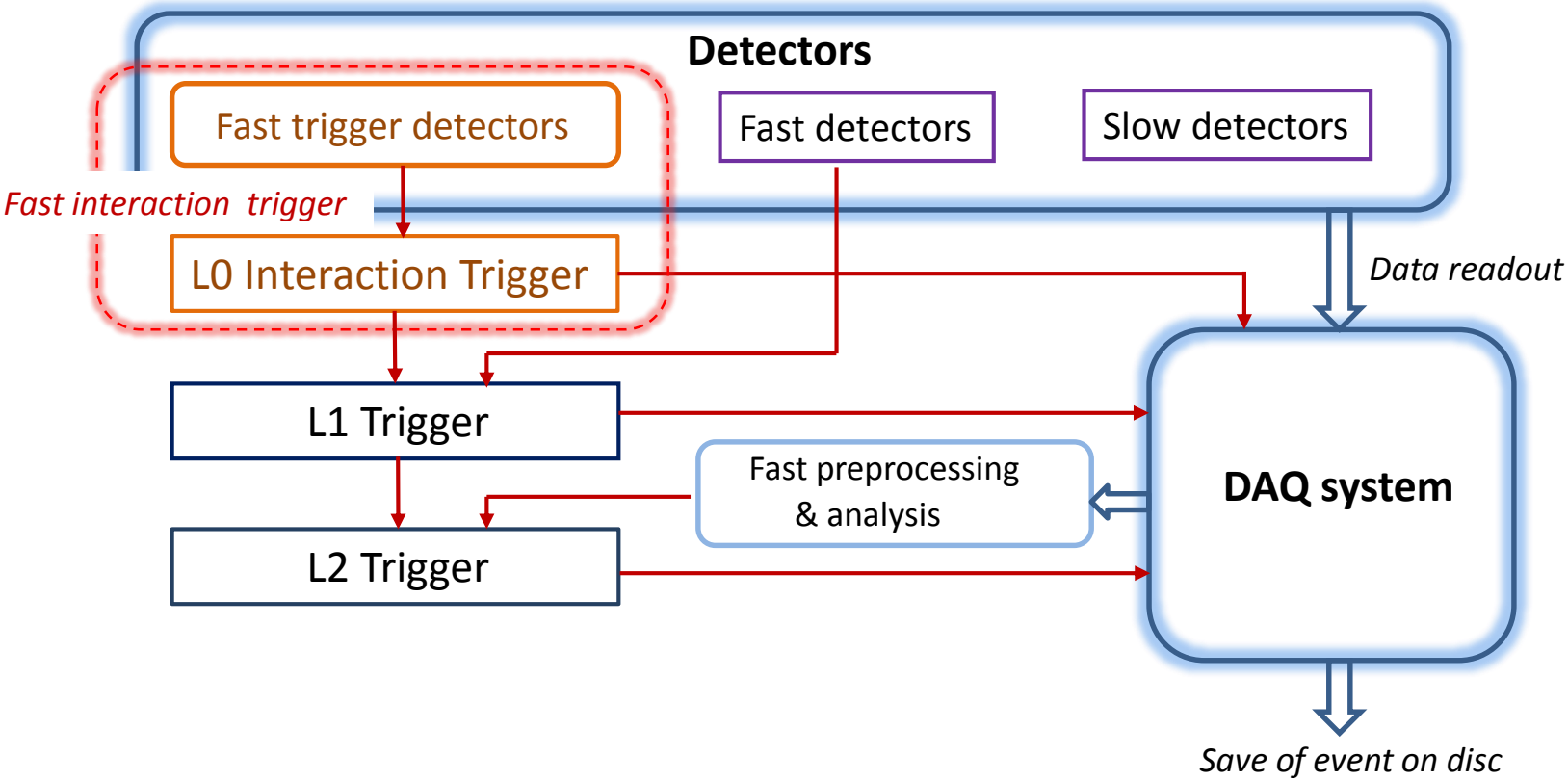
Requirements

operation in strong magnetic fields of MPD (B = 0.5 T) and BM@N ($B \leq 0.9$ T)

Concepts of L0 interaction trigger system for the fixed target and collider experiments are completely different

- **Fixed target mode** – the trigger and T0 pulse are produced with a system of low mass beam detectors and target area detectors
- **Collider mode** – the trigger and T0 are produced with two fast modular Cherenkov detectors

Fast interaction trigger in trigger system



Picosecond timing

Recent progress in picosecond timing

- **New photodetectors**
  - MCP-PMTs
  - SiPMs
- **Large TOF detectors based on RPCs**
- **New readout electronics**
  - TDCs (HPTDC, …)
  - GHz digitizers

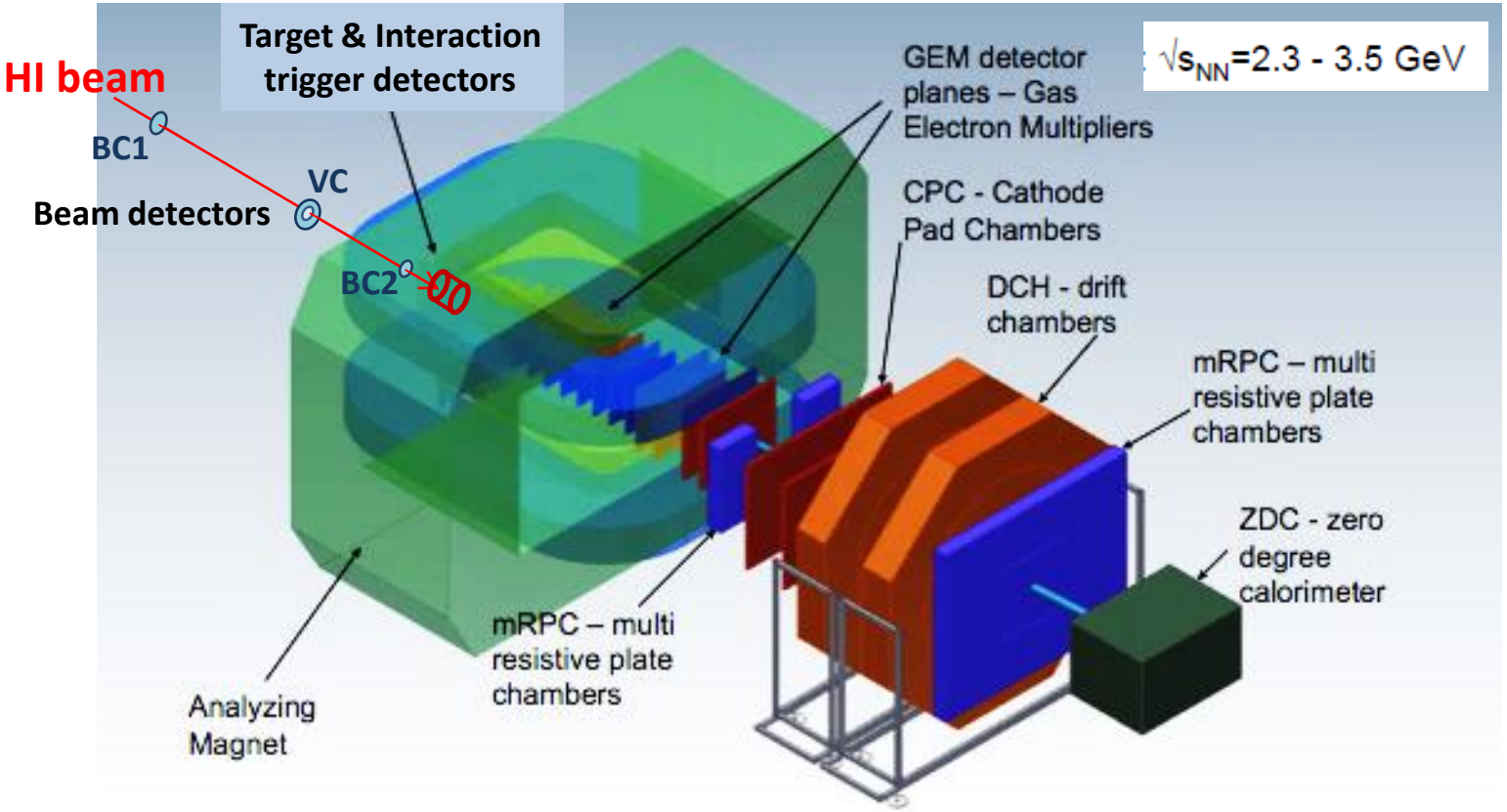
Contributions to time resolution of detector with MCP-PMT

- ✓ 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

The task is to minimize these contributions as much as possible

BM@N experiment

BM@N

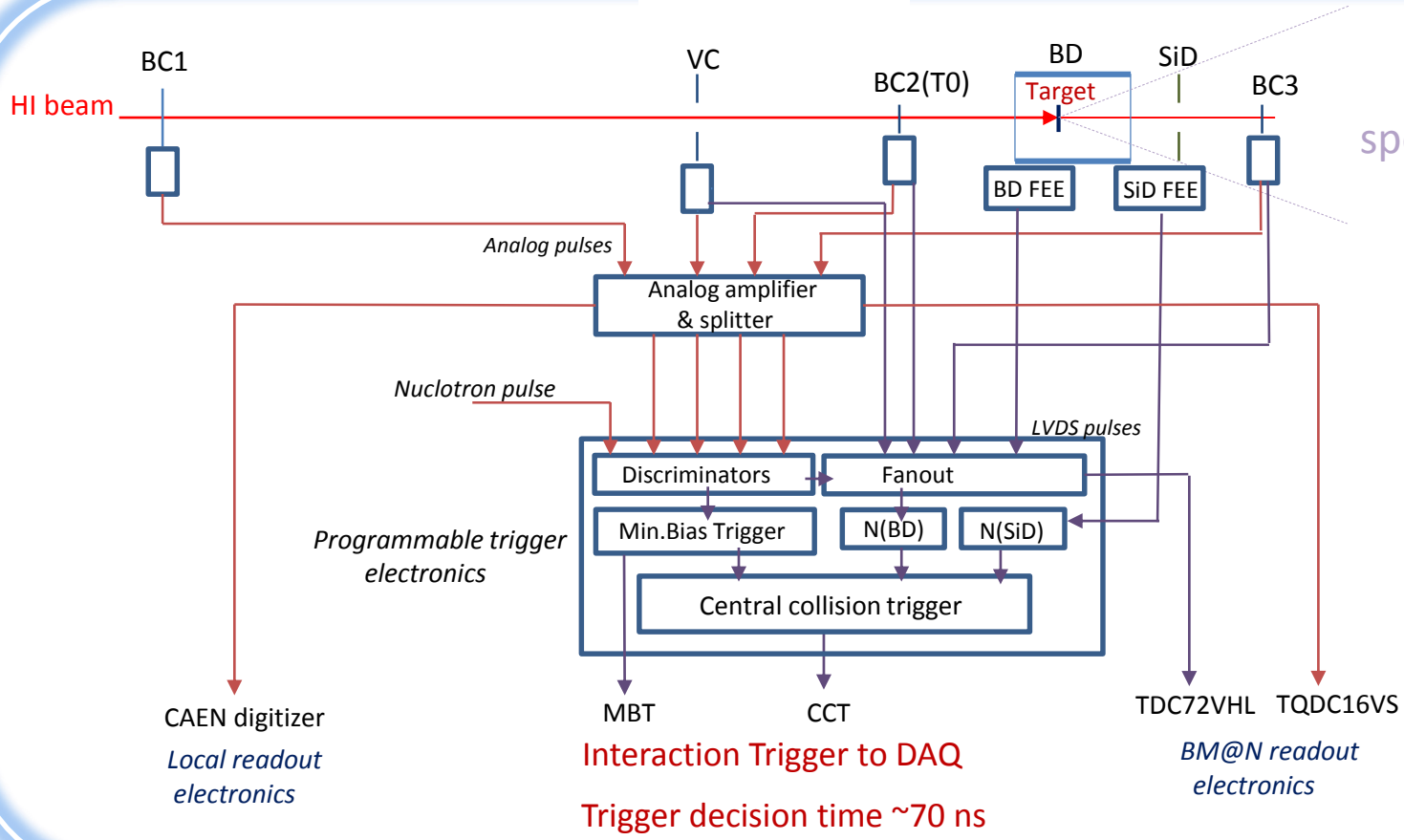


General scheme of BM@N setup

Interaction trigger 2017

BM@N

Trigger 2017

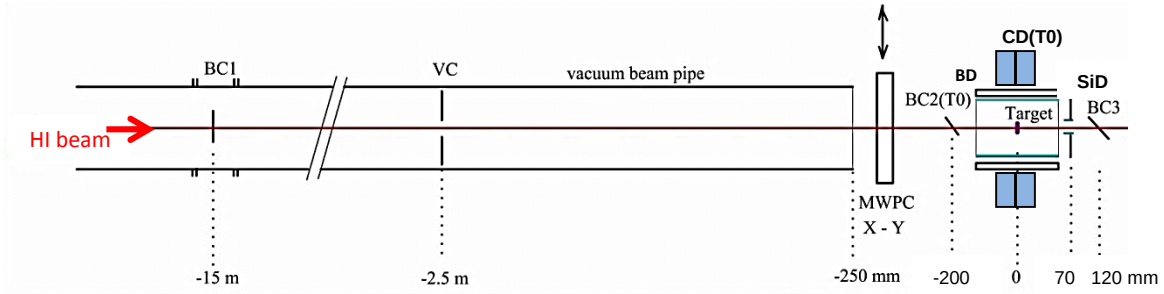


Interaction Trigger to DAQ

Trigger decision time ~70 ns

Trigger detector setup 2019

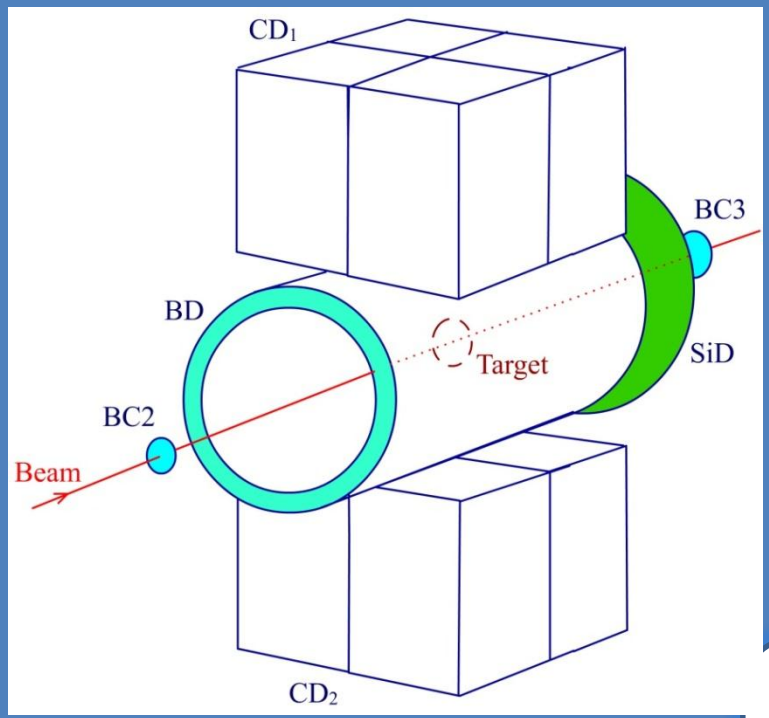
BM@N



Beam detector	PMT	Beam ion	Scintillator	Comments
BC1	XP2020	C, Ar Kr, Xe Au	BC-418 100×100×0.5 mm BC-418 100×100×0.5 mm BC-400B 100×100×0.25 mm	In vacuum pipe
VC	XP2020		BC-418 130diam.×3 mm, hole 30-mm diam.	In vacuum pipe
BC2(T0)	MCP-PMT PP2365E	C, Ar Kr, Xe Au	BC-418 10diam.×0.8 mm BC-418 10diam.×0.5 mm BC-400B 10diam.×0.15 mm	
BC3	R2490-07	C, Ar Kr, Xe Au	BC-418 30×30×1 mm BC-418 30×30×0.5 mm BC-400B 30×30×0.15 mm	

Target area and trigger concept

BM@N



A scheme of the BM@N target area

Trigger detectors:

BC1, BC2, BC3 – beam counters
VC – veto counter
BD – barrel detector (40 channels)
SiD – silicon detector (60 channels)
CD – modular Cherenkov detector (FFD modules)

T0 detectors:

BC2 – runs with beam < 10^6 ion/spill
CD – runs with beam > 10^6 ion/spill

Trigger Rates:

Valid beam: 10^5 s^{-1}
Min. bias: 3×10^3 s^{-1}
Central coll.: ~ 3×10^2 s^{-1}
} for 3% target

Interaction trigger logic

Interaction Trigger = $BC1*BC2*VC_{veto}*BC3_{veto}*BD*SiD$

Valid beam (10-ns coinc.)

Min.bias (20-ns coinc.)

Central collision

Trigger electronics 2017

BM@N

T0U module with programmable trigger logic based on FPGA

Trigger & T0 detectors

Analog & LVDS pulses from detectors

LV to FEE

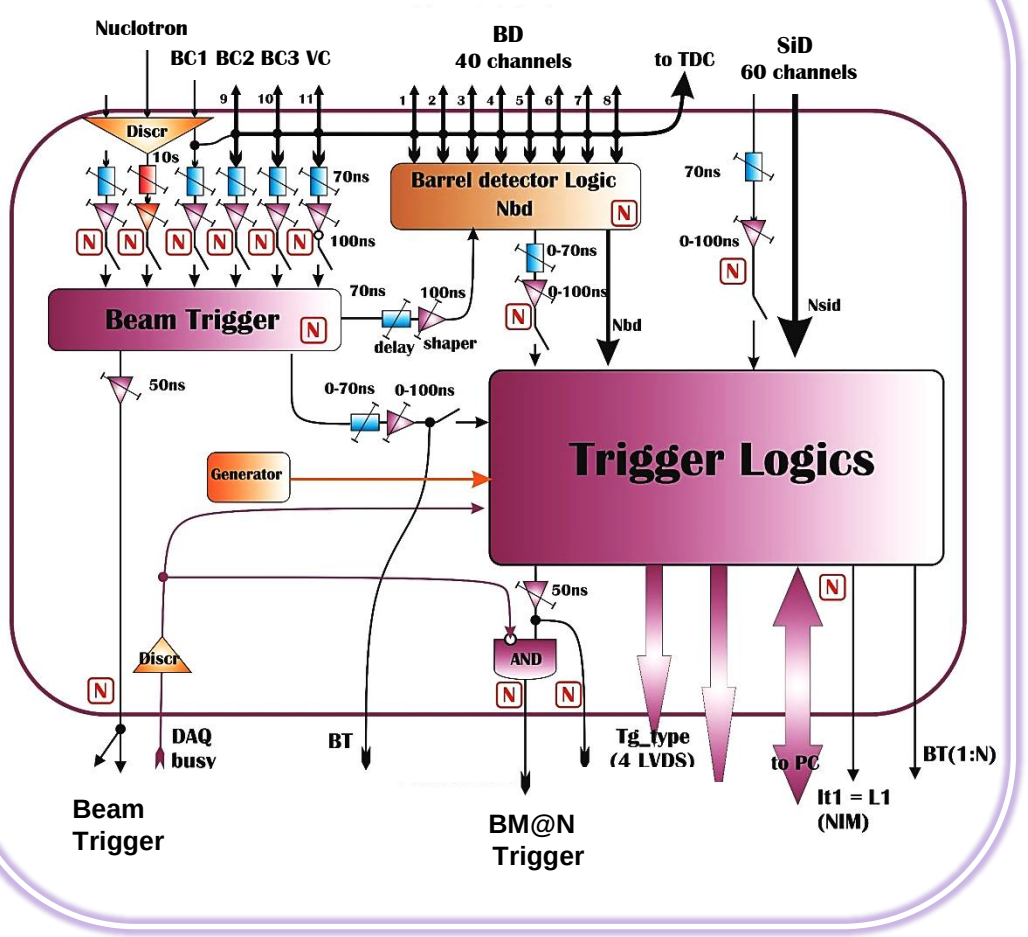
LVDS pulses to TDC

Readout electronics

Trigger to DAQ

Special triggers for BM@N detectors

Main trigger panel



Main Trigger Detectors

BM@N

T0 detector (BC2)

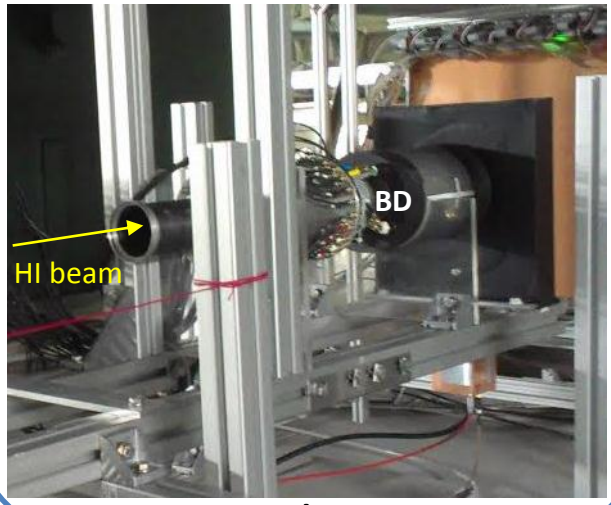
Photodetector TYPE **PP0365G**
18mm MCP-PMT

Plastic scintillator
20-mm diam. and 0.8-mm thick

March 2017

Barrel detector

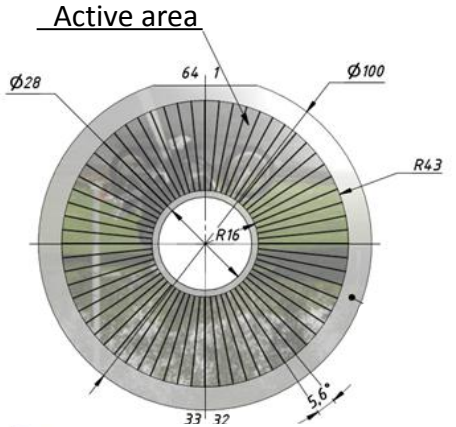
40 scintillation strips with SiPM readout

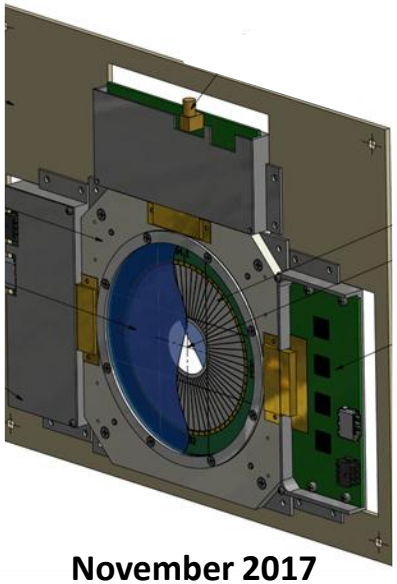


March 2017

Si detector

64 radial strips





November 2017

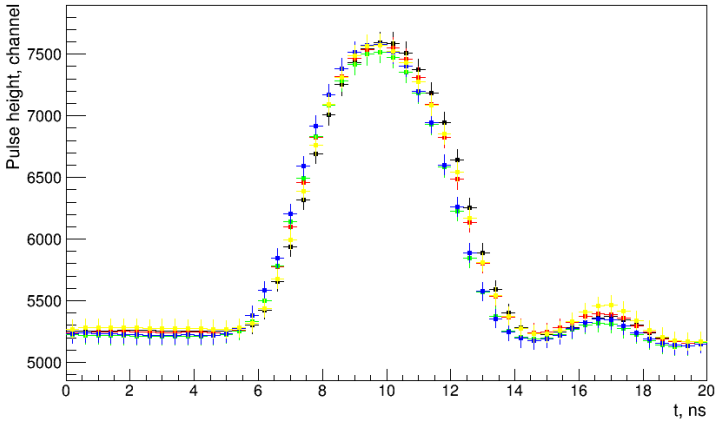
Beam detectors

BM@N

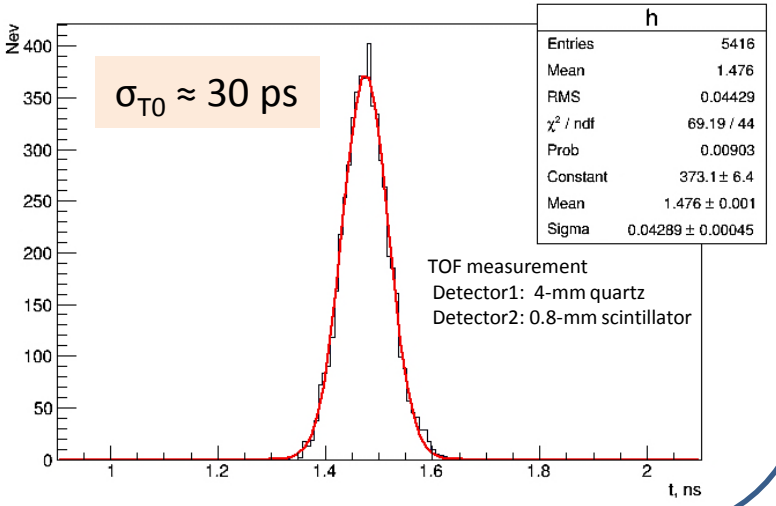
T0 (BC2)

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

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



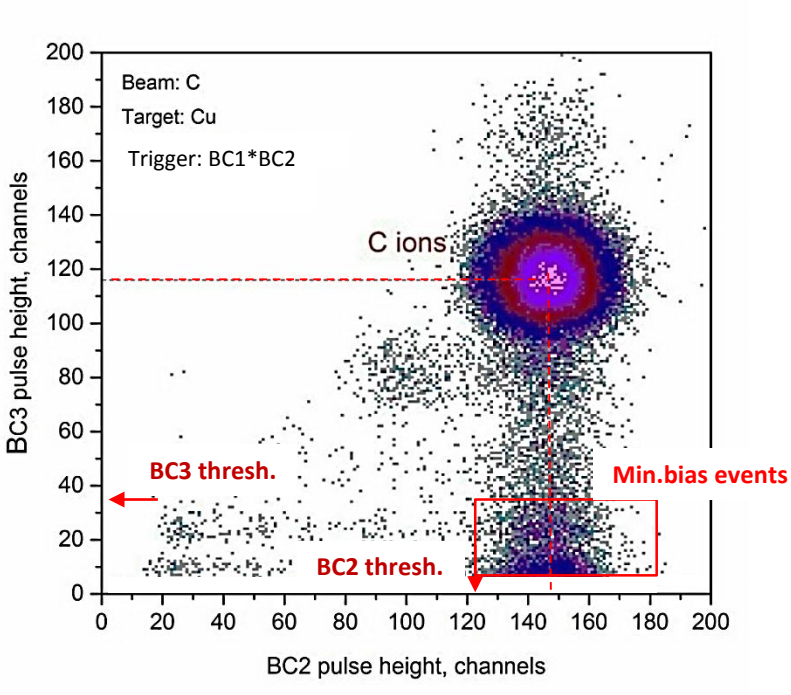
Typical pulses of BC2 measured with CAEN digitizer



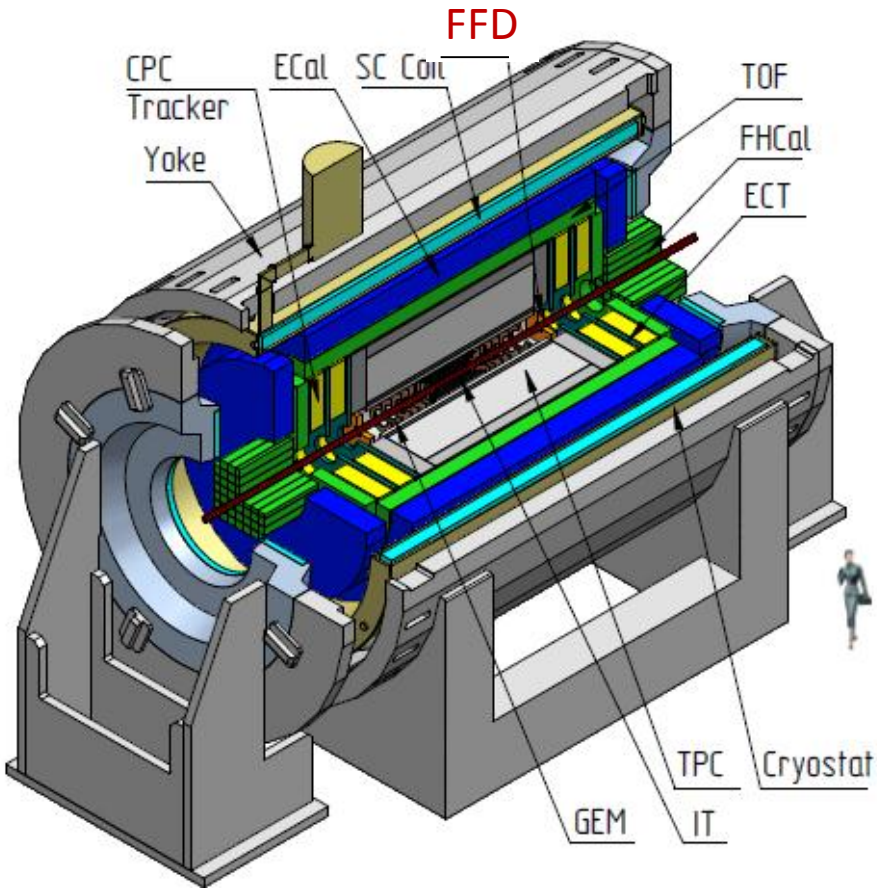
$\sigma_{T0} \approx 30$ ps

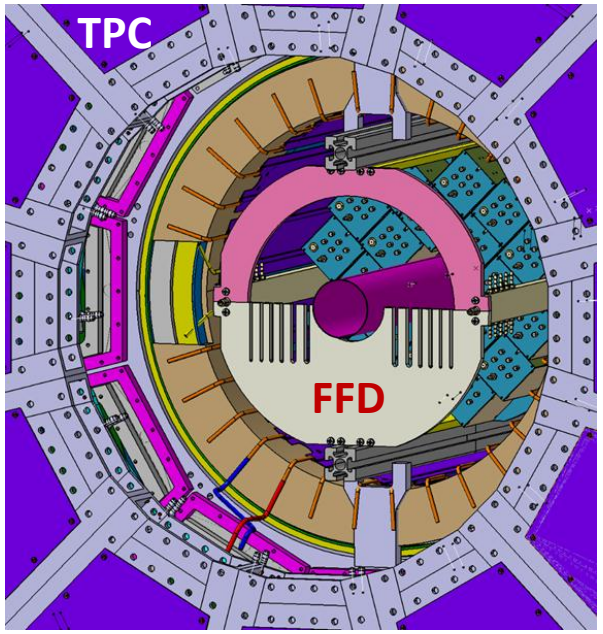
Event selection by Min. Bias trigger

Test of Min. Bias trigger with C-ion beam and prototypes of BC2 and BC3 with 3-mm scintillators in 2016



Fast Forward Detector for MPD experiment



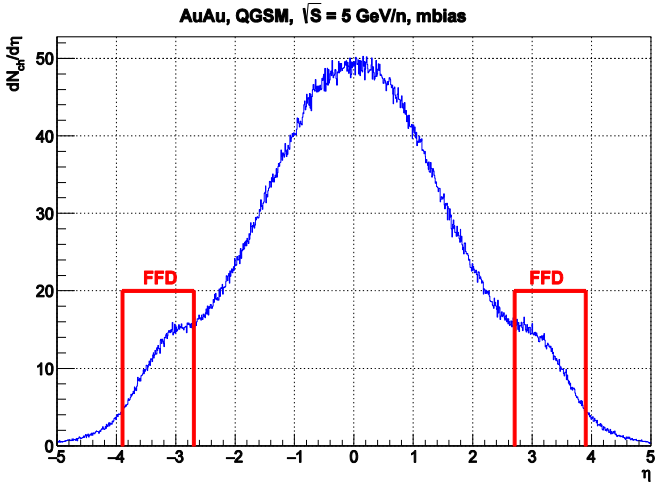


A scheme of installed FFD

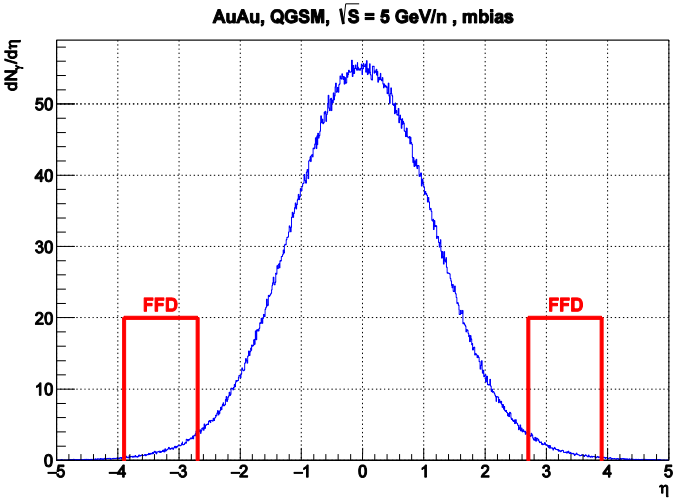
The Fast Forward Detector (FFD) provides
fast Vertex trigger and T0 pulse for TOF detector

Simulation with QGSM + GEAN4 code for Au + Au collisions

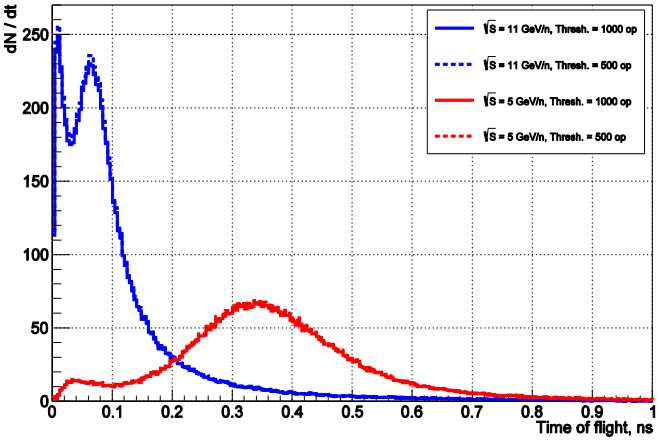
MPD



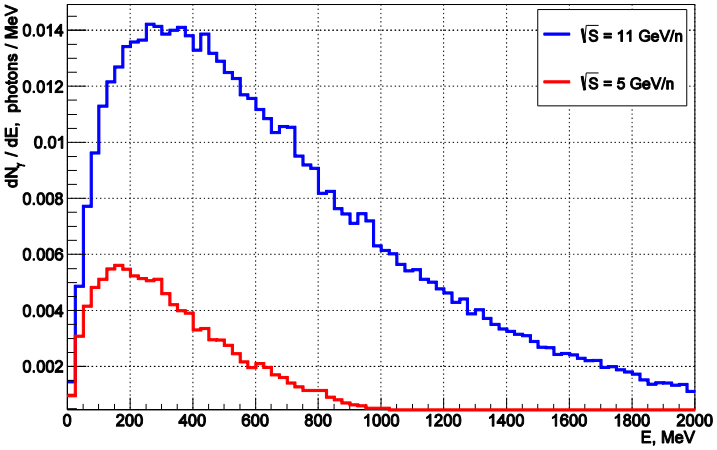
The charged particle distribution



The high-energy photon distribution



The delay of charged particle arrival in FFD



Energy spectra of the photons emitted into the FFD

Problems and Solutions

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Two problems at NICA energies		Solution used in FFD
1. Small multiplicity of produced particles	⟹	Large active area of FFD
2. Small velocity of charged particles	⟹	Detection of high-energy photons

Fast interaction trigger by fast Vertex FFD_E - FFD_W – by fast on-line processing of FFD pulses
Requirement: uncertainty of interaction point position $\Delta z < 3$ cm

Start signal T0 for TOF detector – by off-line analysis of FFD pulses
Requirement: $\sigma_{T0} < 50$ ps for time resolution of TOF system $\sigma_t = (\sigma_{T0}^2 + \sigma_{TOF}^2)^{1/2} < 100$ ps

Interaction trigger of MPD

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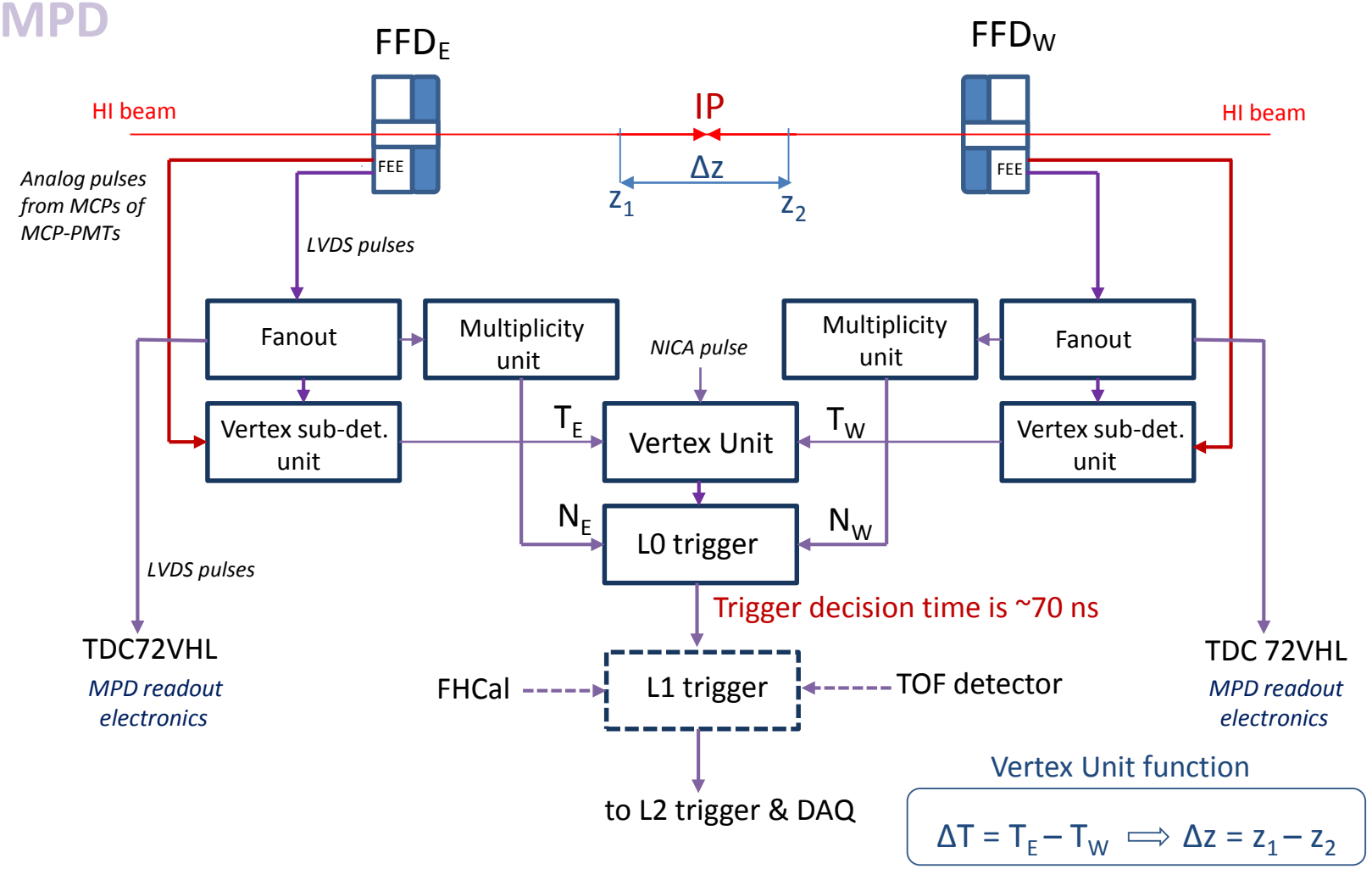

Vertex Unit function

$$\Delta T = T_E - T_W \Rightarrow \Delta z = z_1 - z_2$$

Concept of FFD

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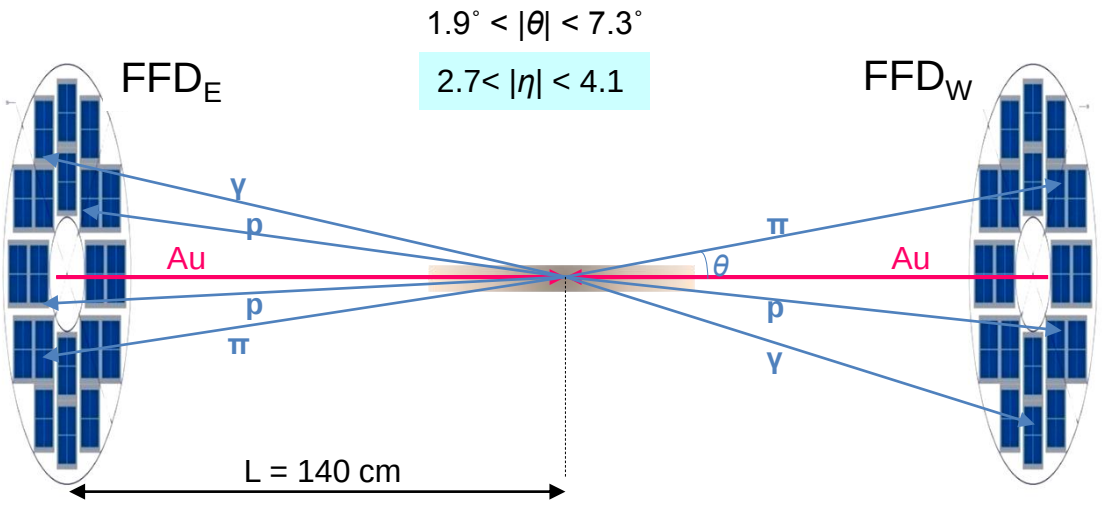
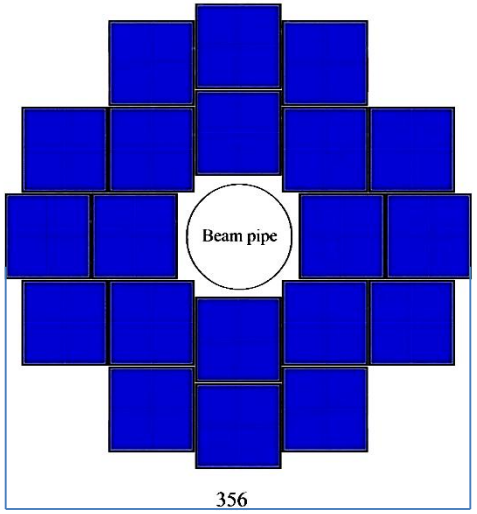


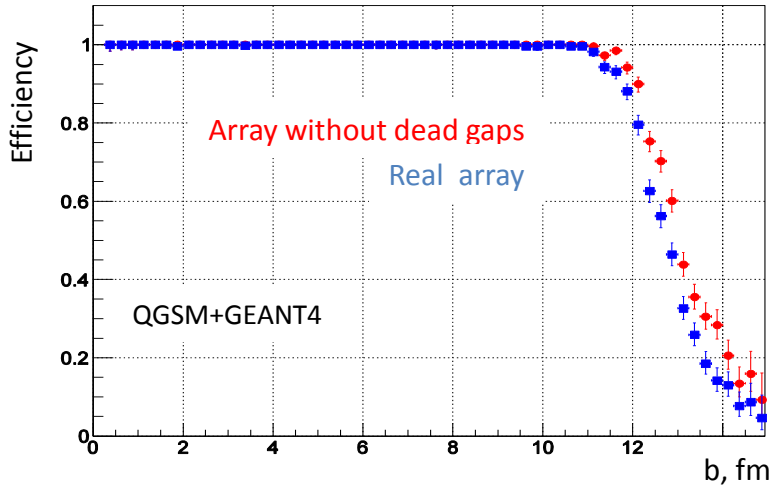
Period of beam crossing: ~75 ns

Maximum rate of
min. bias collisions: ~10^4 s^{-1}



FFD modular array
20 modules
80 +20 channels

MC simulation of trigger efficiency for
Au + Au collisions at $\sqrt{s_{NN}} = 5$ GeV



Design of FFD

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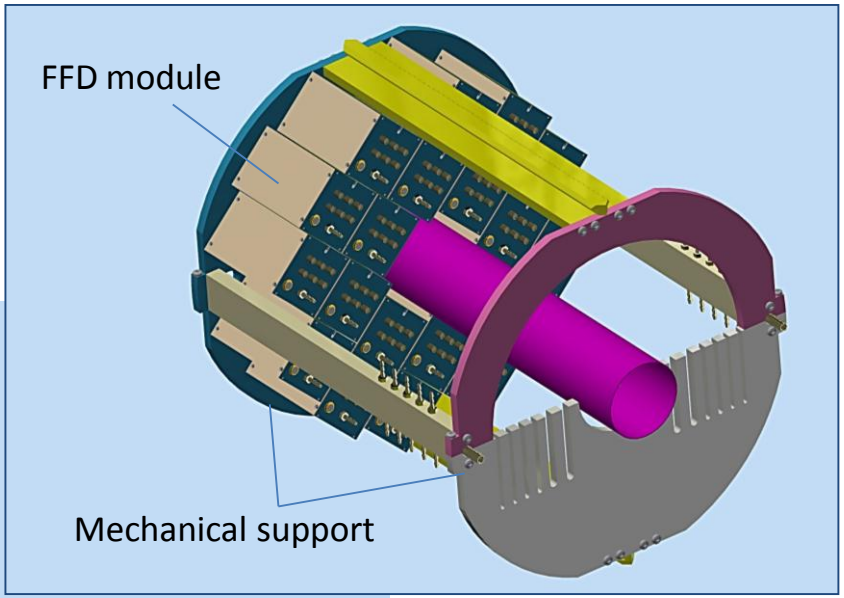
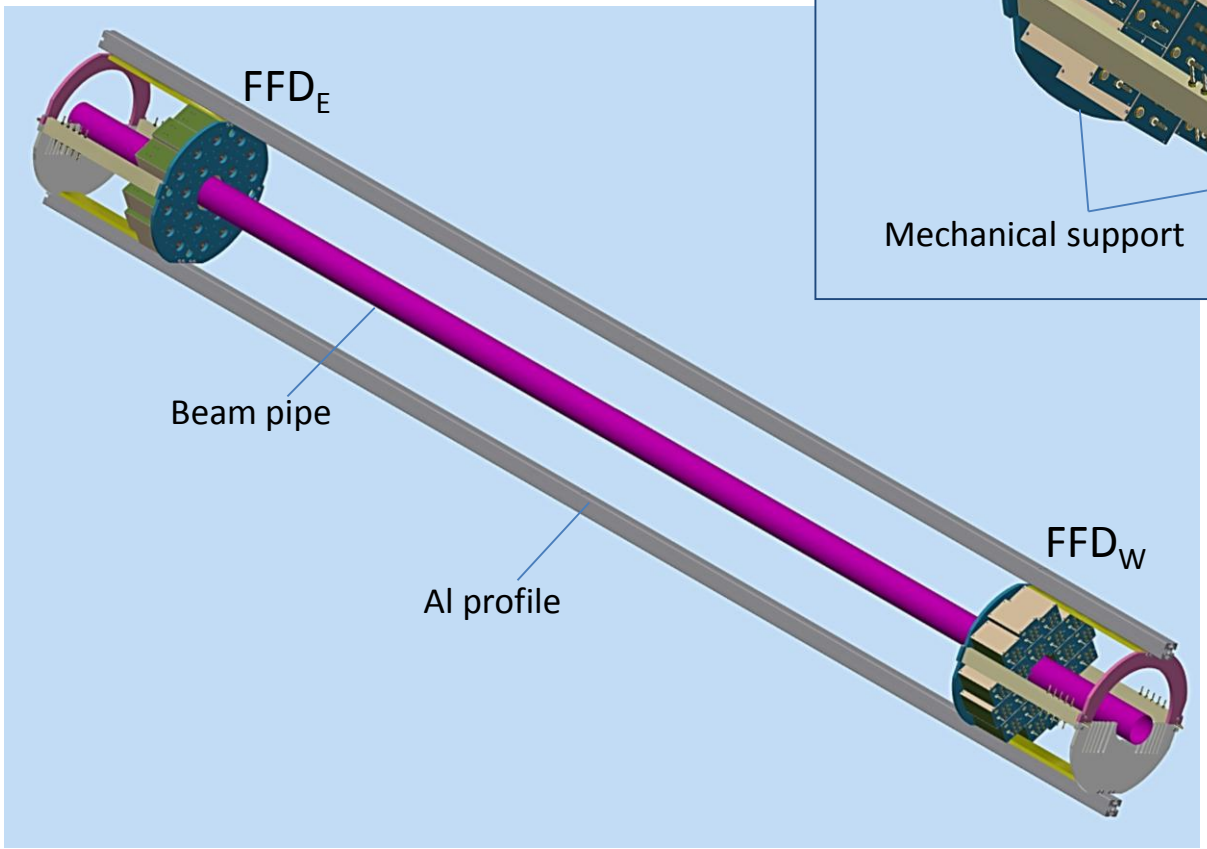
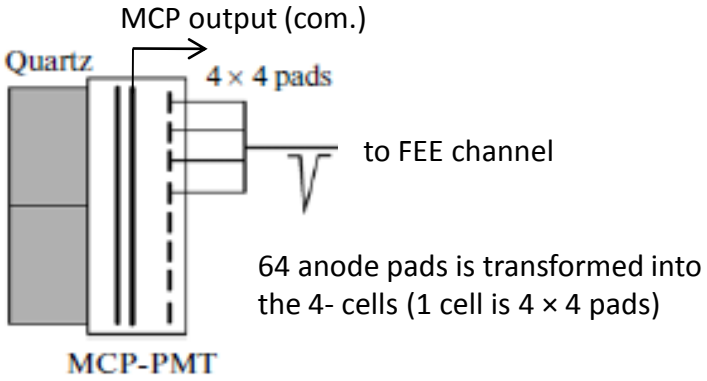


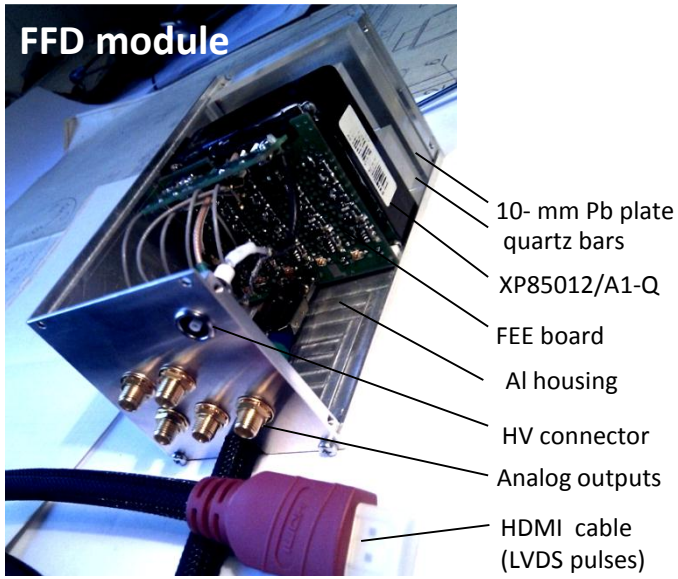


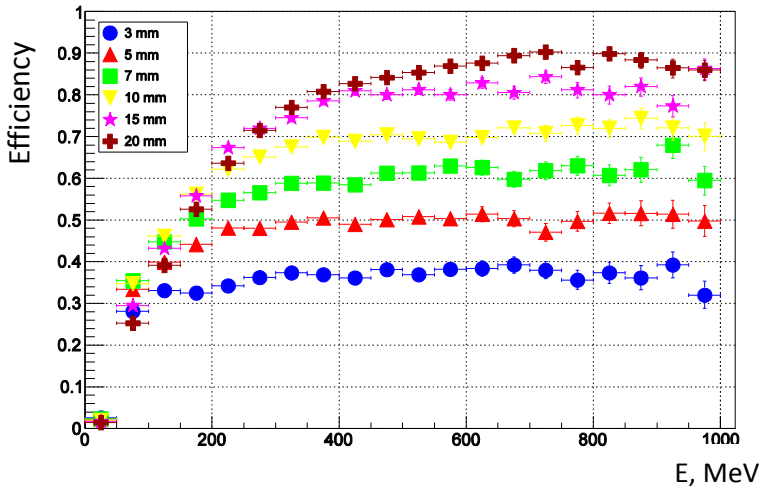
FFD module

MPD

Planacon MCP-PMT XP85012/A1-Q (S) with photocathode of 53 × 53 mm^2 (81% of front surface)





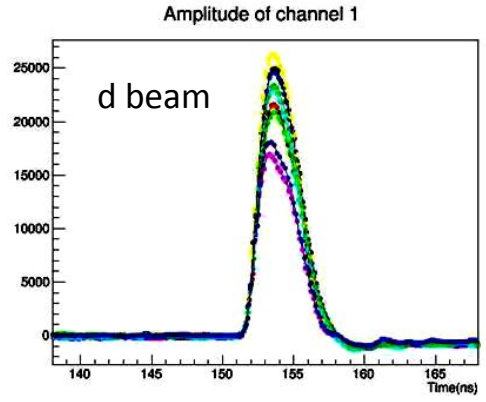


The efficiency of photon detection for different thicknesses of the lead converter from 3 to 20 mm.

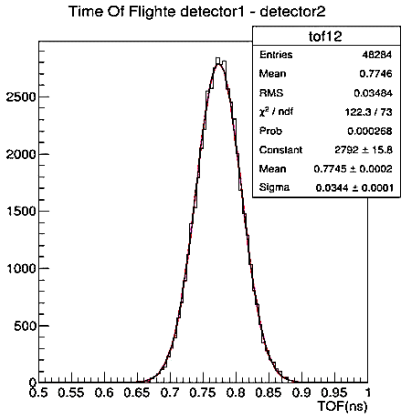
Time resolution

MPD

Ev.B. DRS4 readout

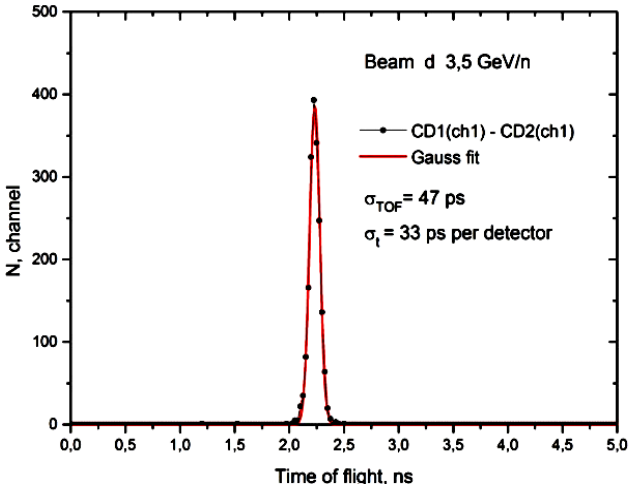


Typical pulses



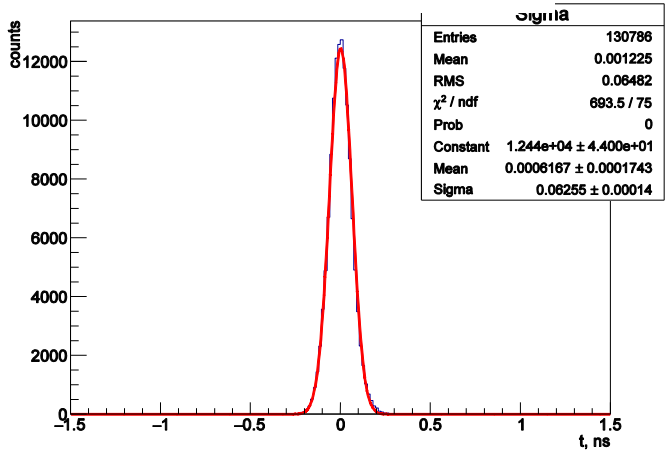
Time resolution (TOF)

CAEN mod.N6742 readout



Time resolution (TOF)

TDC72VHL readout



Time resolution (TOF)

Realistic chain of cables and electronics.

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

MPD

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 project: Photonis MCP-PMTs	Yes	28
MPD/NICA	FFD Cherenkov	625	80	Photonis MCP-PMTs XP85012/A1	Yes	~40

* sub-detector

** time resolution of single channel (sigma)

Summary

- For BM@N experiment, the detectors and electronics of fast interaction trigger and T0 have been developed and tested in runs with deuterons and carbon ions.

- For MPD experiment, the performance of Fast Forward Detector has been studied with MC simulation and in test measurements with FFD prototypes.

- For both experiments, all requirements to the fast interaction trigger and T0 pulse have been achieved.