Development and study of picosecond start and trigger detector for high-energy heavy ion experiments

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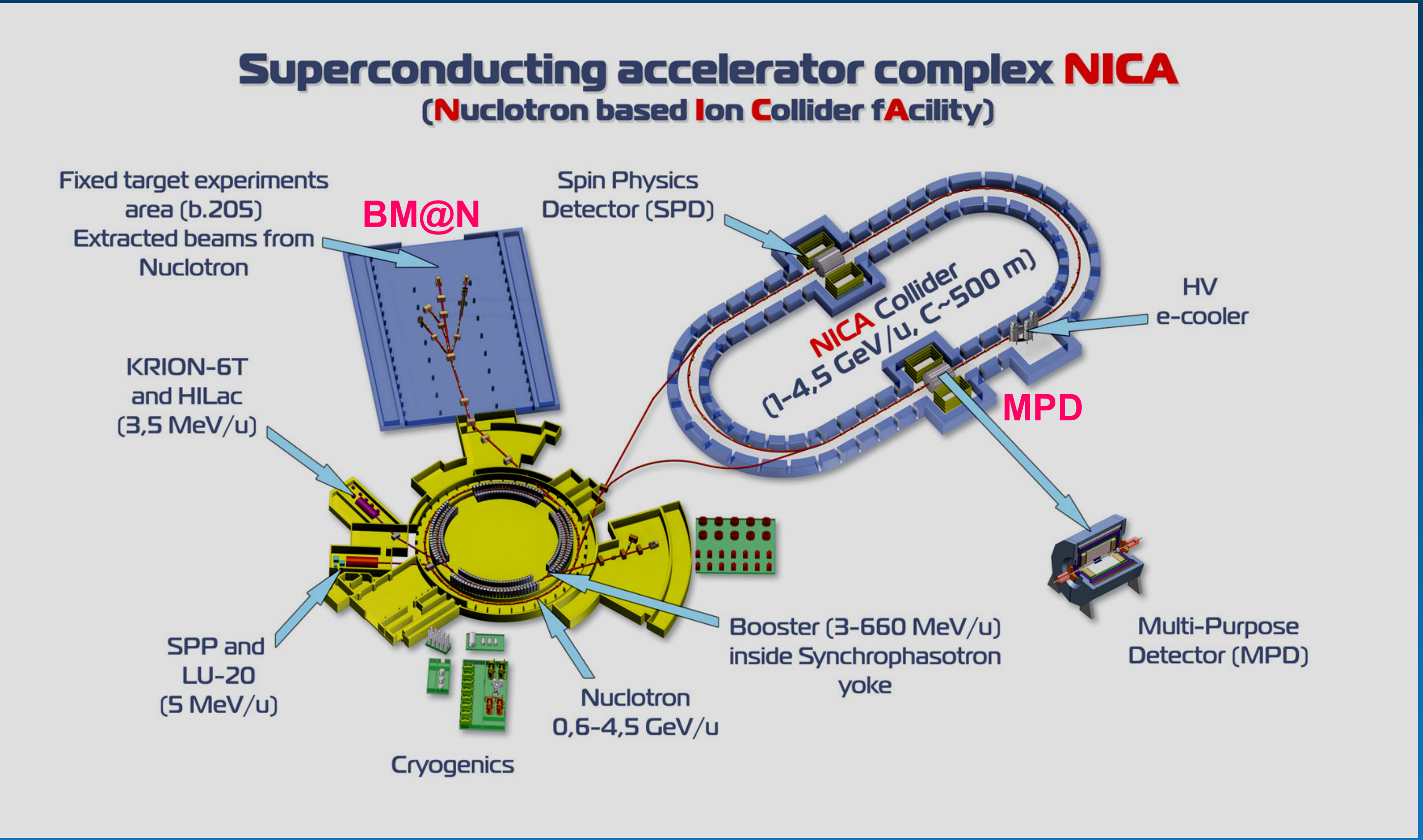
Outline

- MPD and BM@N – new heavy ion projects at JINR
- Modular Cherenkov detectors
- Detector module
- Time calibration
- Beam tests
- Detector response and time resolution
- MC simulation of trigger performance
- Conclusion

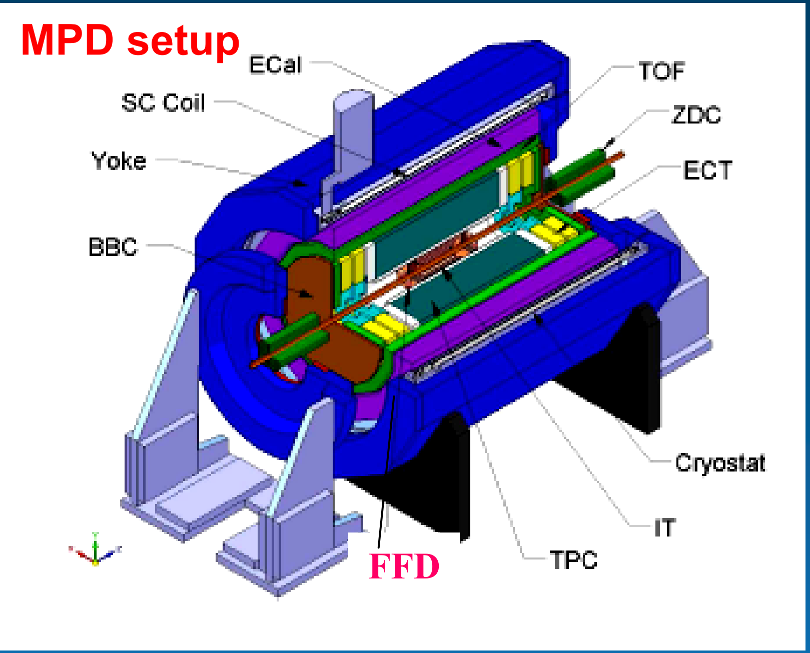
MPD and BM@N – new heavy ion projects at JINR

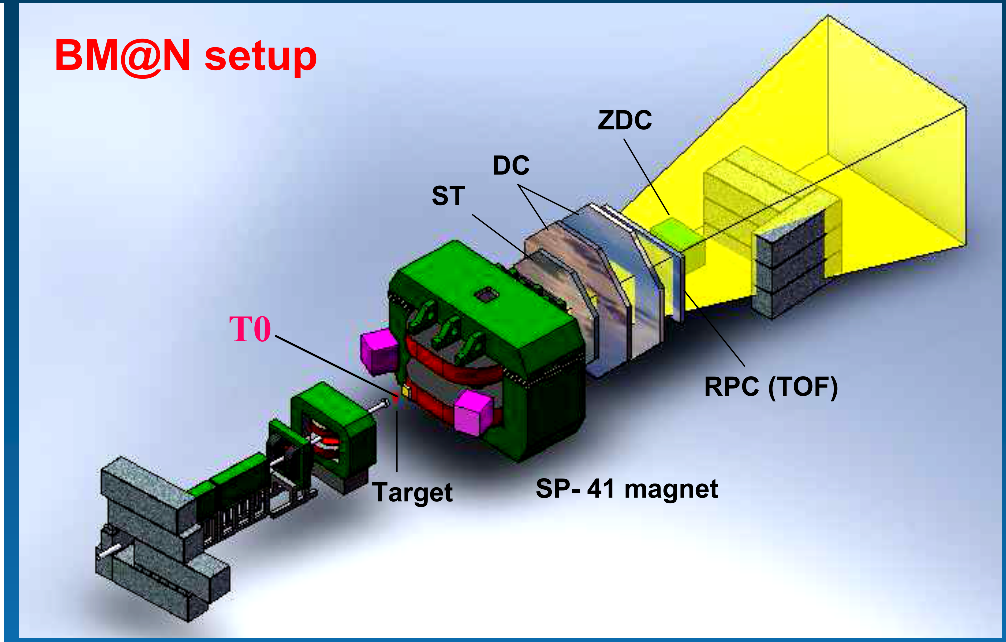


Aim is study of hot and dense baryonic matter formed in Au + Au collisions

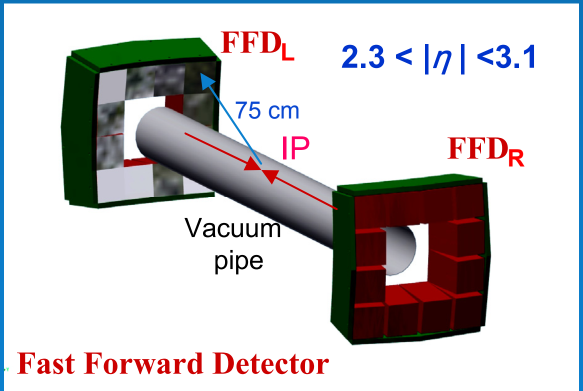
- **BM@N project** – Fixed target experiment, Baryonic Matter at Nuclotron (2016)
- **MPD project** – NICA collider experiment, Multi-Purpose Detector (~2019)

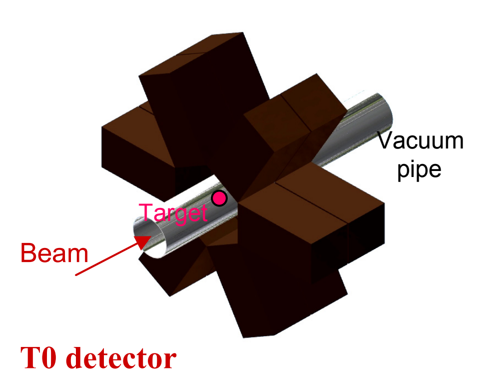
MPD and BM@N – new heavy ion projects at JINR





Modular Cherenkov Detectors with Picosecond Time Resolution





FFD	2 arrays 2×12 modules 2×48 channels
T0	1 array 12 modules 48 channels

Modular Cherenkov Detectors

The detector concept is based on registration of Cherenkov radiation induced by high-energy photons from $\pi 0$-decays and relativistic $\pi\pm$.

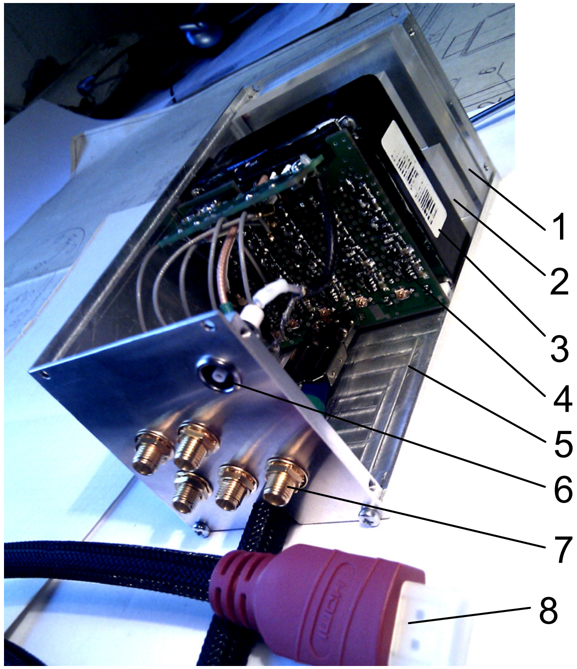
The aim of developed modular detectors :

- Start signal for TOF detector based on RPCs
- L0 trigger of Au + Au collisions

Requirements:

Detector	Project	Time resolution	Operation in magnetic field	L0 trigger min.bias	L0 trigger central coll.
Fast Forward Detector (FFD) T0 detector (T0)	MPD BM@N	< 50 ps < 50 ps	B = 0.5 T B = 0.1 T	Yes Yes	Yes Yes

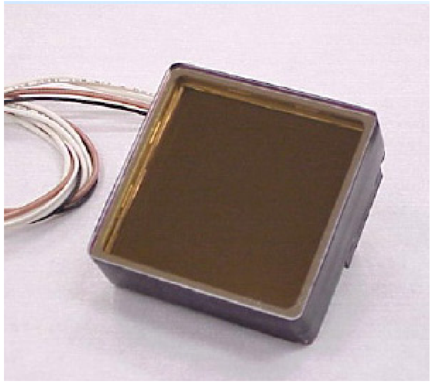
Detector Module



1 – Pb plate (converter of high-energy photons)
2 – quartz radiator bars
3 – MCP-PMT XP85012/A1-Q
4 – FEE board
5 – module housing
6 – HV connector
7 – SMA outputs of analog signals
8 – HDMI cable (LVDS signals + LV for FEE)

Detector of Cherenkov photons

MCP-PMT XP85012/A1-Q
(PHOTONIS)

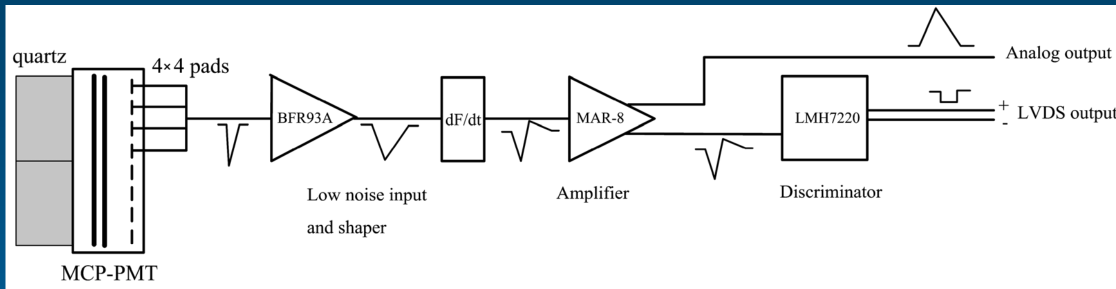


MCP double, chevron, 25 μm pore
8×8 anode pads
53×53-mm photocathode
Quartz window
Package open-area-ratio – 80%
Rise time – 0.6 ns
Efficiency in UV range – 17-20%
Gain ~ 10^5 at 1500 V

- Anode pads of MCP-PMT are joined into 2 × 2 cells (4×4 pads/cell)
- FEE includes:
  - 4 channels for pulses from anode pads (cells)
  - a single channel for pulse from MCPs output

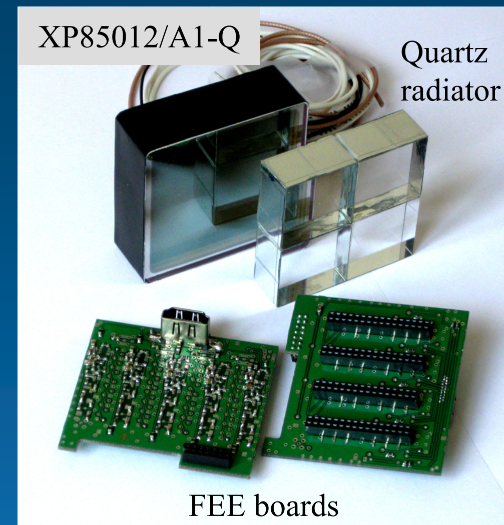
Detector Module

Front-end electronics



A scheme of single channel of FEE

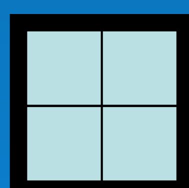
MCP-PMT gain ~10^5 (HV ≈ -1500V)
FEE amplifier gain ~30
Analog output with rise time 1.3 ns and pulse width ~5 ns
Discriminator output – LVDS pulses with width up to 25 ns



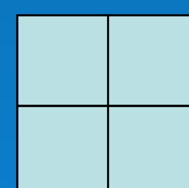
Module main components

Two different quartz radiators were used in test measurements

53×53 mm ≈ photocathode size
Dead area ≈ 20%



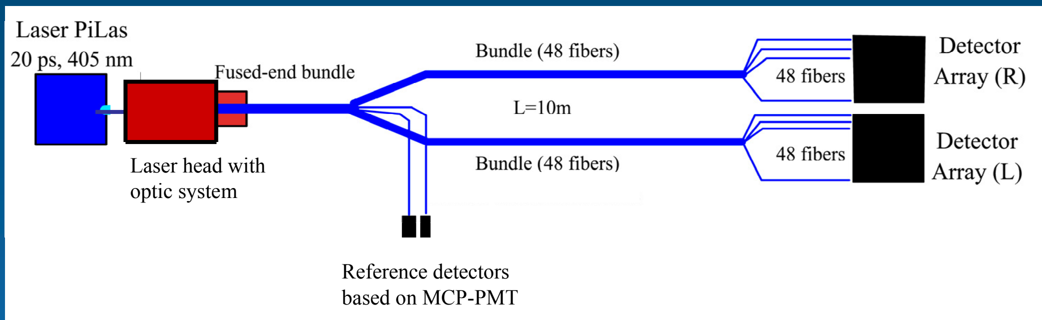
59×59 mm ≈ MCP-PMT size
Dead area ≈ 0%



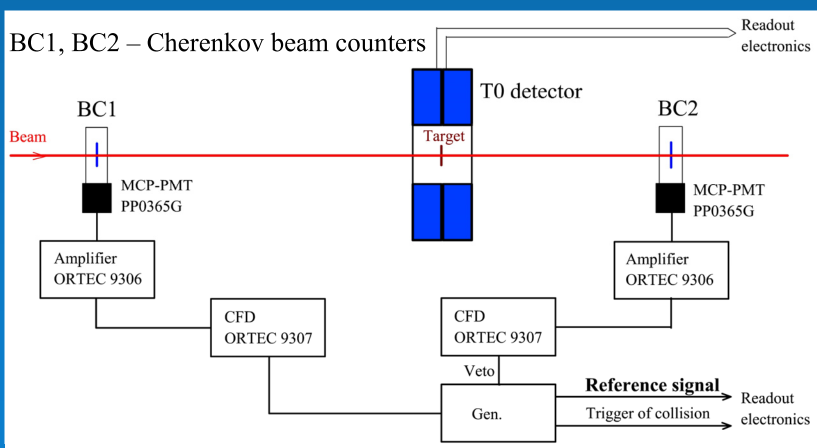
Time Calibration

Two methods of time calibration of detector channels:

1. ps-laser system



2. Reference beam counter system for T0 detector



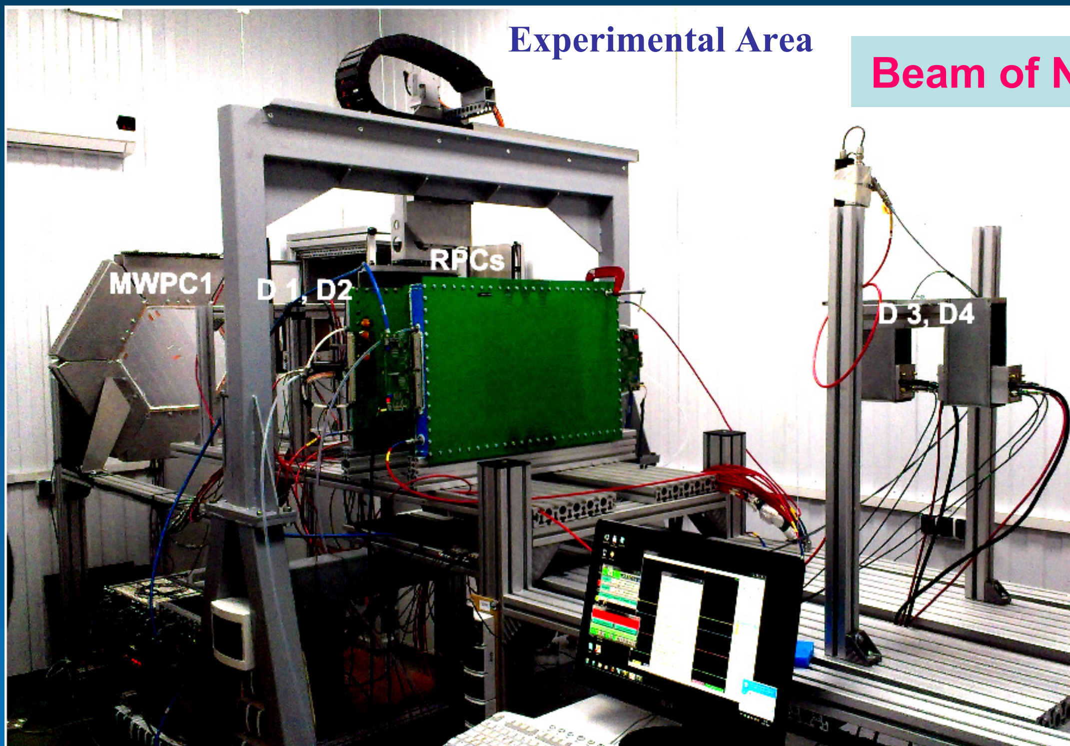
Photodetector MCP-PMT PP0365G (PHOTONIS)

MCP double , chevron, 6-µm pore size
Quartz window
Photocathode diam. 17.5 mm
Rise time 200 ps
Sensitivity in UV range QE ≈ 25–30 %
Typical gain 7×10^{5}

Main components

ps-laser with optic system	PiLas, 20 ps, 405 nm	Advanced Laser Diode Systems
Quartz fiber bundle	fibers WF100/140/300N	BIOLITEC
MCP-PMT (ref. detectors)	PP0365G	PHOTONIS
Electronics (ref. detectors)	9306, 9307	ORTEC

Beam Tests 2013 - 2014



Beam of Nuclotron: 3.5-GeV deuterons

Modules prepared for beam test

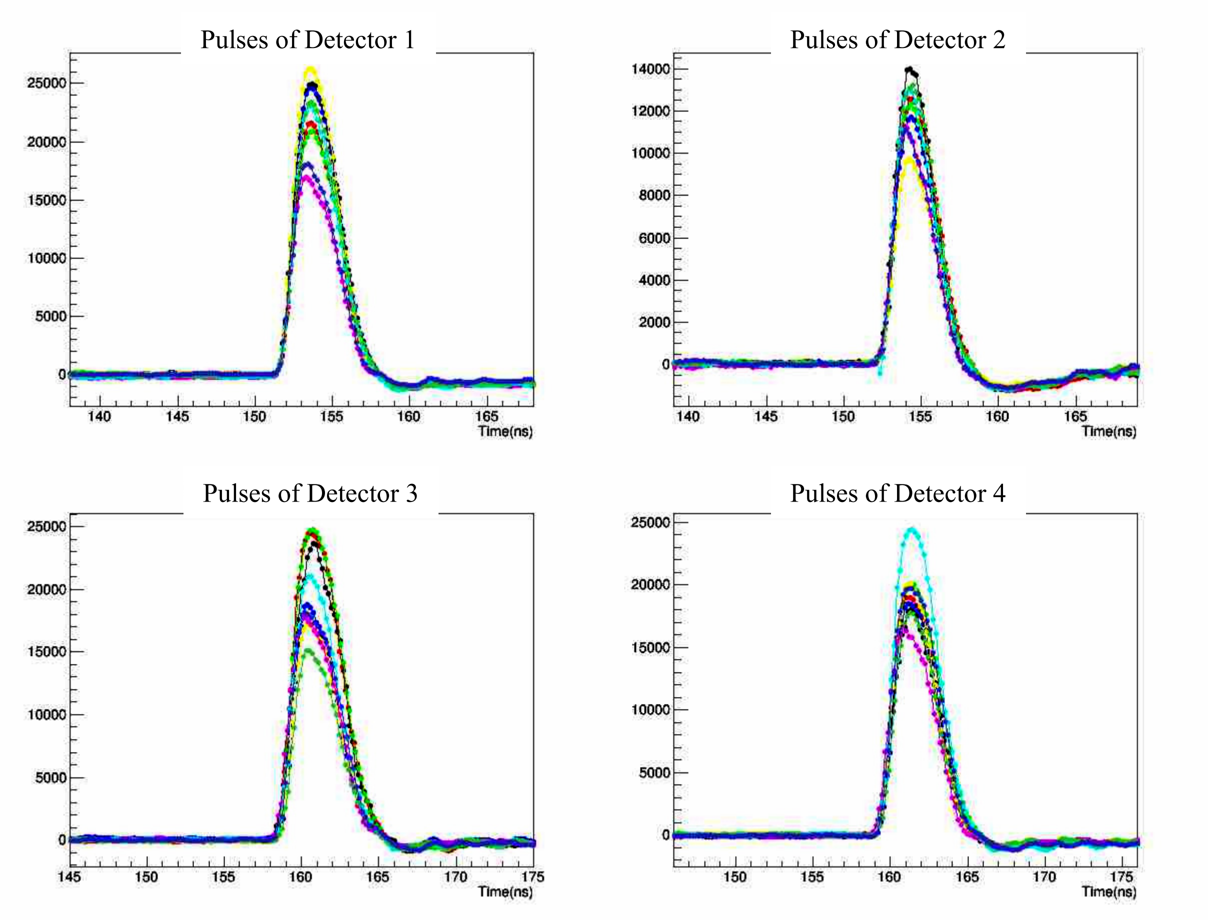
TOF measurements with two pairs of modules D1–D2 and D3–D4:

- analog signals ⟶ DRS4(V4) digitizers from PSI
- LVDS signals ⟶ VME module TDC32VL from JINR
  (32-channel 25 ps multihit time stamping TDC)

Two MWPCs were used for particle tracking through detectors located on beam line

Detector Response and Time Resolution

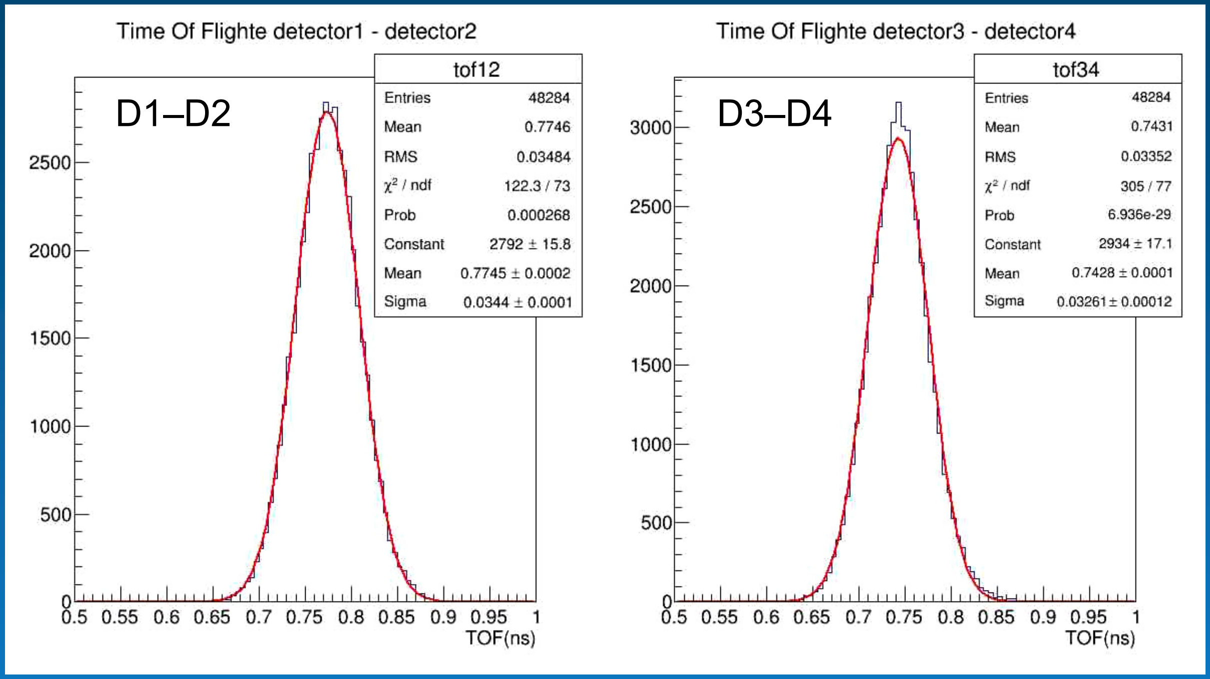
Pulse form measured with DRS4 Evaluation Board V4



10 events when 3.5-GeV deuteron passes through the quartz bars of the detectors

Detector Response and Time Resolution

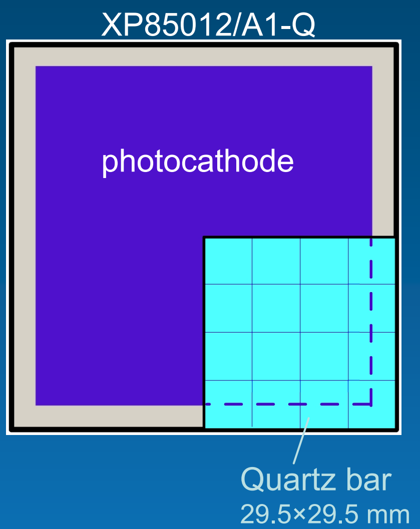
TOF measurements with pair of the modules and DRS4 E.B.V4



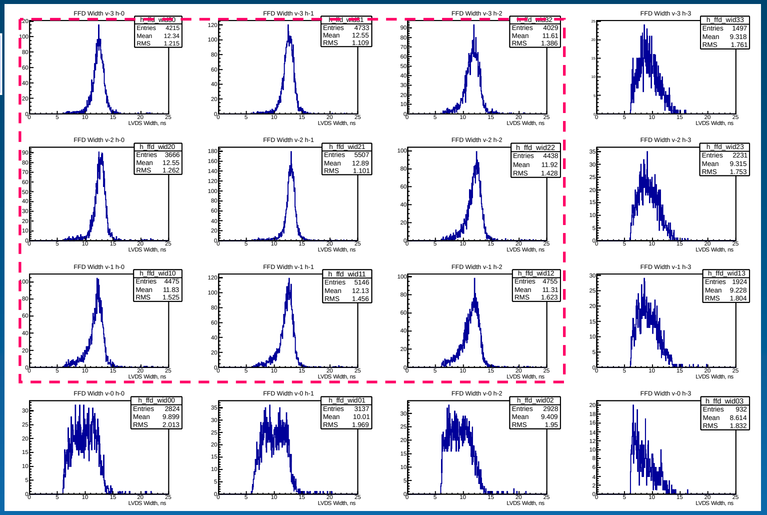
TOF result	33.5 ps
Readout electronics	14 ps
Single detector resolution	21.5 ps

Detector Response and Time Resolution

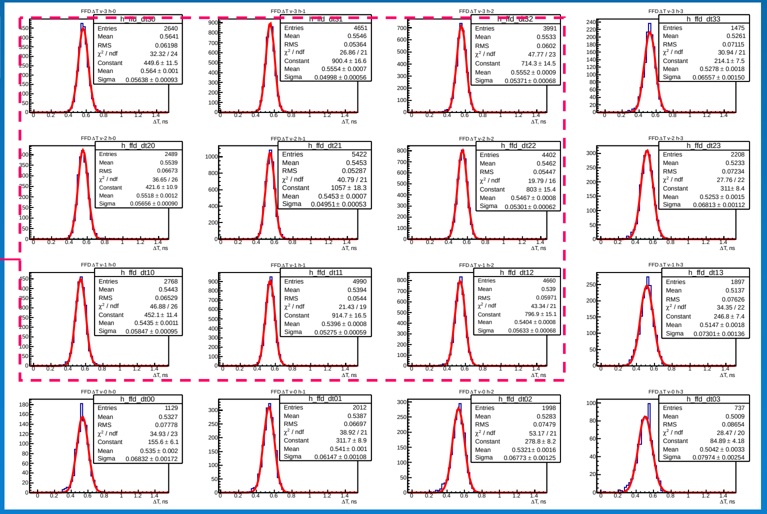
TOF measurements with pair of the modules and TDC32VL



Pulse width distributions



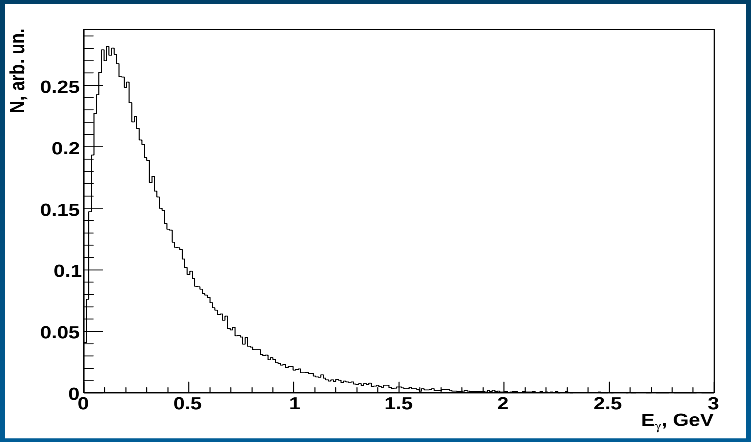
TOF distributions



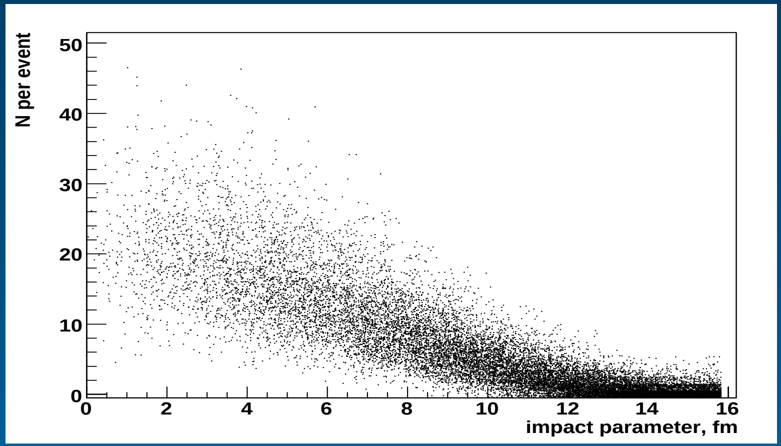
TOF resolution	54 ps
Readout electronics	25 ps
Single detector resolution	34 ps

MC Simulation of Trigger Performance for FFD

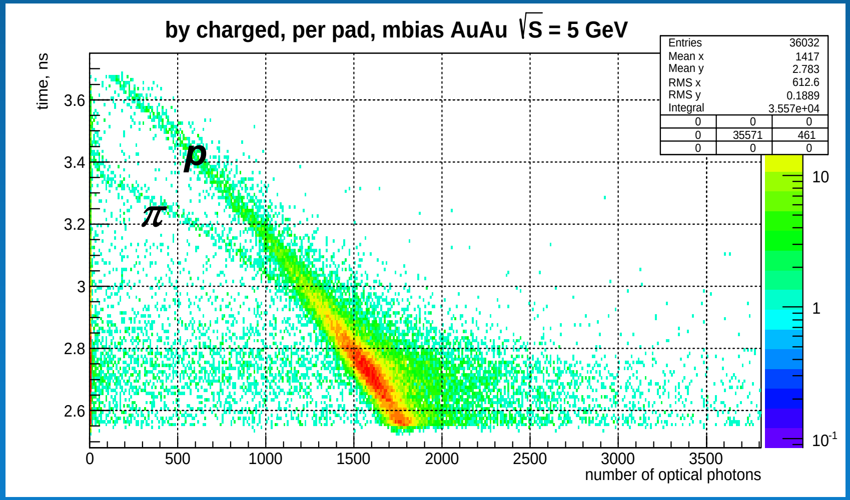
UrQMD + GEANT3



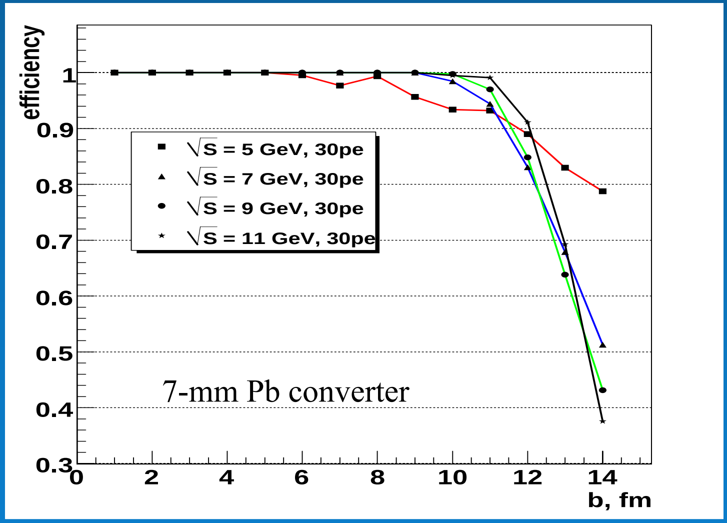
Energy spectrum of photons in FFD acceptance for Au + Au at $\sqrt{s_{NN}}$ = 5 GeV.



Photons in acceptance of single FFD array $\sqrt{s_{NN}}$ = 9 GeV



Plot of number of Cherenkov photons in radiator vs time of arrival of ch. particles at $\sqrt{s_{NN}}$ = 5 GeV

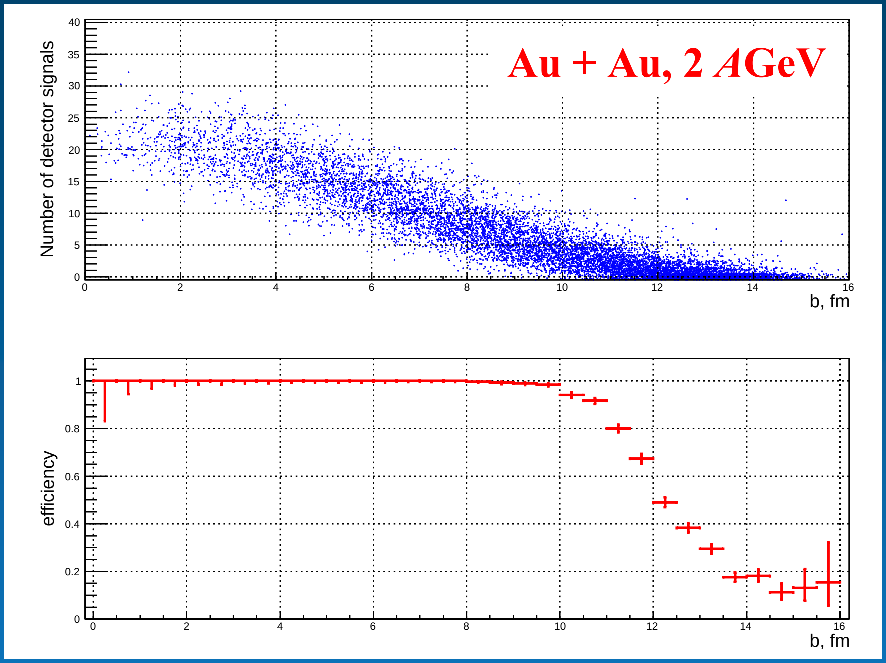


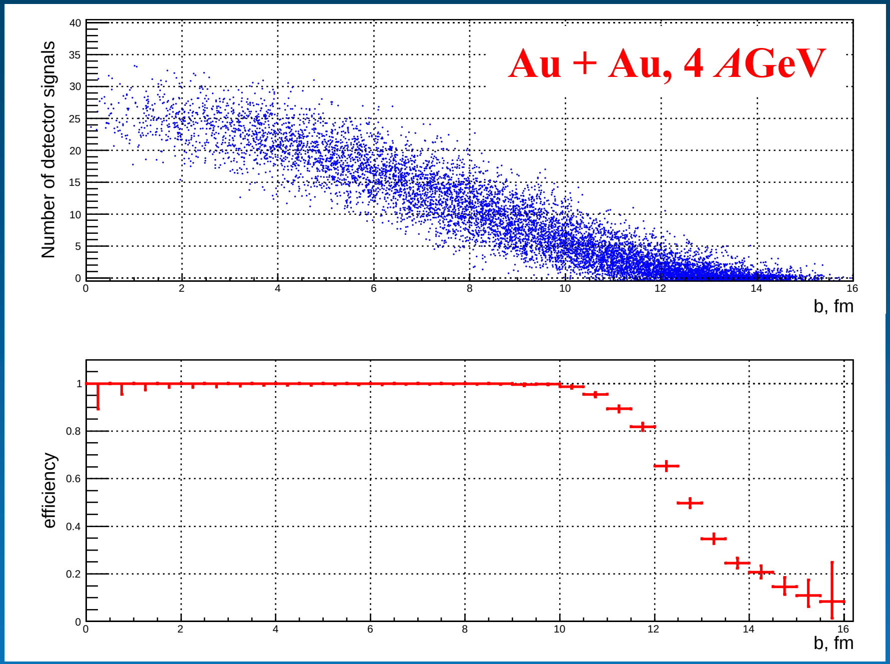
Efficiency of triggering the collisions by photon detection in single FFD array

MC Simulation of Trigger Performance for T0 detector

LAQGSM + GEANT4

photons + ch. pions





Number of signals from T0 detector induced by high-energy photons and ch. pions and corresponding detector efficiency as a function of impact parameter *b* for Au + Au collisions at energies 2 and 4 *A* GeV

- 100% efficiency for collisions with $b < 10$ fm
- Central collisions provide maximum number of detector signals and this fact can be used for triggering Au + Au central collisions

Conclusion

- The developed modular Cherenkov detectors, FFD and T0, provide time resolution much better than 50 ps required.

  In test measurements with LVDS signals we got for the detector array

  $\sigma_t \approx 34$ ps for single pulse or

  $\sigma_t \approx 8$ ps for event with 20 pulses in Au + Au central collision

  Even better result is obtained with method of digitizing pulse form.

- In final version of the modules we decided to use
  - 10-mm lead converter with photon conversion efficiency of 70%
  - quartz radiator 53×53 mm which is equal to photocathode area of XP85012

- The T0 detector will be produced in 2014 and tested with beam in Feb. 2015.