Fast Forward Detector (FFD) for MPD experiment

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Aim and Requirements

Aim of FFD

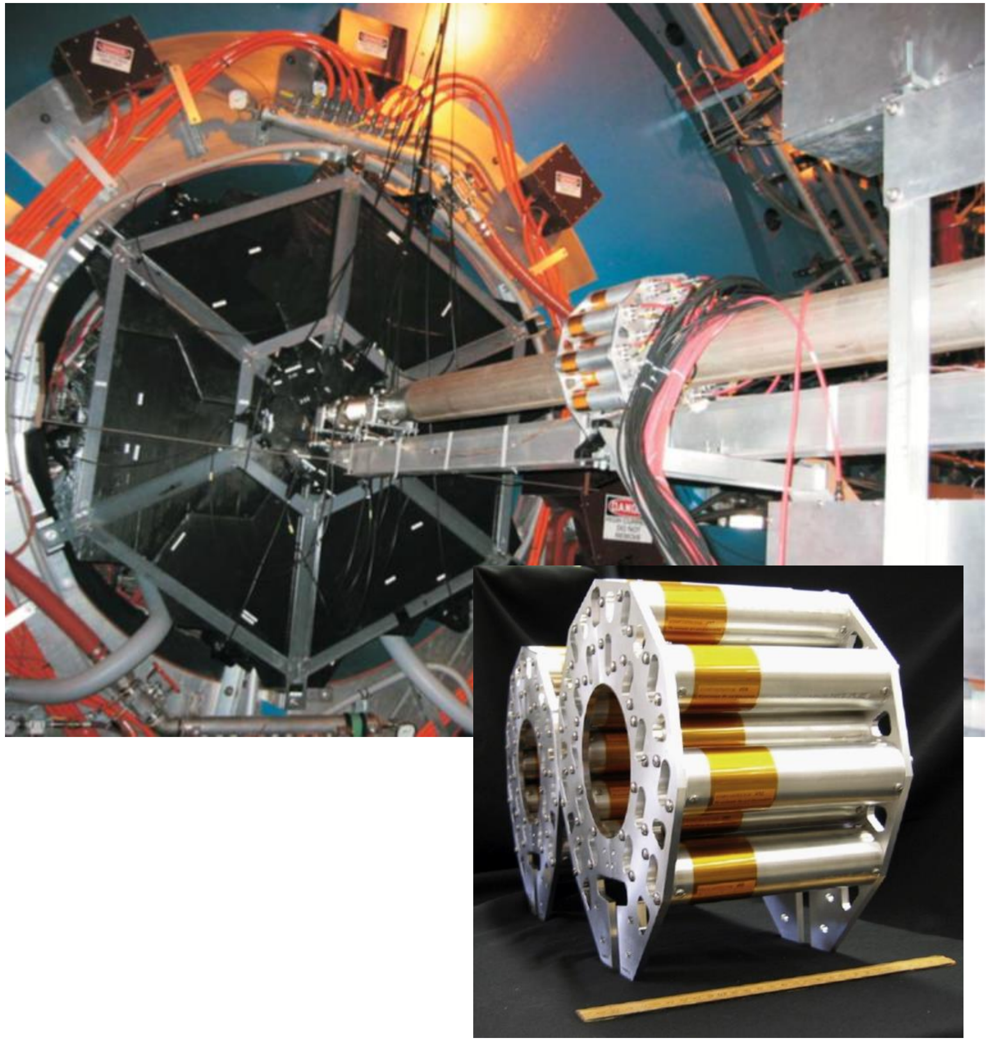
- Fast triggering of nucleus–nucleus collisions in center of MPD setup
- Generation of the start signal T0 for TOF detectors

Requirements

- High efficiency of the collision trigger
- Time resolution of T0 pulse with $\sigma_t \leq 50$ ps
- Operation in strong magnetic fields of MPD (B = 0.5 T)

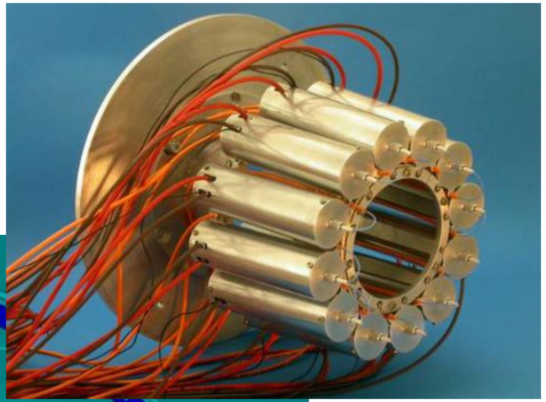
Some examples of trigger/T0 detectors

VPD / STAR (RHIC / BNL)

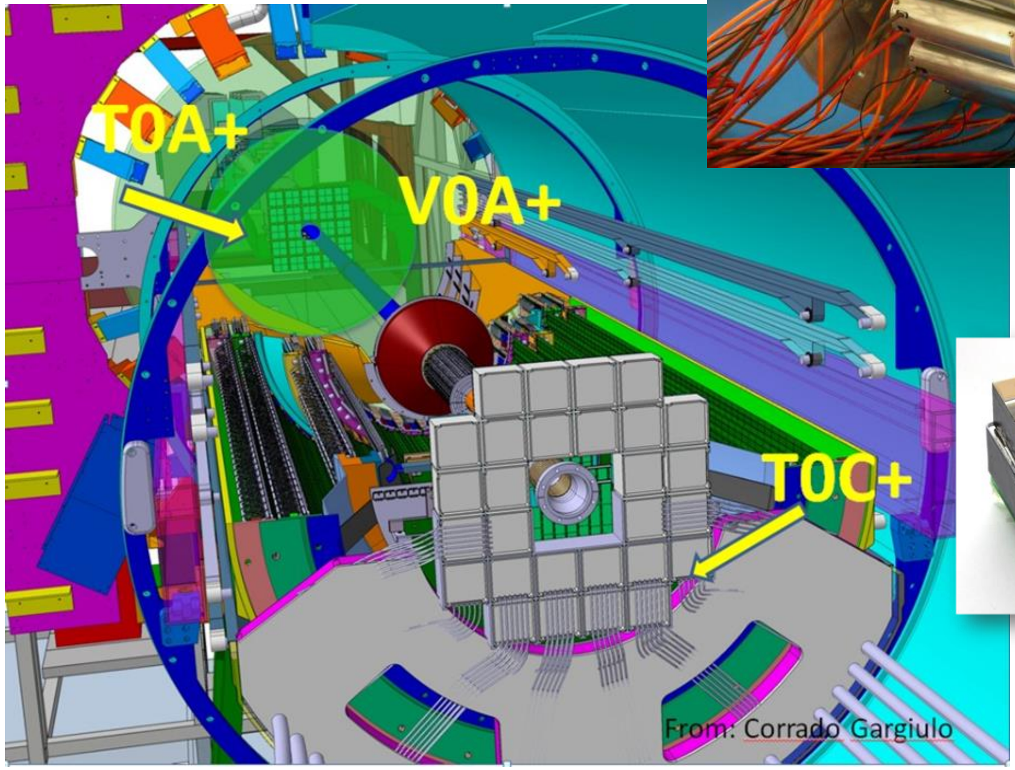


Fast Interaction Trigger (FIT) and T0 ALICE (LHC / CERN)

Current configuration of T0



Upgrade project



XP85012

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 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)

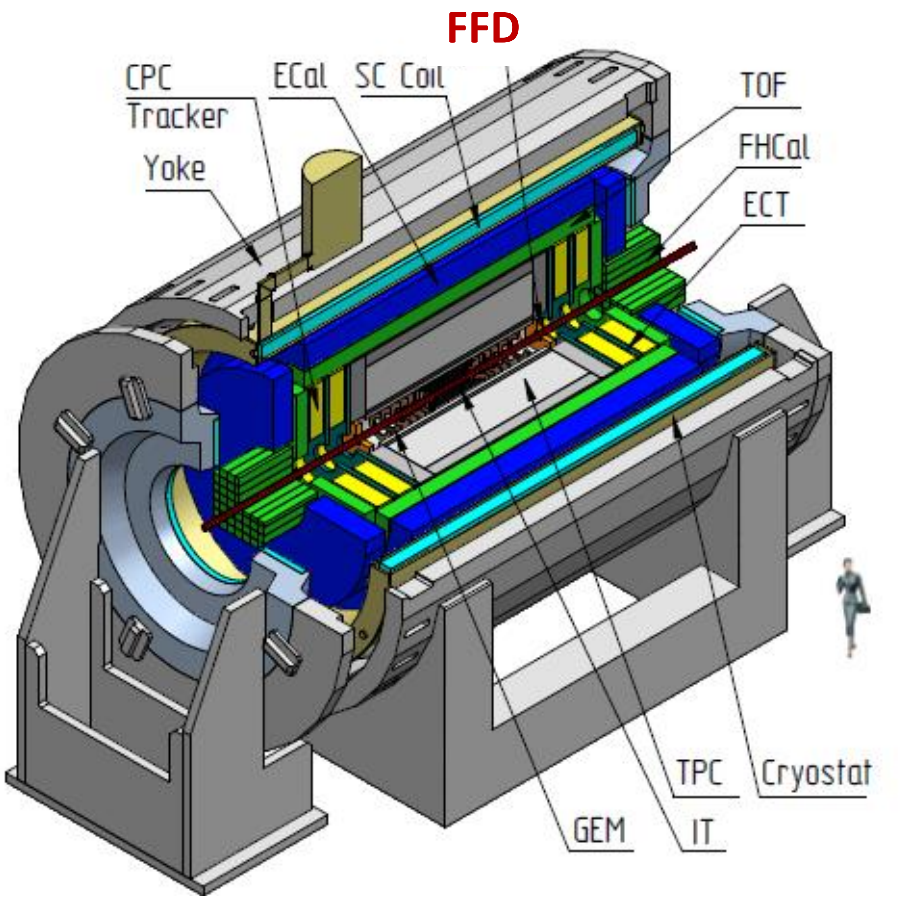
Problems and Solutions

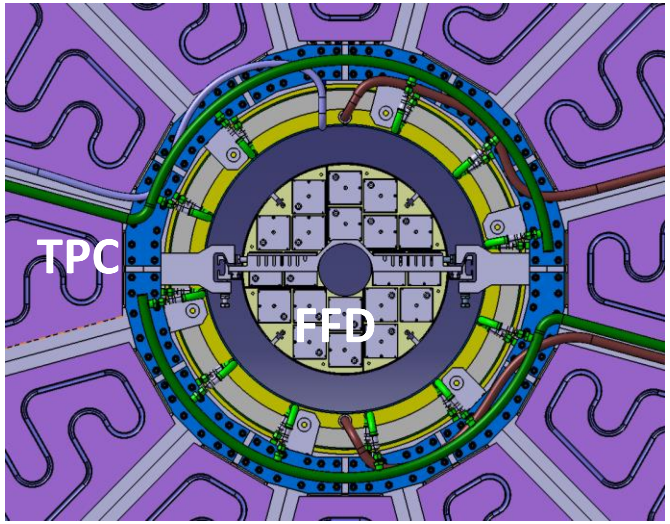
Two problems at NICA energies		Solution used in FFD
1. Small multiplicity of produced particles	$\Longrightarrow$	Large active area of FFD
2. Small velocity of charged particles	$\Longrightarrow$	Detection both high-energy photons and charged particles

Fast interaction trigger by fast Vertex FFD_E - FFD_W
by fast on-line processing of FFD pulses from two sub-detectors,
uncertainty of interaction point position $\Delta z < 3$ cm is expected

Start signal T0 for TOF detector
by off-line analysis of all FFD pulses

FFD in Multi Purpose Detector (MPD)

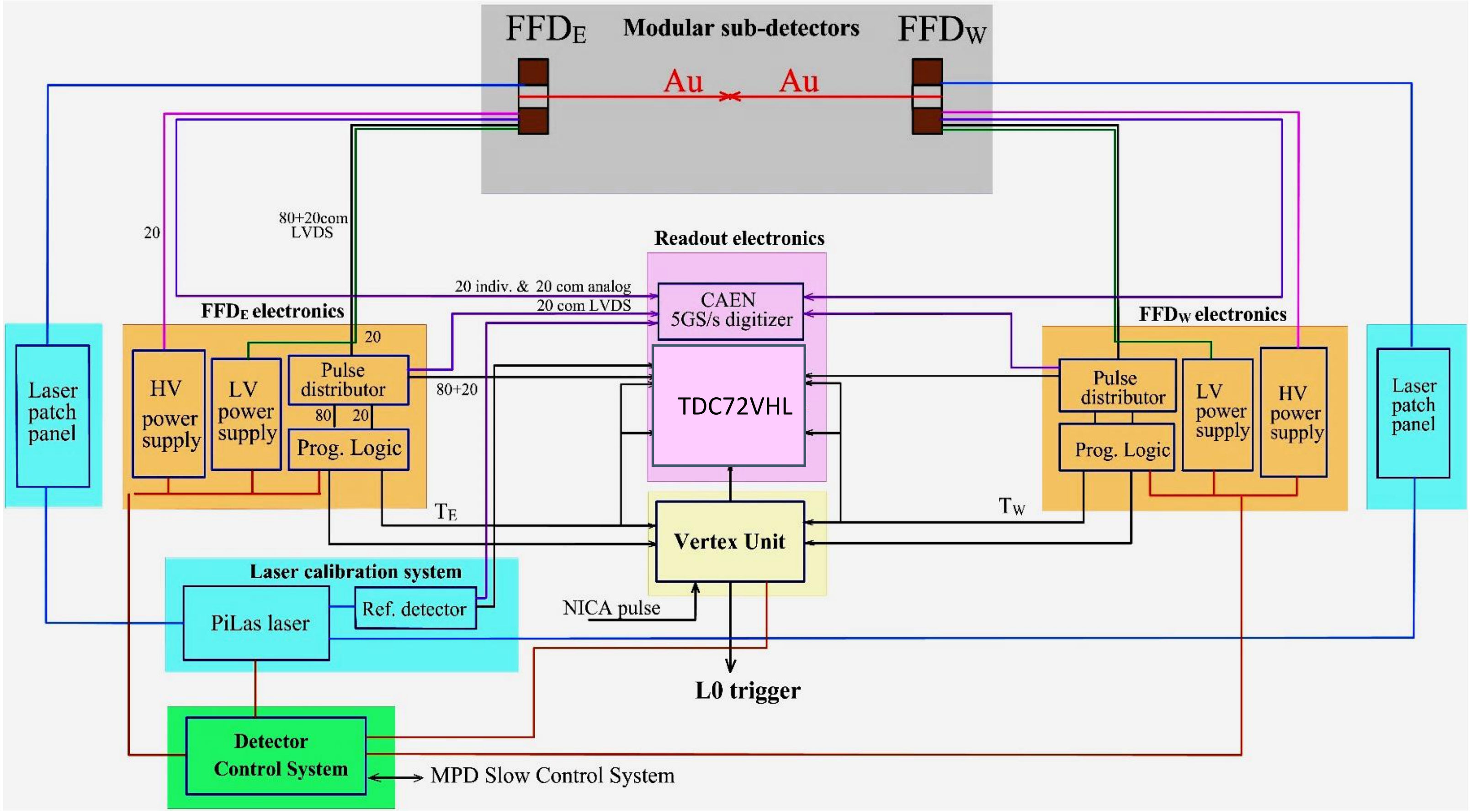




A scheme of installed FFD

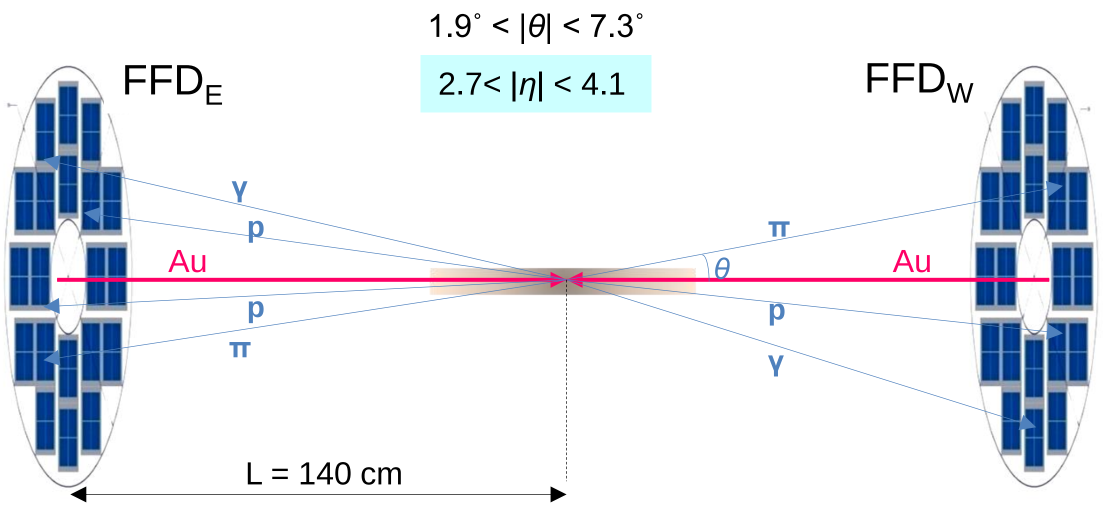
The Fast Forward Detector (FFD) position in MPD

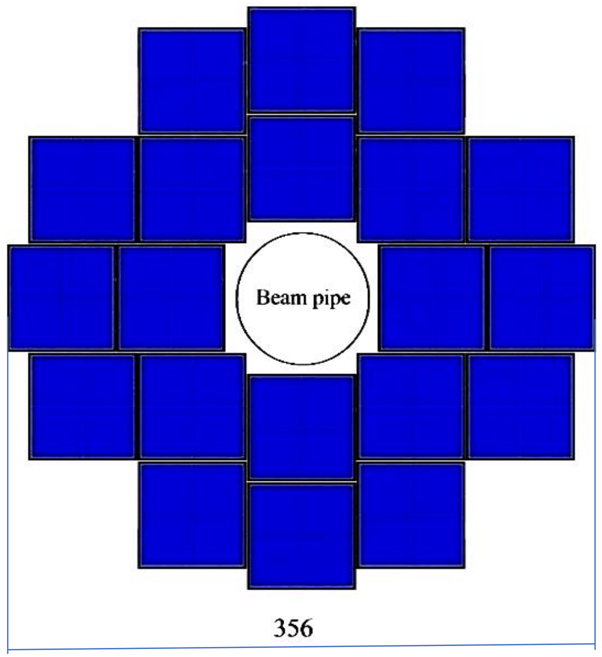
FFD sub-systems



A scheme of the FFD sub-systems

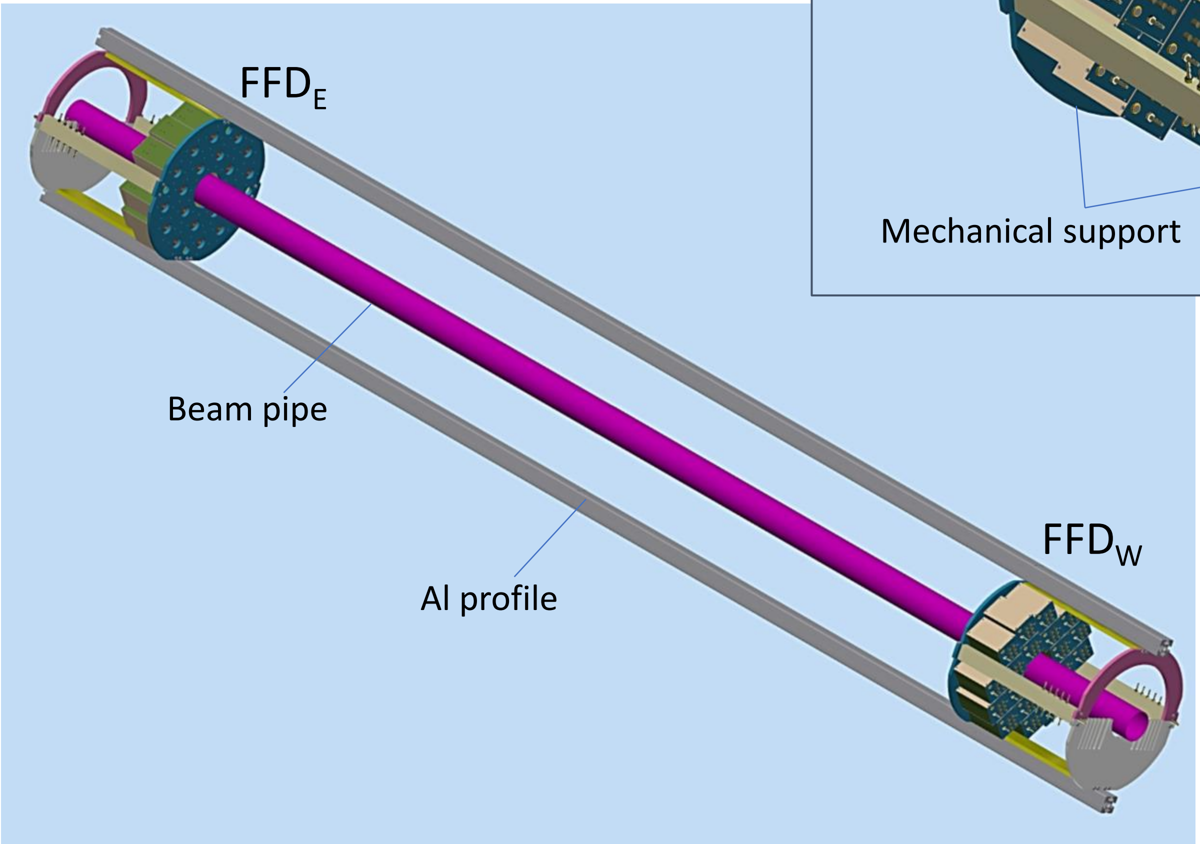
Concept of FFD

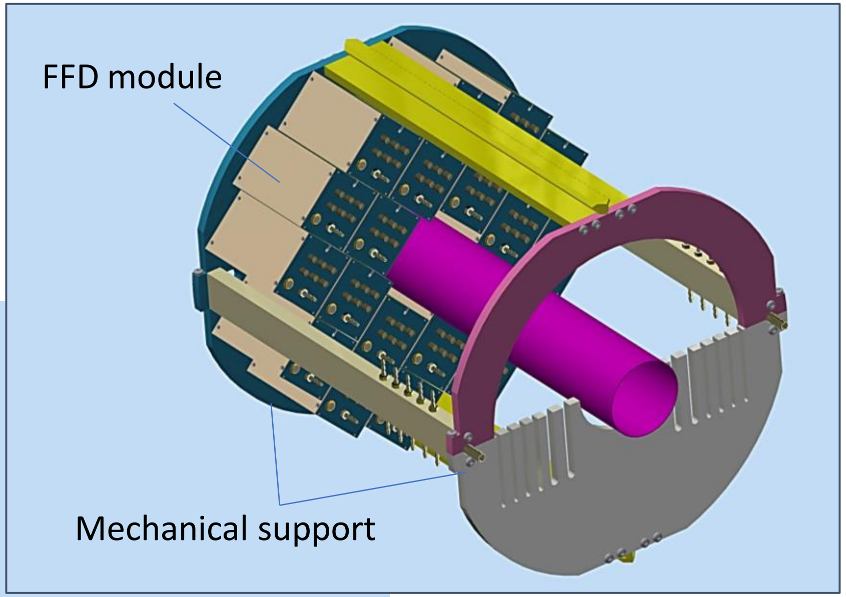




FFD – two arrays of Cherenkov detector modules
20 modules per array
80 +20 channels per array

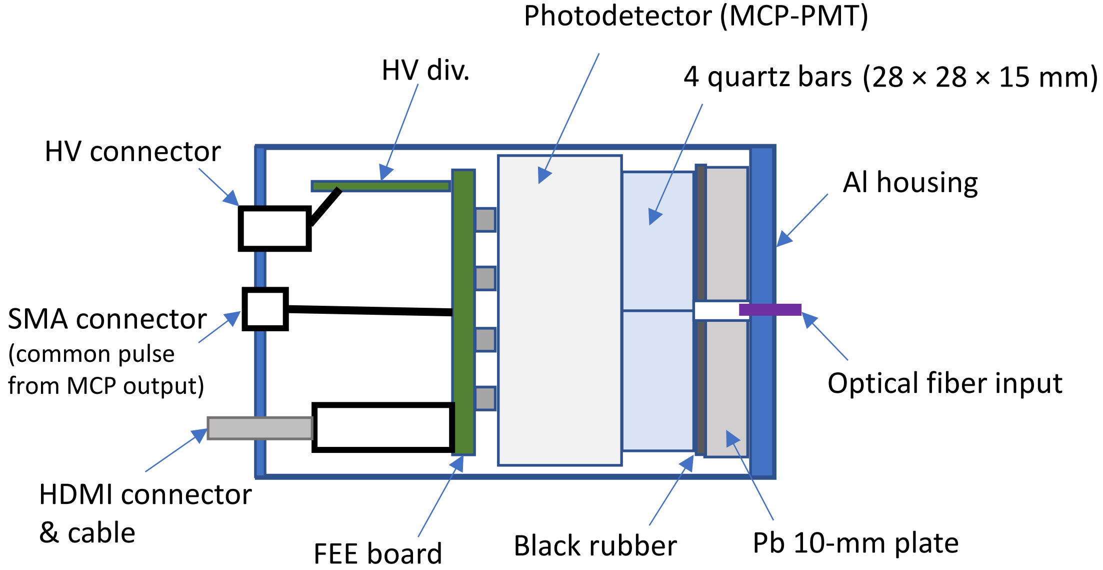
FFD design


FFD$_E$
Beam pipe
Al profile
FFD$_W$


FFD module
Mechanical support

FFD module

Module scheme



FFD module size: 64 × 64 × 110 mm^3

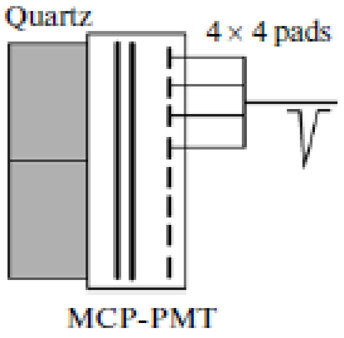
Quartz radiator size: 56 × 56 × 15 mm^3

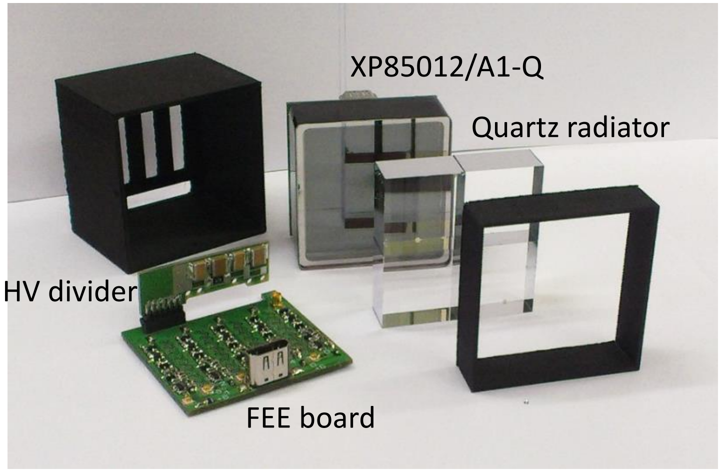
Occupancy: 76.6%

Photodetector

MCP-PMT
XP85012/A1-Q (S)

MCP output (com.)





Some elements of the FFD module

Study of FFD performance for Au + Au collisions

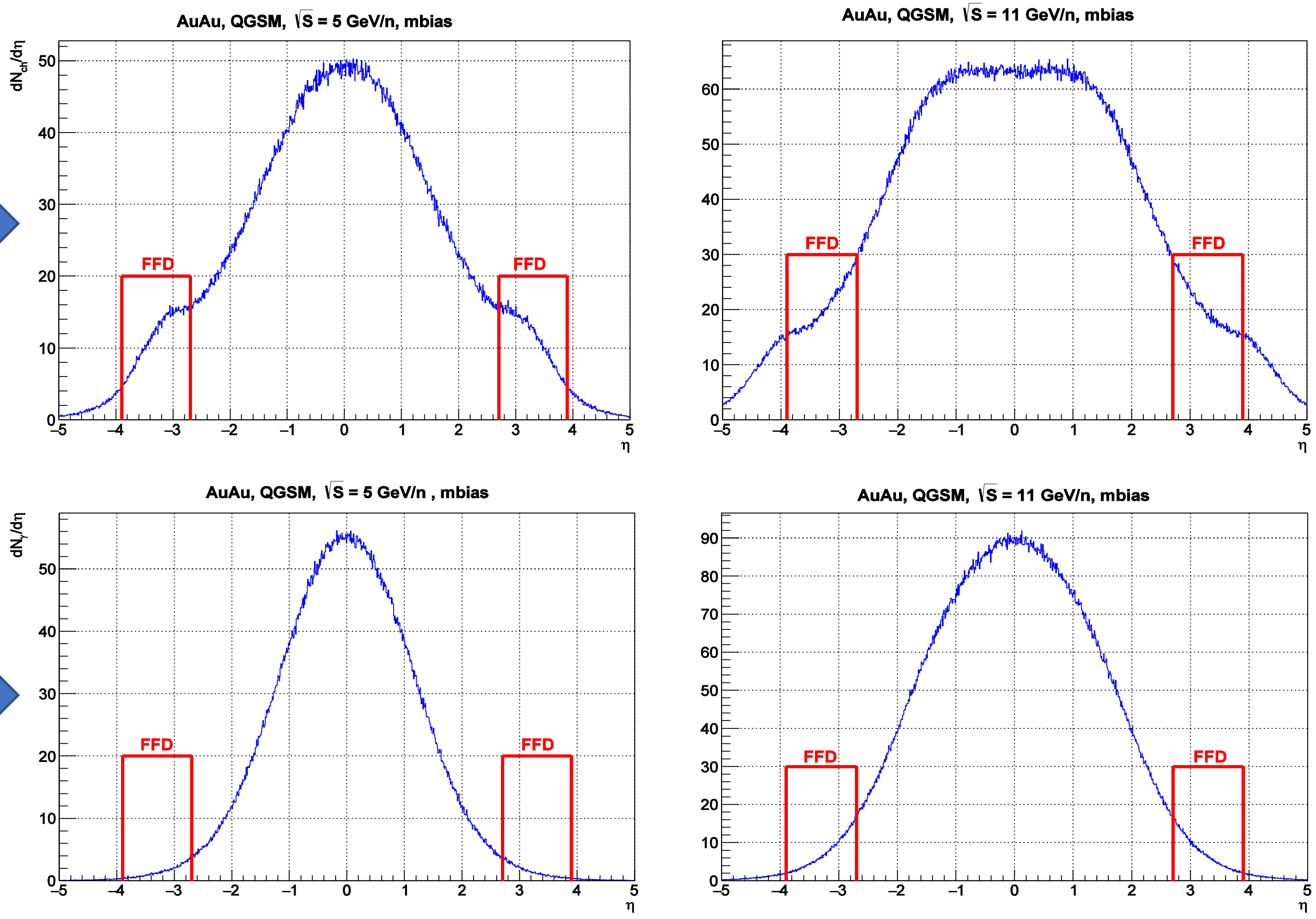
Particle distributions on pseudorapidity for Au + Au collisions (min. bias) at $\sqrt{s_{NN}}$ = 5 and 11 GeV

5 GeV

11 GeV

Charged particles

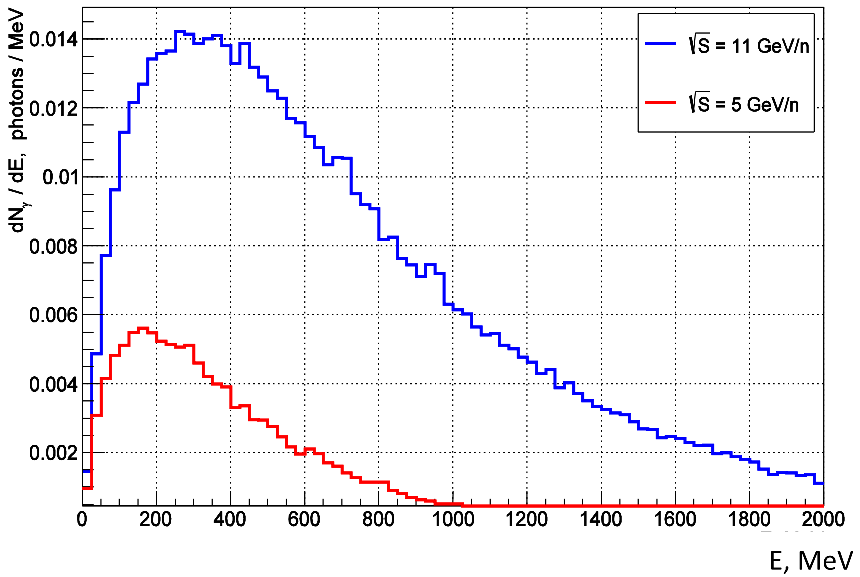
High-energy photons



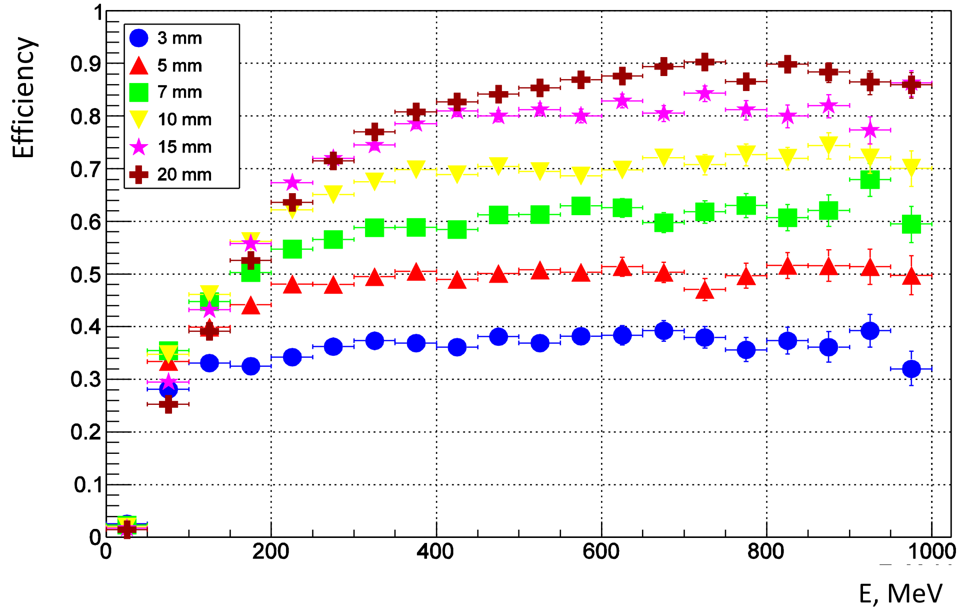
Simulation with QGSM + GEAN4 code *(S. Lobastov)*

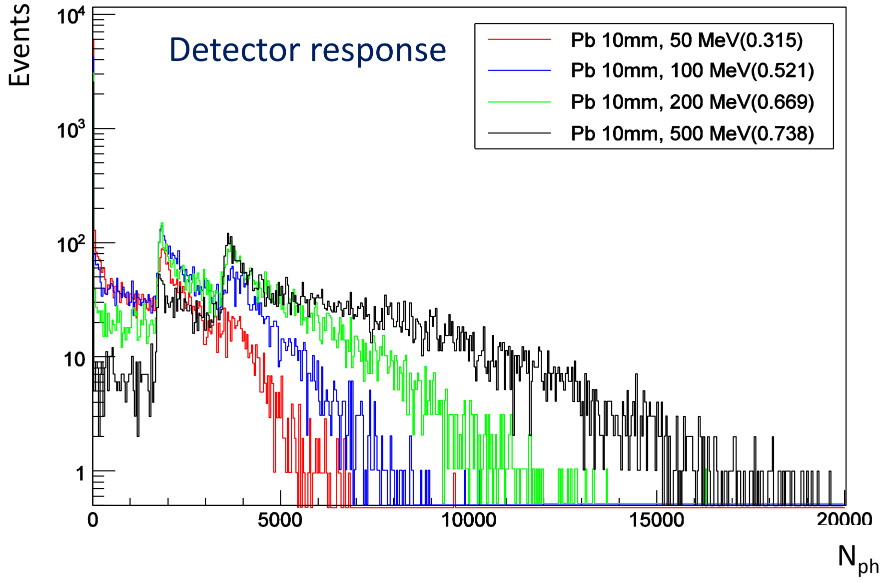
Detection of high-energy photons

Energy spectra of photons in Au+Au collisions



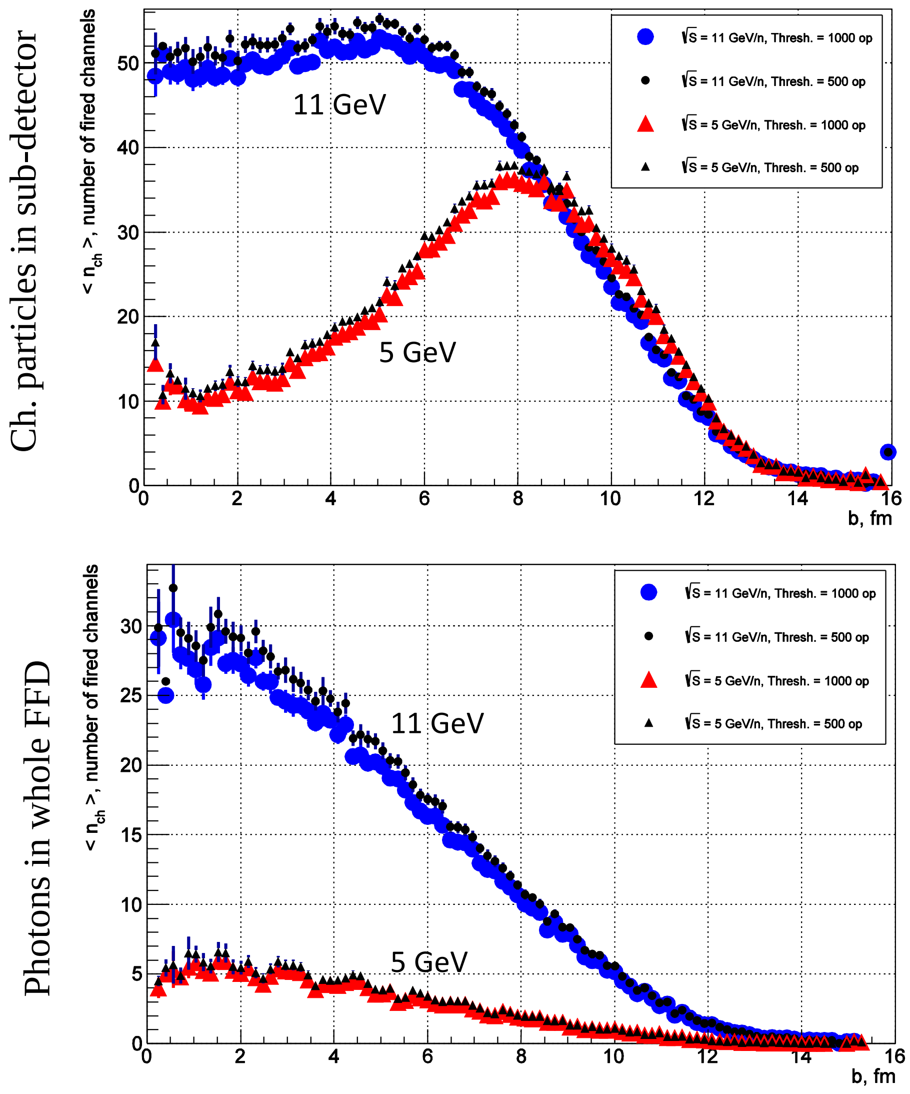
Efficiency of photon detection as a function of Pb-plate thickness

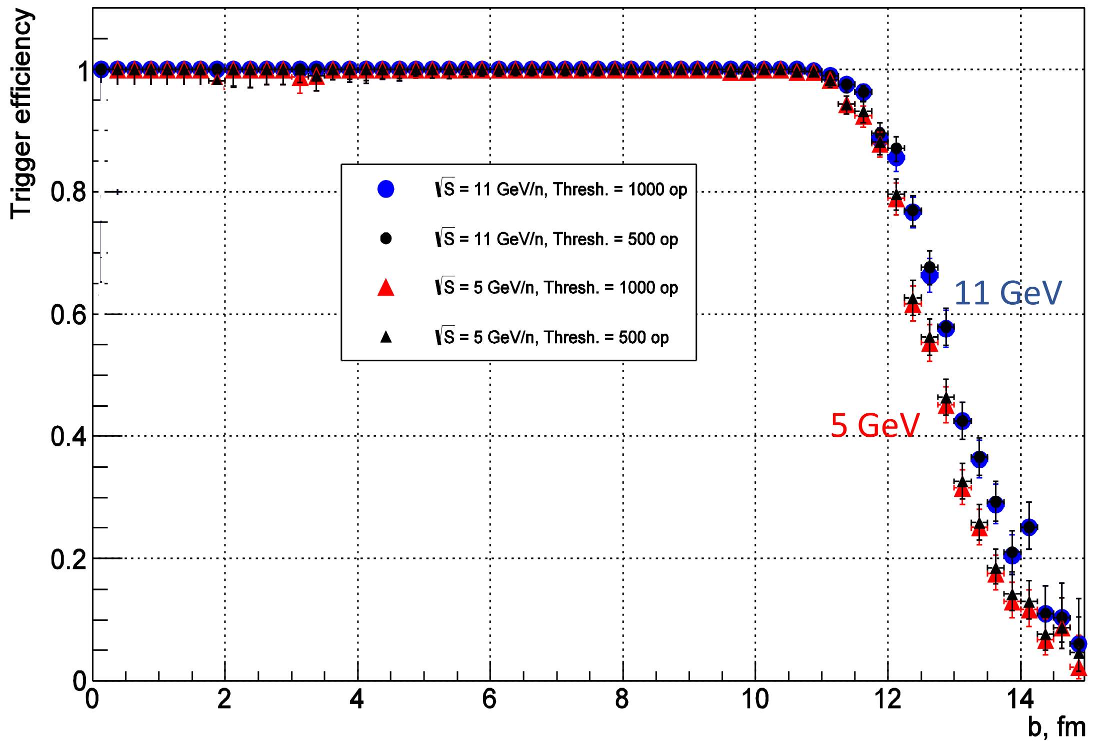




Distributions of Cherenkov photon yield in FFD module with 10-mm Pb plate induced by photons with different energies (50, 100, 200, and 500 MeV)

Detector efficiency for Au + Au collisions





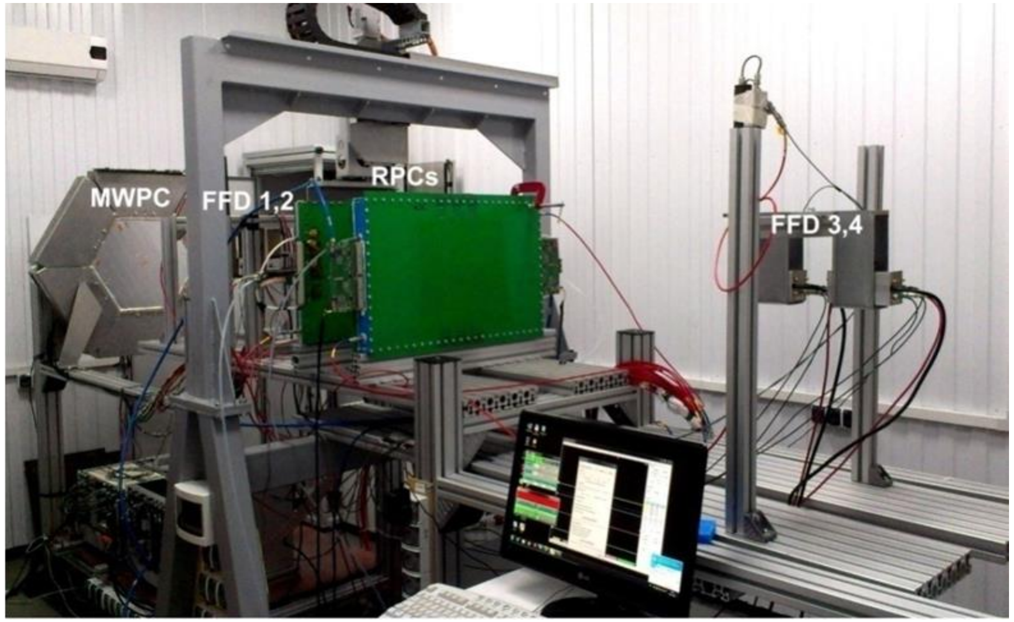
The mean number of fired channel for two threshold (500 and 1000 Ch. ph.)

Tests with prototypes

Module prototype

Tests with cosmic rays and LED

Tests with 3.5- GeV deuteron beam



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

Three types of readout electronics were used in the tests:

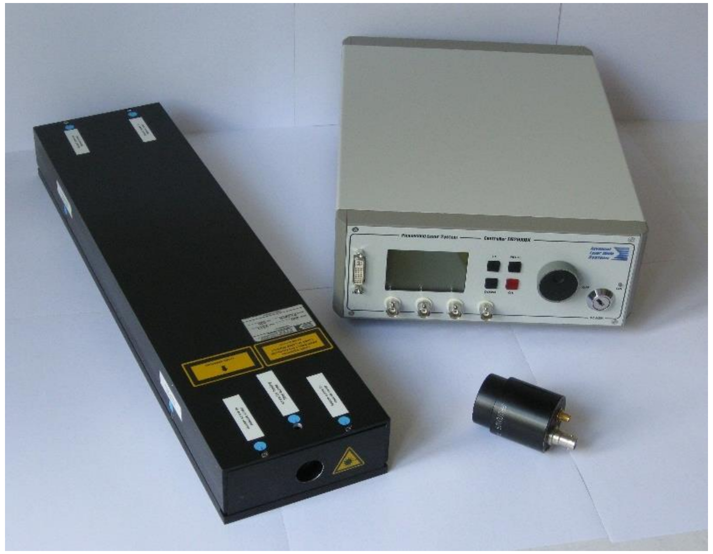
1. Evaluation Board DRS4 v5 (time jitter ~4 ps)
2. Digitizer CAEN mod.N6742 based on DRS4 chip (time jitter ~20 ps)

⇦ Analog pulses

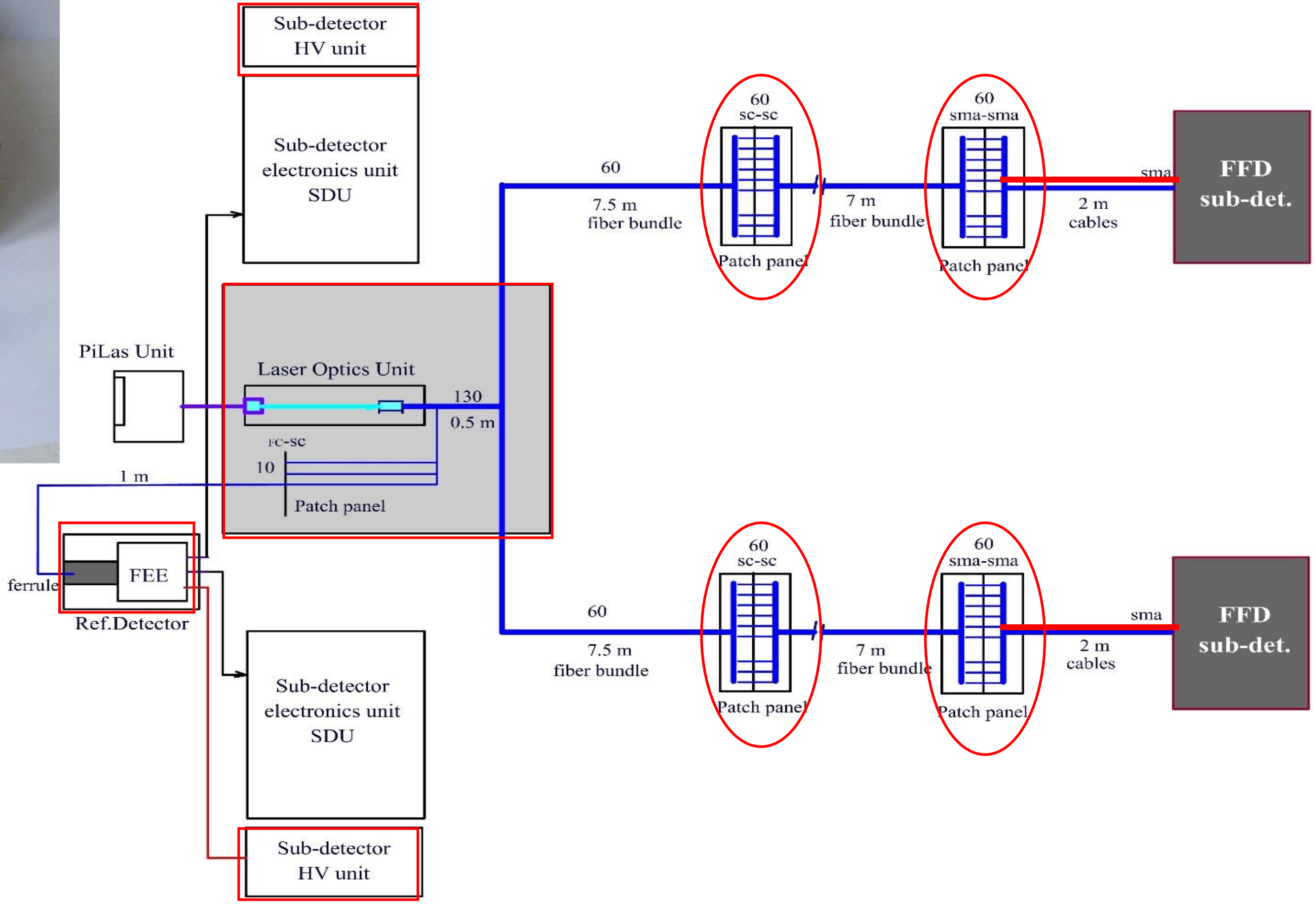
3. TDC72VHL based on HPTDC chip and produced at JINR (time jitter ~25 ps)

⇦ LVDS pulses

Laser system



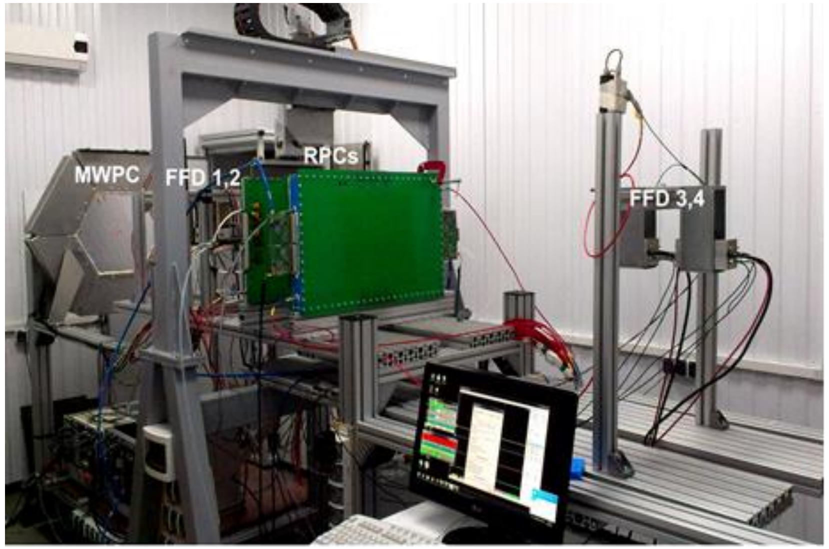
- PiLas laser
- Optical system
- MCP-PMT for reference detector
- Fiber bundles from Biolitec



Fiber type: WF 100/140/300N, NA=0.22

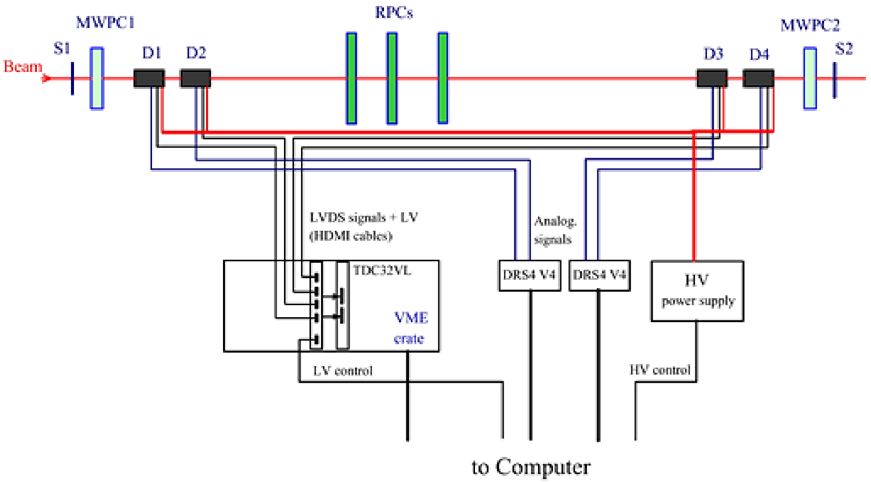
Beam Tests

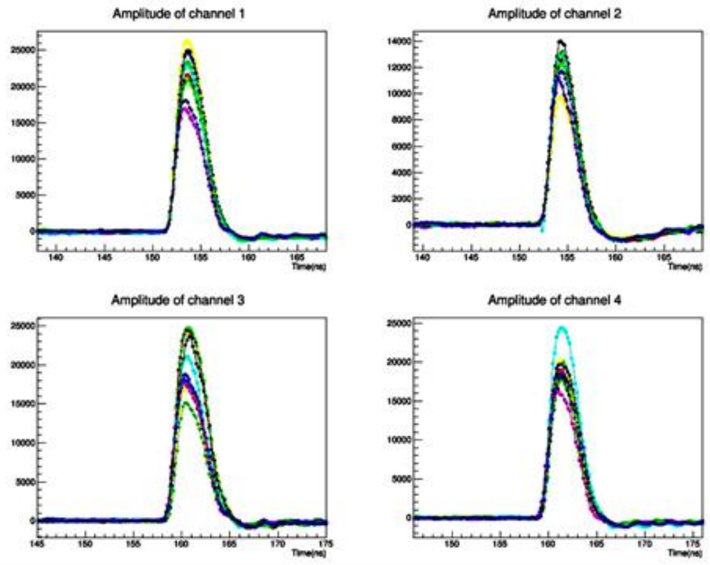
The experimental study of detector module performance was carried out with a 3.5-GeV deuteron beam of the Nuclotron



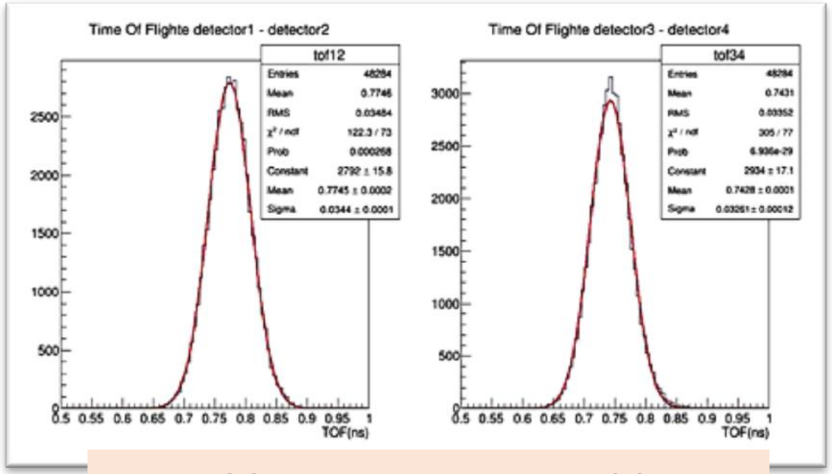
LVDS signals were fed to inputs of TDC32VL (VME)

Analog pulses – to two digitizers Eval. Board DRS4 V4





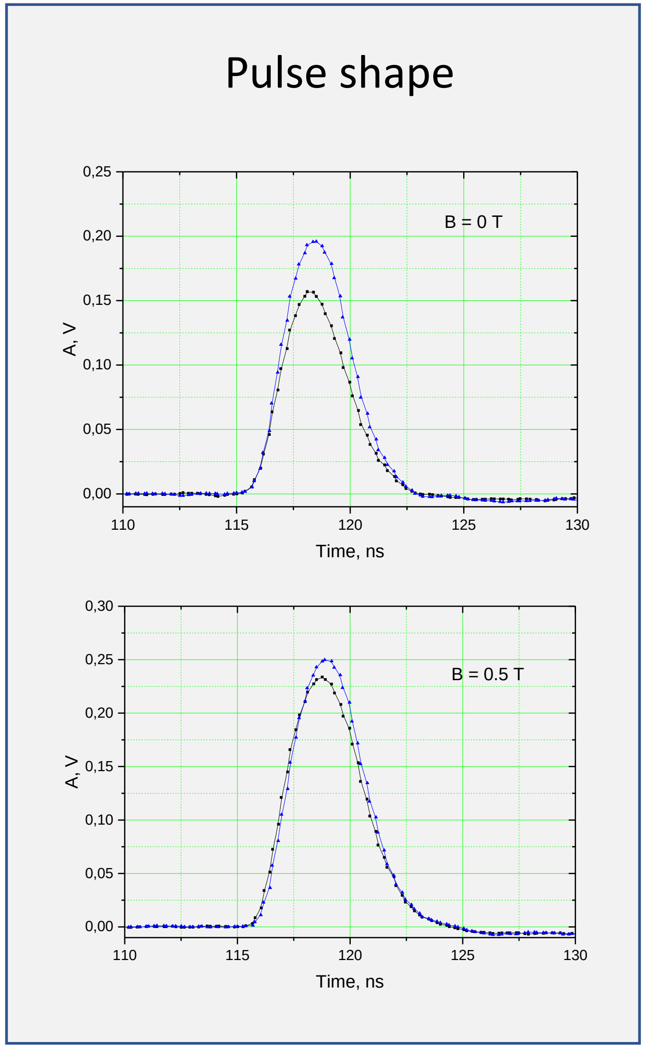
The pulses of FFD modules for 10 events measured with the digitizer Evaluation Board DRS4 V4



σ_{TOF} = 33 ps ⟹ $\sigma_{single\ det.}$ = 23.5 ps

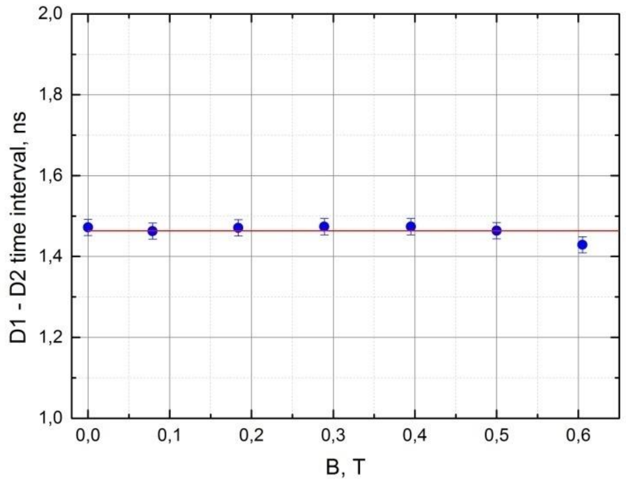
Tests in MF 2016

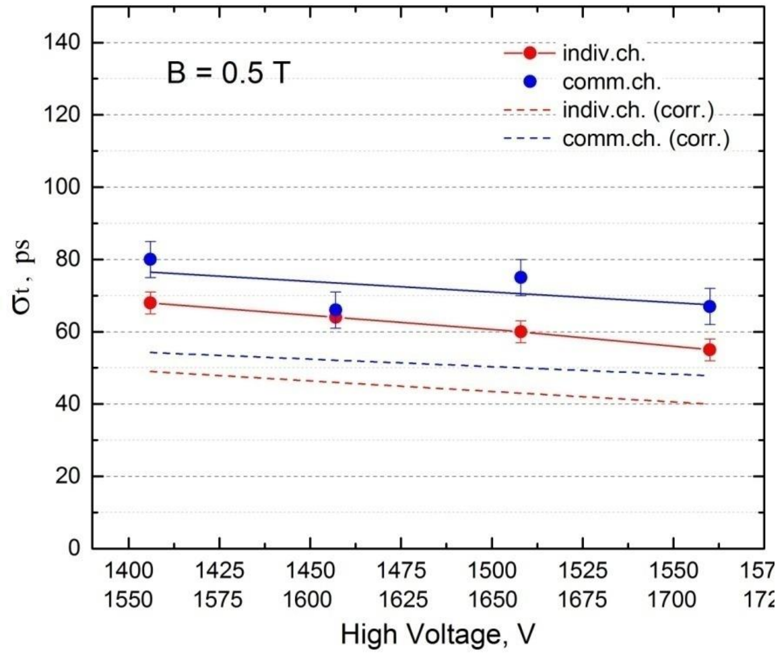
Tests in Magnetic Field of BM@N Magnet

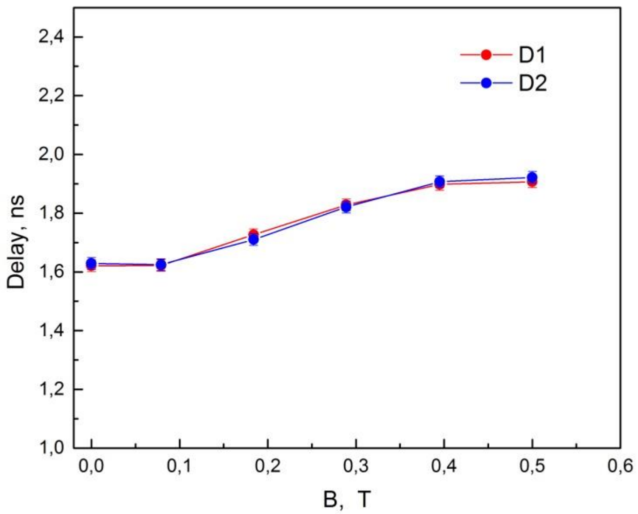


Conditions:

Magnetic field B = 0.5 T
FFD module orientation D2 – 0°, D1 – 180°
Pulses from generator + LED
Digitizer DRS4 v5 E.B.

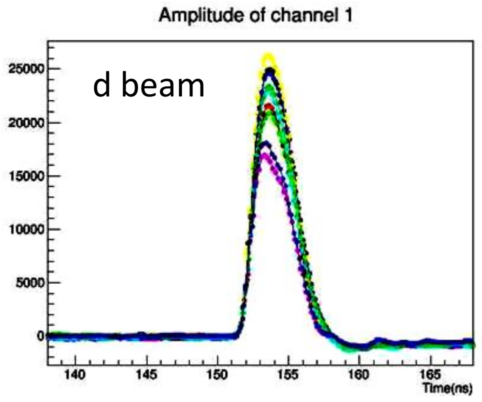




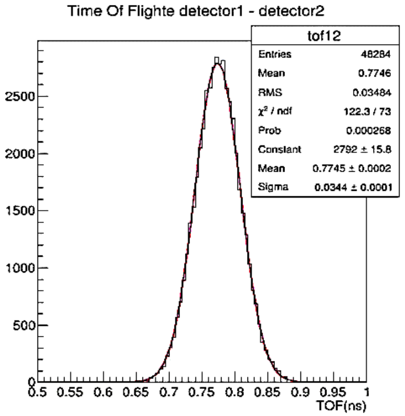


Time resolution

Ev.B. DRS4 readout

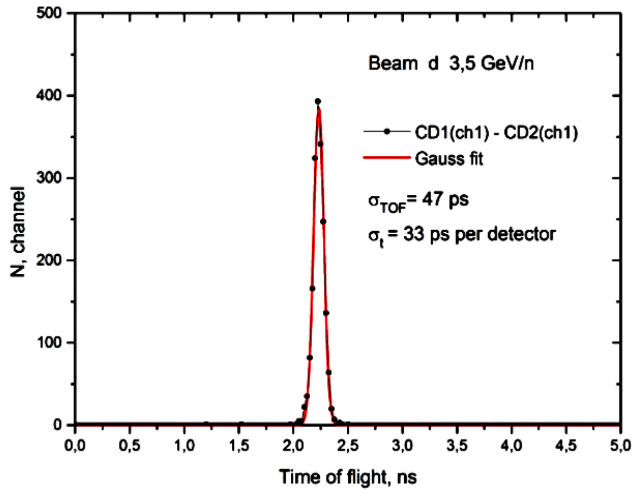


Typical pulses



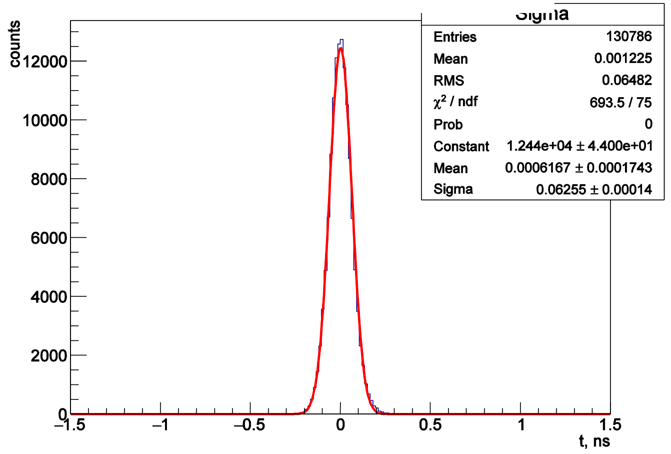
Time resolution (TOF)

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

Plans for next two years 2017 - 2018

- Production and tests of FFD modules
- Prototyping and production of FFD electronics
- Production and test of laser system
- Cable system
- Detector control system
- HV and VL system
- Local DAQ
- Design of FFD mechanics and installation into MPD

All expenses will not exceed the FFD budget

Status of FFD sub-systems

Sub-system	Available parts	2016	2017 - 2018
FFD sub-detector arrays	• XP85012/A1-Q (27 units) • Quartz radiators • FEE board (12 units) • Module prototypes (4 units)	• XP85012/A1-Q (20 units) • FEE board (20 units) • Module housing production • Detector mechanics design	• FEE board production (12 units) • Module housing production • Detector mechanics production
Electronics, cables, and power supplies	Electronics & cables prototype NIM crates (2 units)	Development of final version & tests	• Electronics and cable production • 24-ch. HV power supplies production (2 units)
Vertex electronics	Concept	R&D and tests	Production
Readout electronics			TDC72VHL production (4 units)
Laser calibration system	• PiLas laser + optical system • Reference photodetector + electronics • Optical fiber system	• Design of new fiber system • Tests	• Fiber system production • Tests
Detector control system	Concept	Development	Development, production, tests
Integration in MPD		Concept	Production of mechanics

Design of FFD integration in MPD mechanical structure depends on FFD position in MPD

Conclusion

The fast interaction trigger and T0 detectors, developed on a base of MCP-PMTs and SiPMs for MPD and BM@N experiments at JINR, provide the efficient trigger of nucleus - nucleus collisions and the T0 pulses for TOF detectors with ~ 30 – 40 ps resolution that corresponds to requirements to these systems.

The tests with C ion beam showed that the beam detectors with thin plastic scintillators provide both the picosecond time resolution and good pulse height resolution for selection of beam ions in trigger. Thus, in future runs with beams of high-energy nuclei, scintillators with thickness from 0.1 to 1 mm will be used in the beam counters.

Plan for next two years

- ✓ Production of FFD modules,
- ✓ Development of the Vertex-Trigger electronics and control system for MPD experiment,
- ✓ Development of trigger and detectors, electronics, and control system for BM@N runs with heavy ion beams,
- ✓ MC simulation of the detector performance