Status of the Fast Forward Detector

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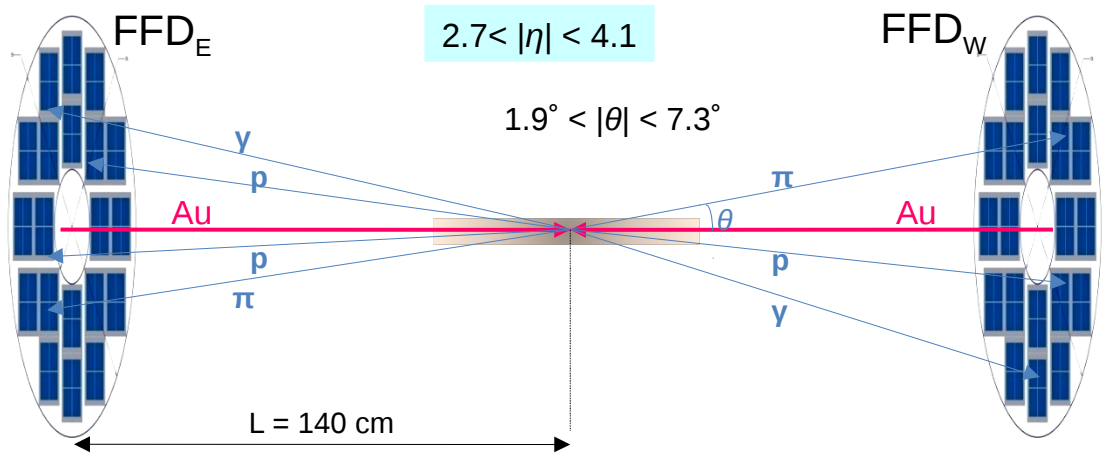
MPD Collaboration Meeting
Dubna, October 2018

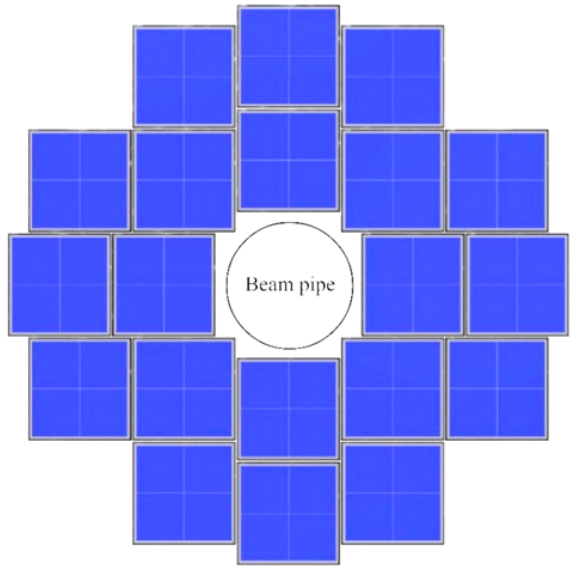
FFD aim and concept

- ✓ Fast interaction trigger by vertex with FFD_E and FFD_W pulses
- ✓ T0 pulse for TOF detector



A schematic view of the FFD

FFD sub-detector array
with 80-channel granularity



A front view of the FFD array

Timing

Start signal for TOF

$$\sigma_{FFD} = (\sigma^2_{\mathrm{mod}} + \sigma^2_{el} + \sigma^2_{readout} + \sigma^2_{meth})^{1/2}, \quad < 50 \text{ ps}$$

σ_{mod} – the resolution of FFD module itself,

σ_{el} – the contribution of FFD electronics and cables,

$\sigma_{readout}$ – the contribution of readout electronics,

σ_{meth} – the contribution of method used.

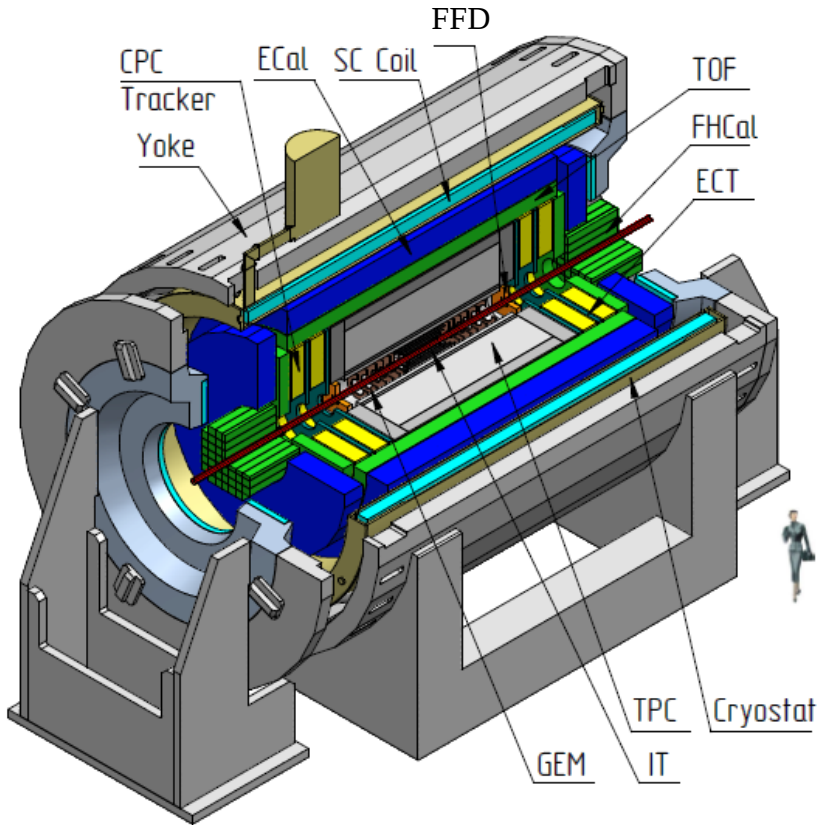
All contributions have been studied with beam and cosmic rays.

Fast interaction trigger (vertex trigger)

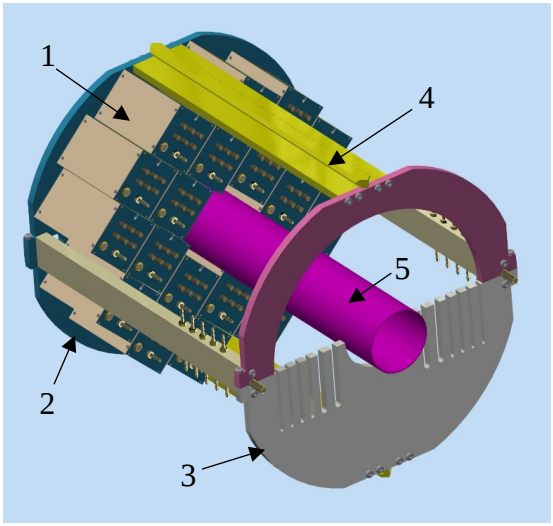
Fast measurement of $\Delta t = t_E - t_W$ ==> Z position of IP

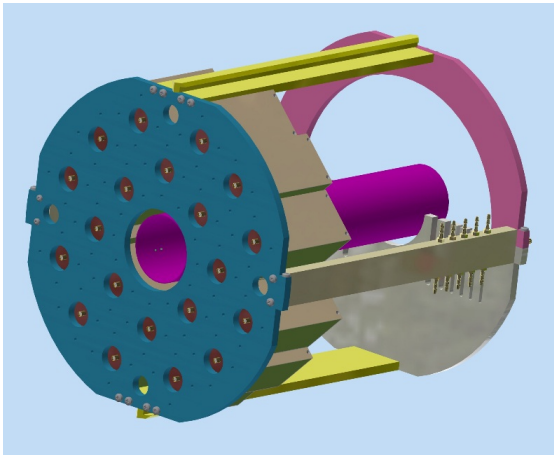
expected vertex time resolution is ~100 ps (sigma) corresponds to
~ 3 cm resolution in *Z* position.

FFD in MPD setup



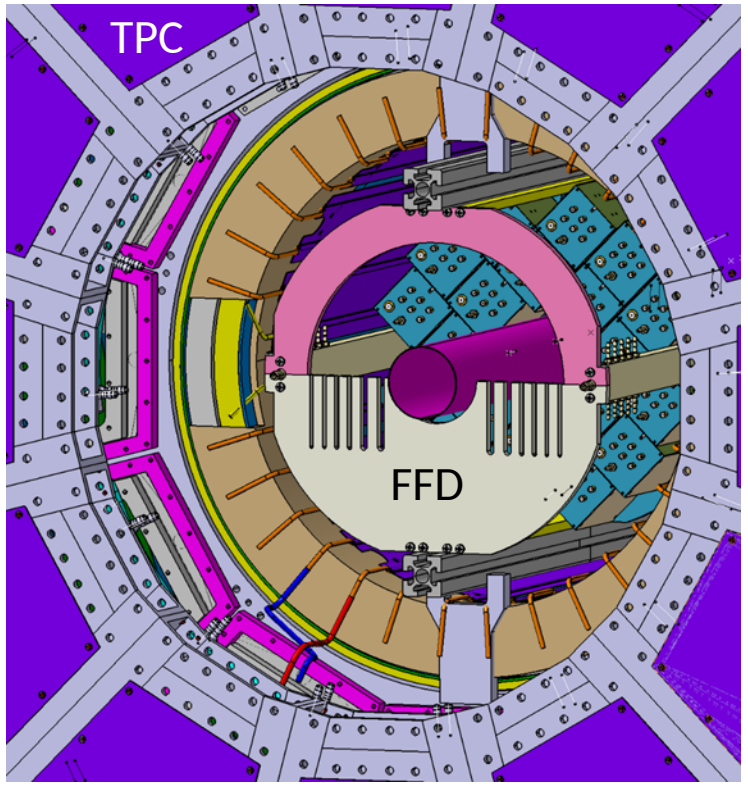
The FFD layout in the MPD setup





1 – the modules, 2 – the mechanical support of modules, 3 – the mechanical support of cables, 4 – the support of sub-detector assembly, 5 – the beam pipe

FFD design (Draft)



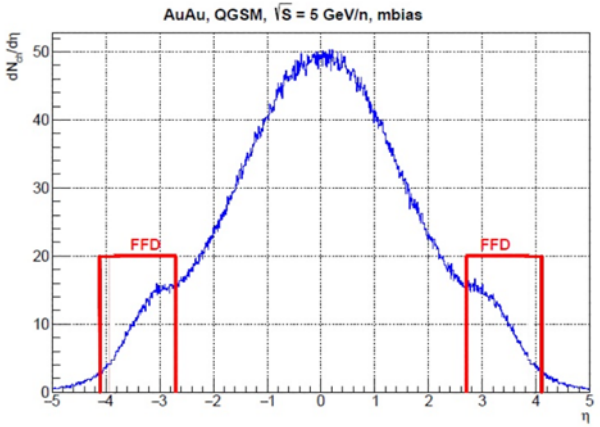
Study of FFD performance

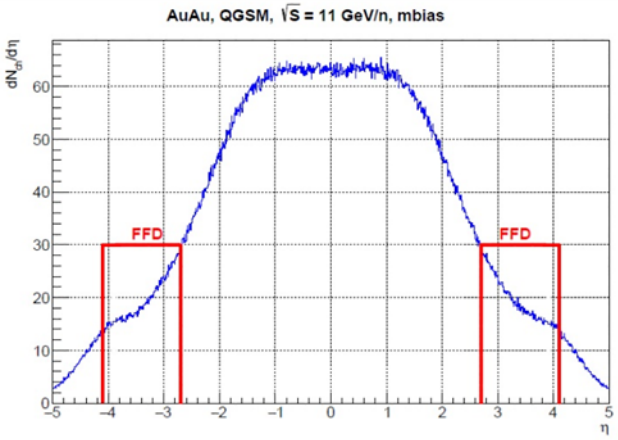
S. Lobastov

MC simulation

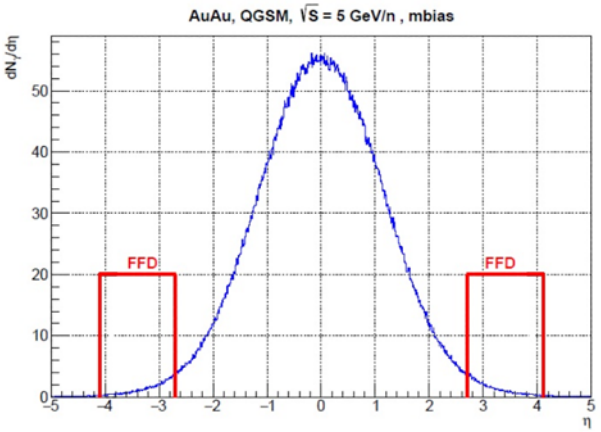
Au + Au collisions (min. bias)

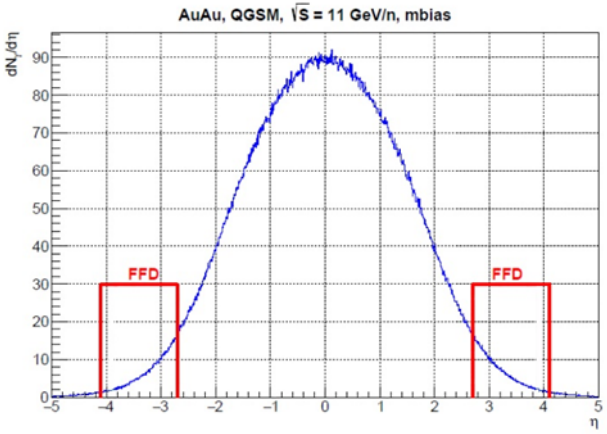
charged particles



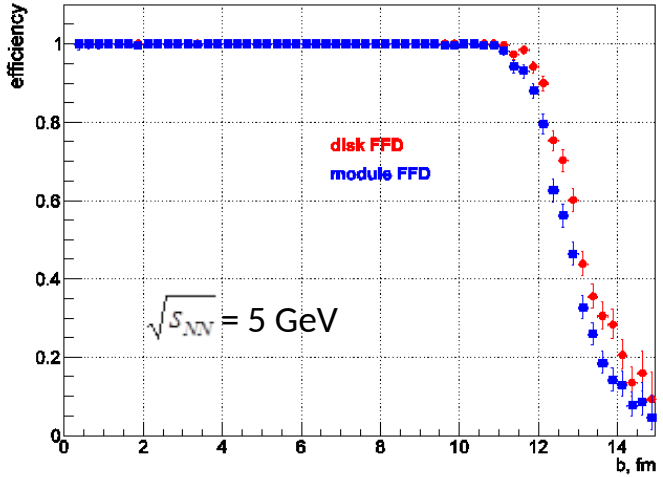


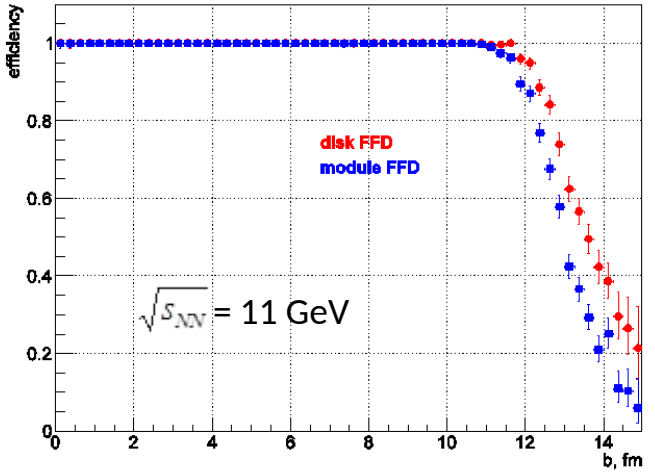
high-energy photons



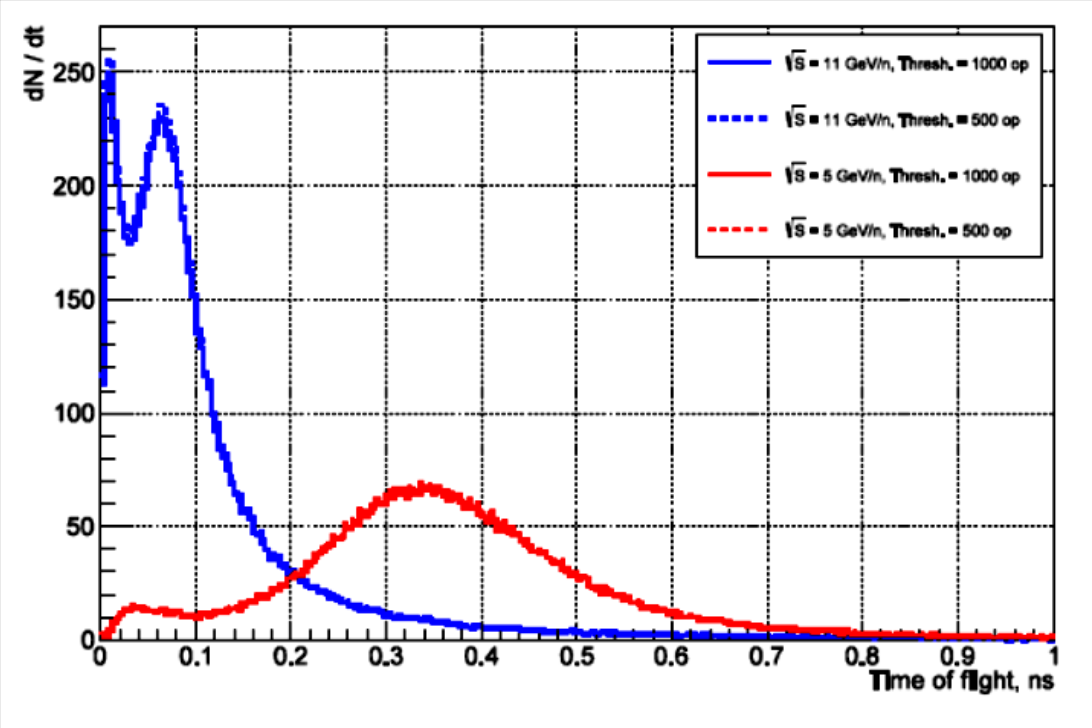


The vertex-trigger efficiency for Au + Au collisions



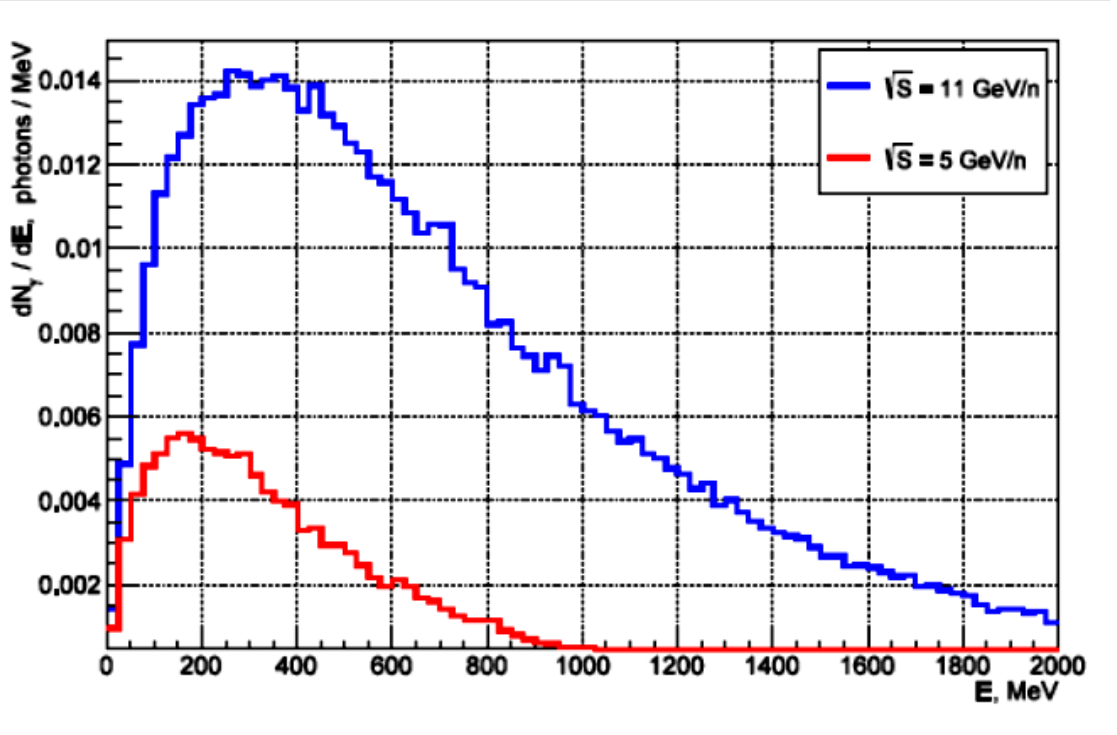


Ch. particle timing



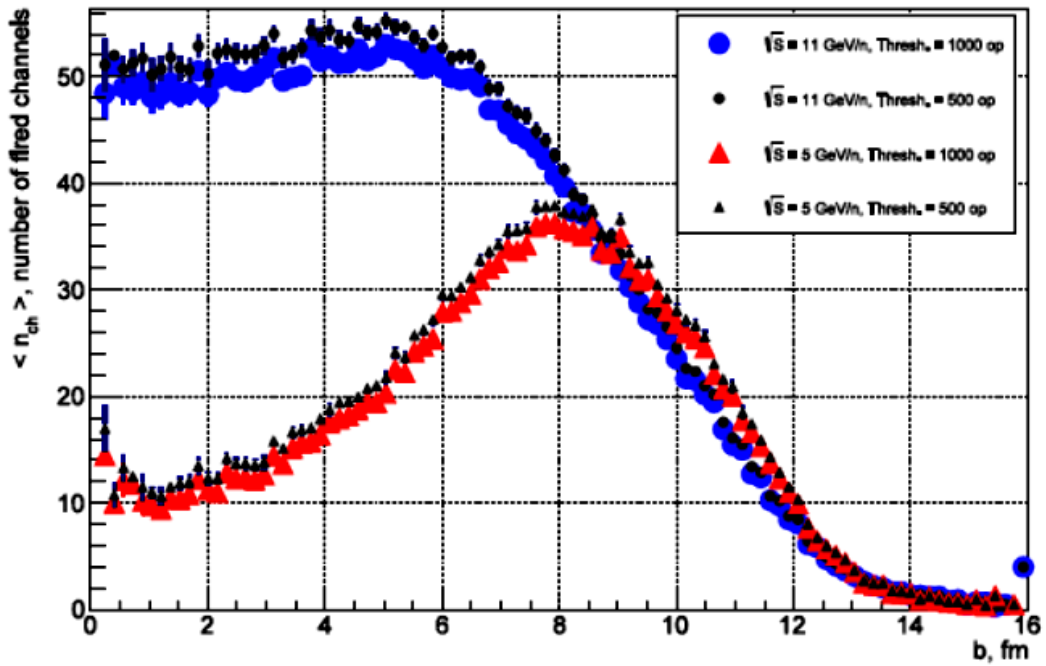
The delay of charged particle arrival in FFD modules in comparison with arrival time of photons for Au + Au collisions at $\sqrt{s_{NN}}$ = 5 (red) and 11 (blue) GeV
the solid curves – the threshold of 1000 Ch. photons,
the dashed curves – the threshold of 500 Ch. photons.

Photon energy spectra



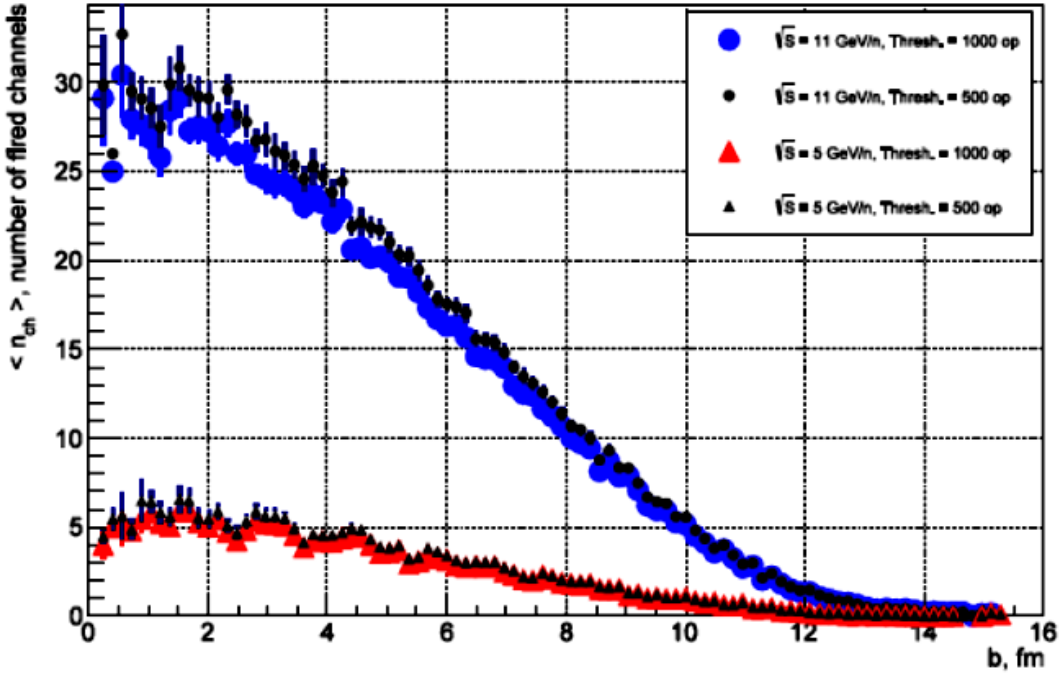
Energy spectra of the photons emitted into the FFD acceptance in Au + Au collisions at $\sqrt{s_{NN}}$ = 5 and 11 GeV.

Multiplicity of ch. particles detected in FFD



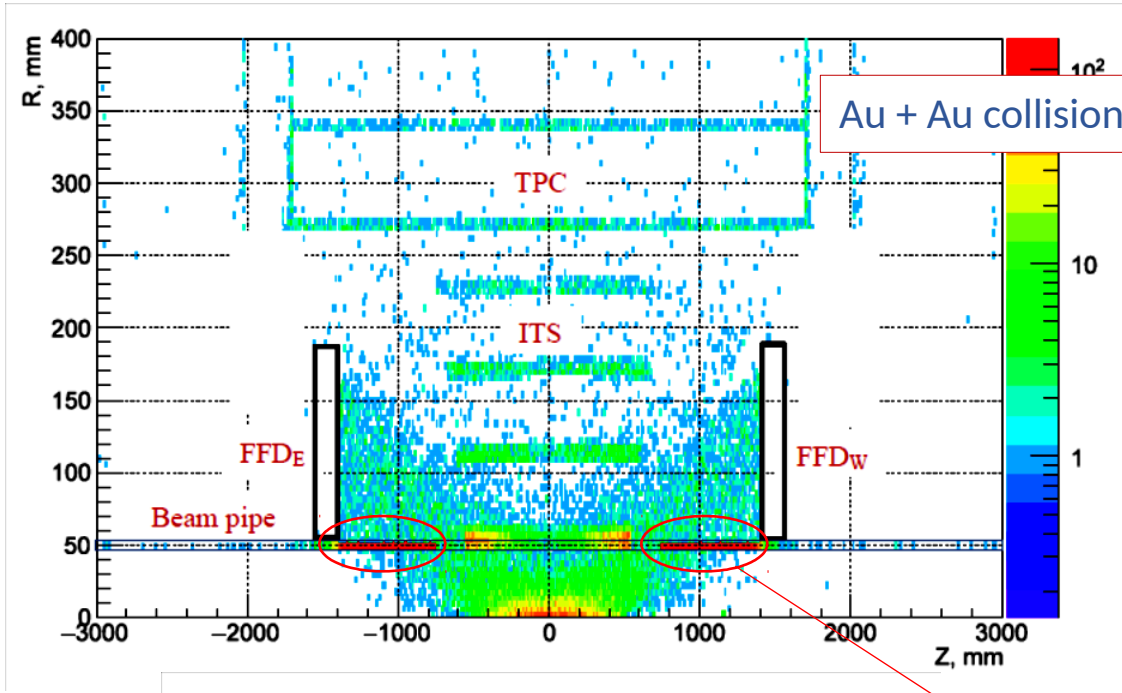
The mean number of detected charged particles in a single FFD array as a function of the impact parameter of Au + Au collisions for two energies $\sqrt{s_{NN}}$ = 5 and 11 GeV and two thresholds of 500 and 1000 Ch. photons.

Multiplicity of photons detected in FFD

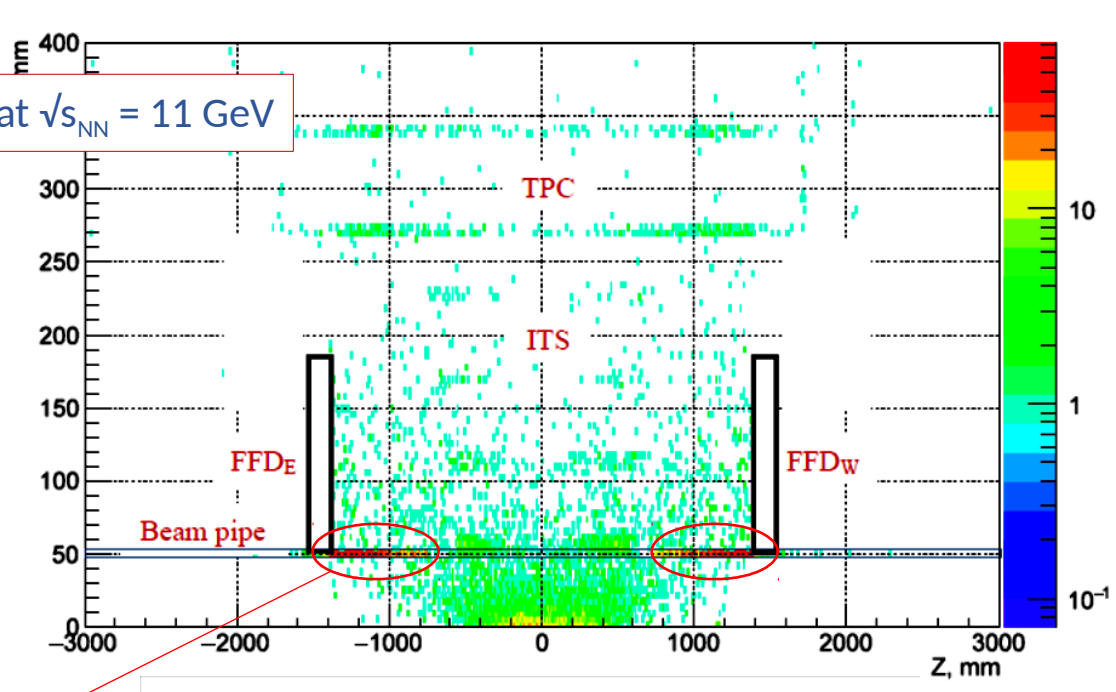


The mean number of detected photons in whole FFD as a function of the impact parameter for the same conditions.

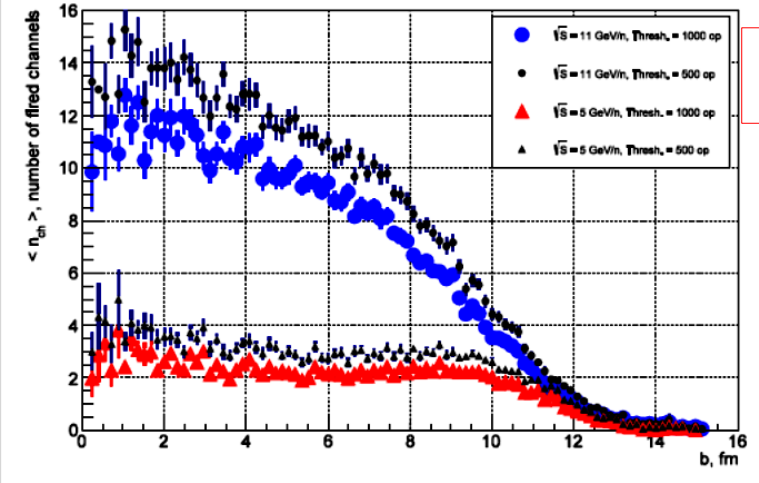
Background in FFD



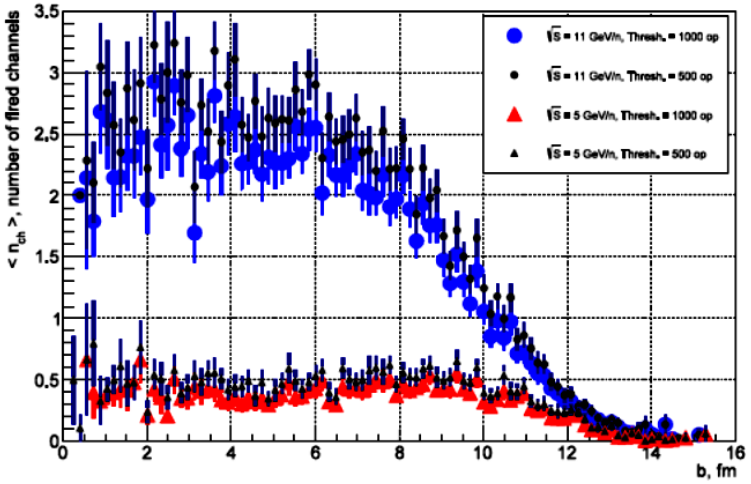
Au + Au collisions at $\sqrt{s_{NN}}$ = 11 GeV



Main source is interactions with vacuum tube (1mm Al)



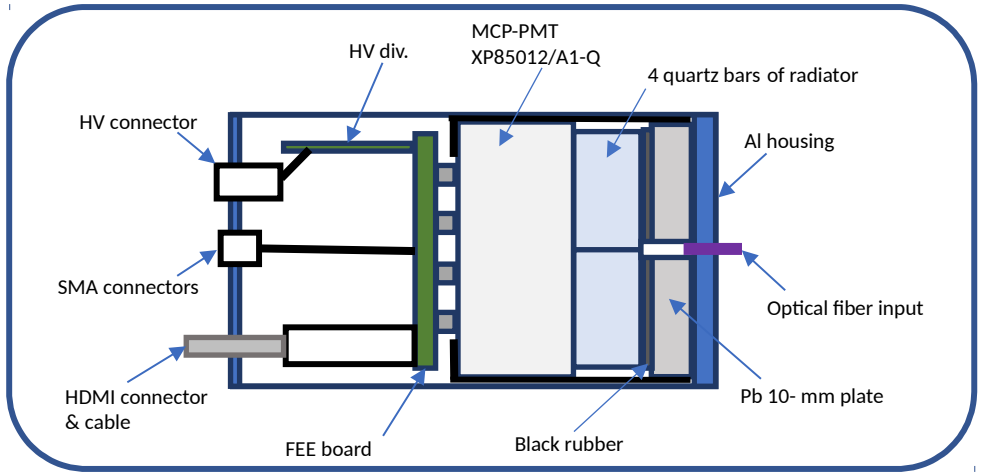
Background charged particles detected in FFD modules for minimum bias Au + Au collisions at $\sqrt{s_{NN}}$ = 11 GeV.



The same as but for background photons.

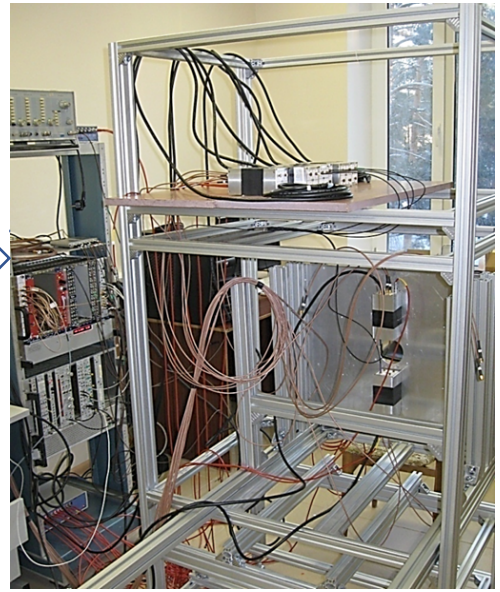
FFD modules

Several module prototypes were produced and tested in 2014 – 2016
with beam of Nuclotron and cosmic muons



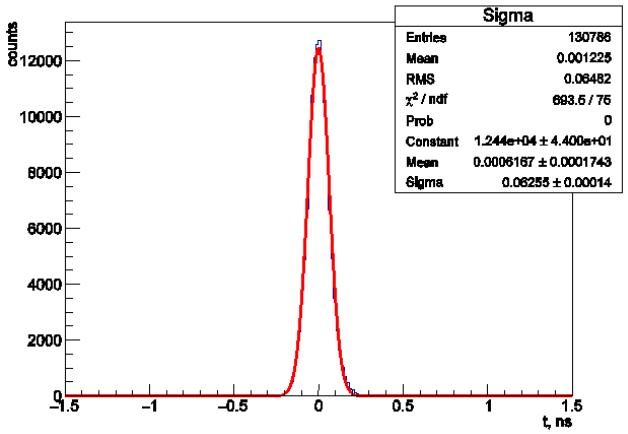
A scheme of the FFD module

Testing of module prototypes
in laboratory

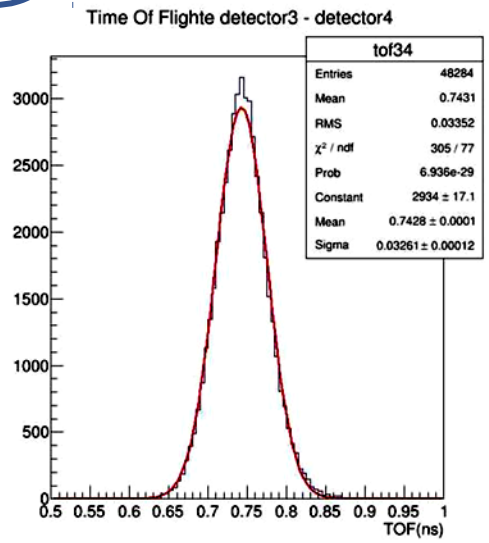


Time resolution of individual channel of FFD module + cables + electronics $\sigma_t \approx 44$ ps

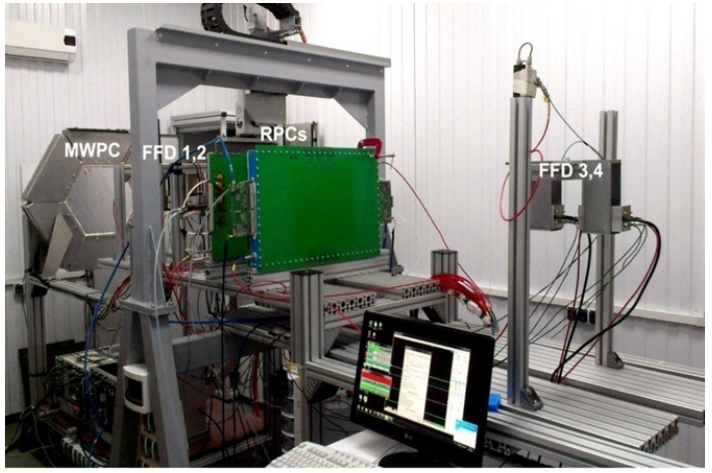
Measurements with two FFD modules



Test with TDC72VHL readout, realistic
chain of cables and electronics



Test with DRS4 digitizer



Measurement with 3.5 GeV/n deuterons
MPD-test area

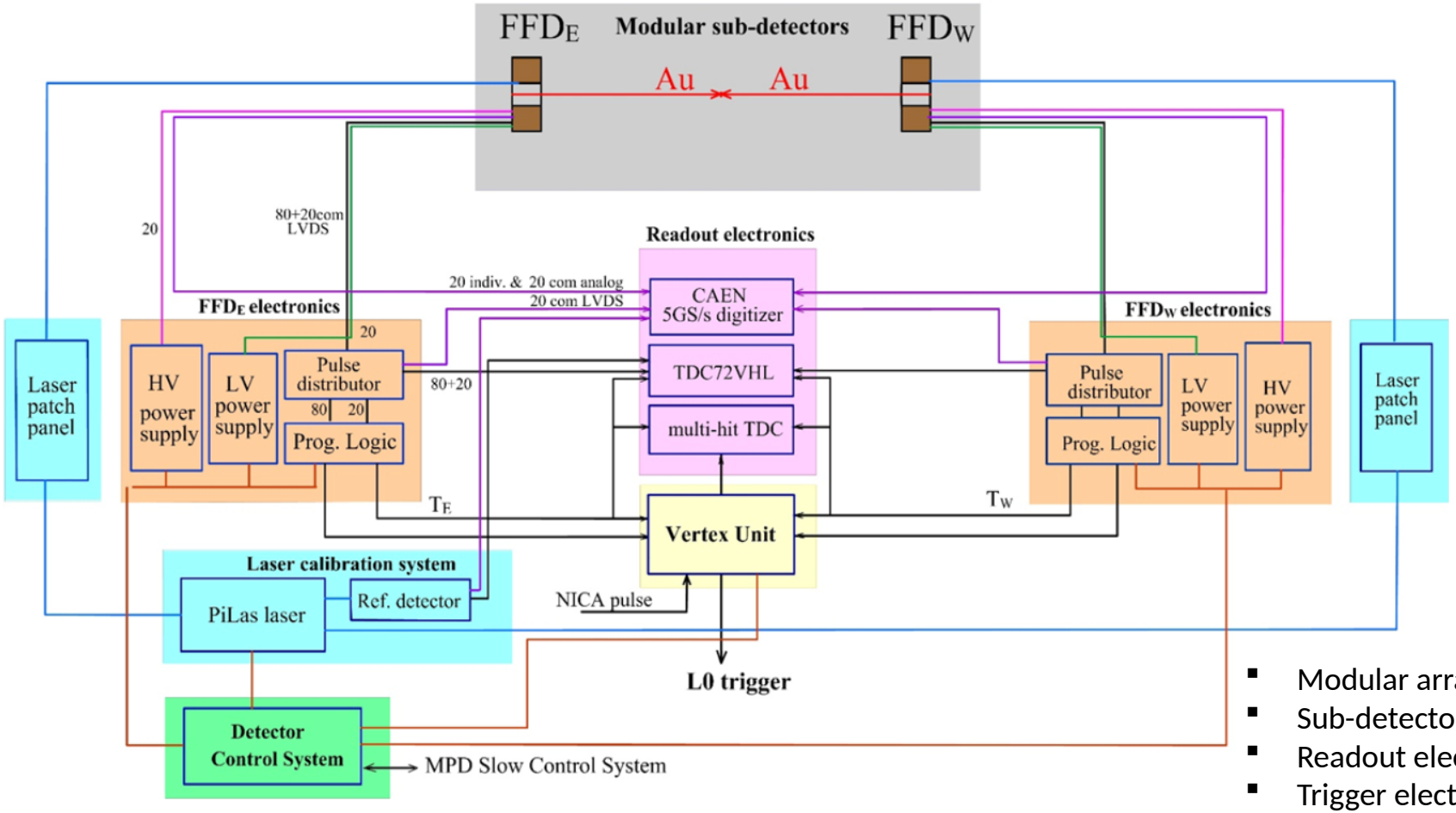
Plan of module production

- ❑ 2018 - final design and tests
- ❑ 2019 - production of
  - ✓ Module mechanics
  - ✓ Front-end electronics
  - ✓ Lead converters
  - ✓ Assembly of modules
  - ✓ Test with cosmic muons and laser
- ❑ 2020 - tests of modular arrays with cosmic muons and laser

Existing elements

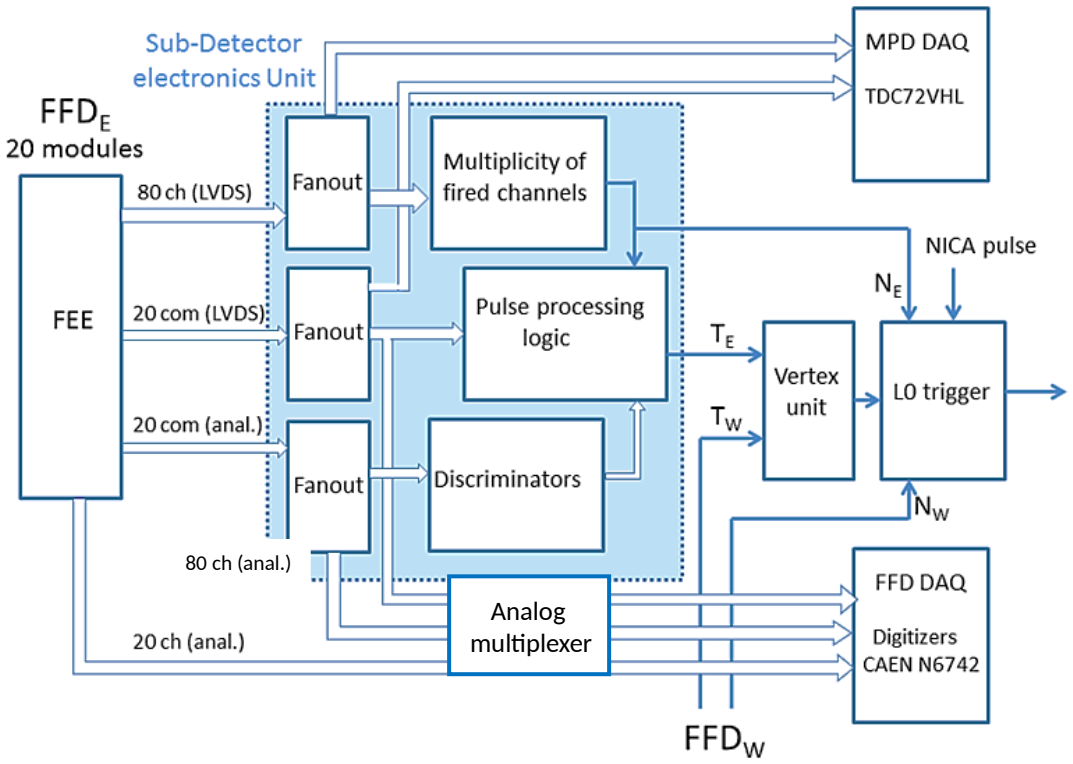
- All MCP-PMTs XP85012
- All quartz radiators
- Optical grease

FFD electronics structure



- Modular arrays of sub-detectors
- Sub-detector electronics & power supplies
- Readout electronics
- Trigger electronics
- Laser calibration system
- Detector control system

Sub-Detector trigger electronics



Block-scheme of the FFD electronics

The electronics of FFD pulses processing consists of

- East and West branches of Sub-Detector electronics Units (SDU)
- Vertex Unit (VU) and L0 trigger module
- Readout electronics of MPD DAQ (main)
- FFD DAQ (local)

The FFD electronics is located in a special rack outside the MPD magnet.
The length of cables from FFD array to the electronics is approximately 8 m.

The SDU has a modular structure.
Altera Cyclone V GX FPGA used for trigger signal preprocessing and for individual channels data processing.

Plan

2018 - final design, testing

2019 - production and testing

2020 - production and testing

Readout electronics

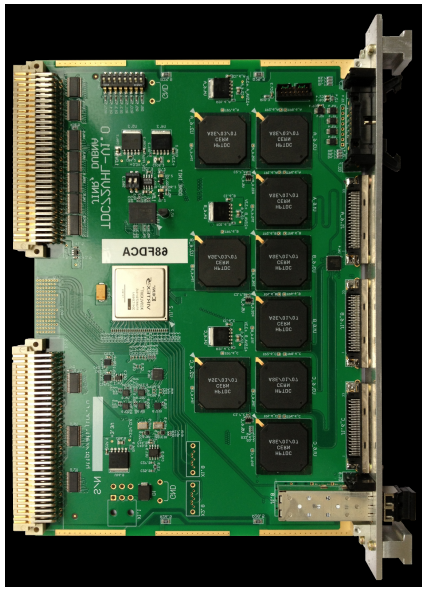
Main DAQ readout electronics

The main readout electronics of FFD and TOF detectors
is based on TDC72VHL (25 ps multi-hit time stamping TDC)
LHEP/JINR.
Each FFD sub-detector has 100 LVDS channels plus
2 channels for calibration and it requires 2 TDC modules.

Status:

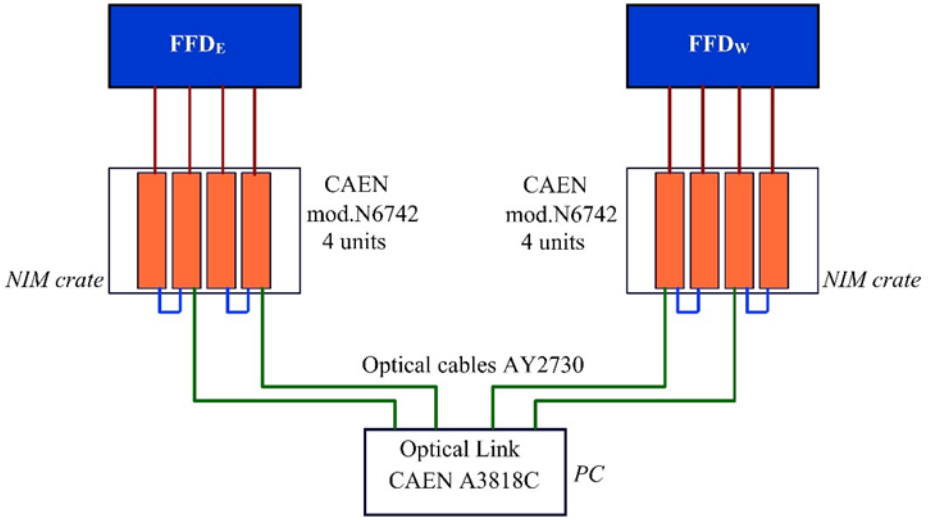
2018 - 2 modules were delivered
for tests with cosmics

2019 - purchase of 4 units



Readout electronics of local control

Local DAQ is based on 5 GS/s 16-inputs digitizers CAEN mod. N6742



A scheme of FFD local DAQ

CAEN mod. N6742 digitizer

Status: All digitizer modules were delivered in 2018

High voltage and low voltage power supplies

HV power supply for MCP-PMTs of FFD modules

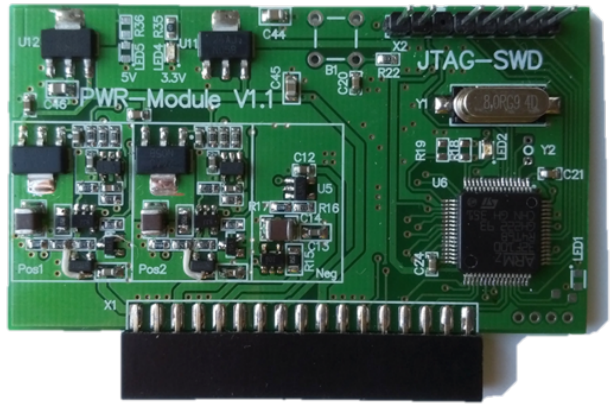
To provide HV power a high voltage system produced by ISEG and WIENER companies (Germany) is used.
It consists of three 16-channel modules with multiple floating ground and controller module.

A view of the 16- channel HV module and HV crate

Status: The system was delivered in 2018

LV power supply for FFD module FEE

The first prototype of LV power supply has been assembled and successively tested



A view of the LV power supply board.

Status:

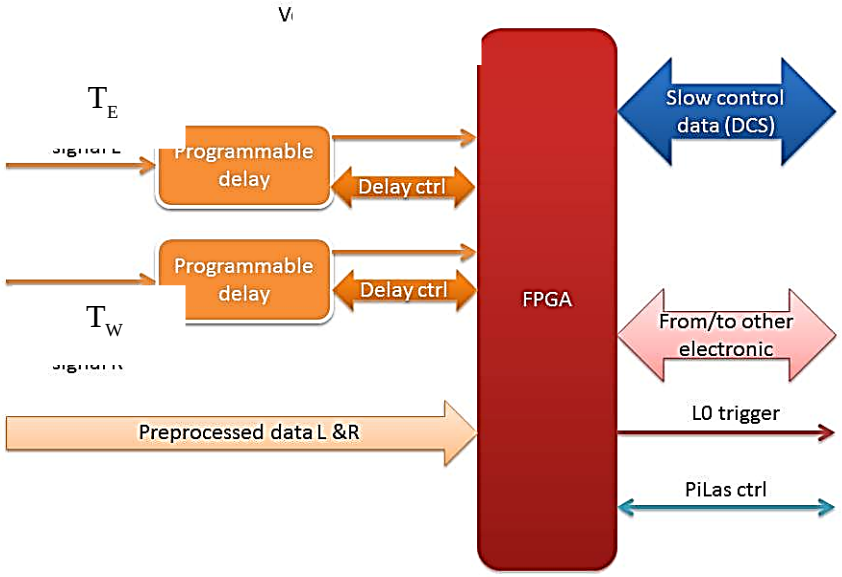
2018 - prototyping

2019 - production

Electronics of fast interaction trigger

The FFD is the main detector providing fast interaction trigger for nucleus – nucleus collisions in center of the MPD setup by fast vertex analysis of signals generated by FFD_E and FFD_W .

The Vertex Unit (VU) uses preprocessed data coming from both SDUs (SDU_E, SDU_W) and has a modular structure.



Block-diagram of the VU

Status and plan:

2018 - <u>Now we are in the stage of prototyping.</u>
The prototype is based on programmable delay chip IC SY89295 or IC854S296I-33 which provides quite stable adjustable delay in a range from 3.2 to 14.8 ns with 10-ps step and a small time jitter.

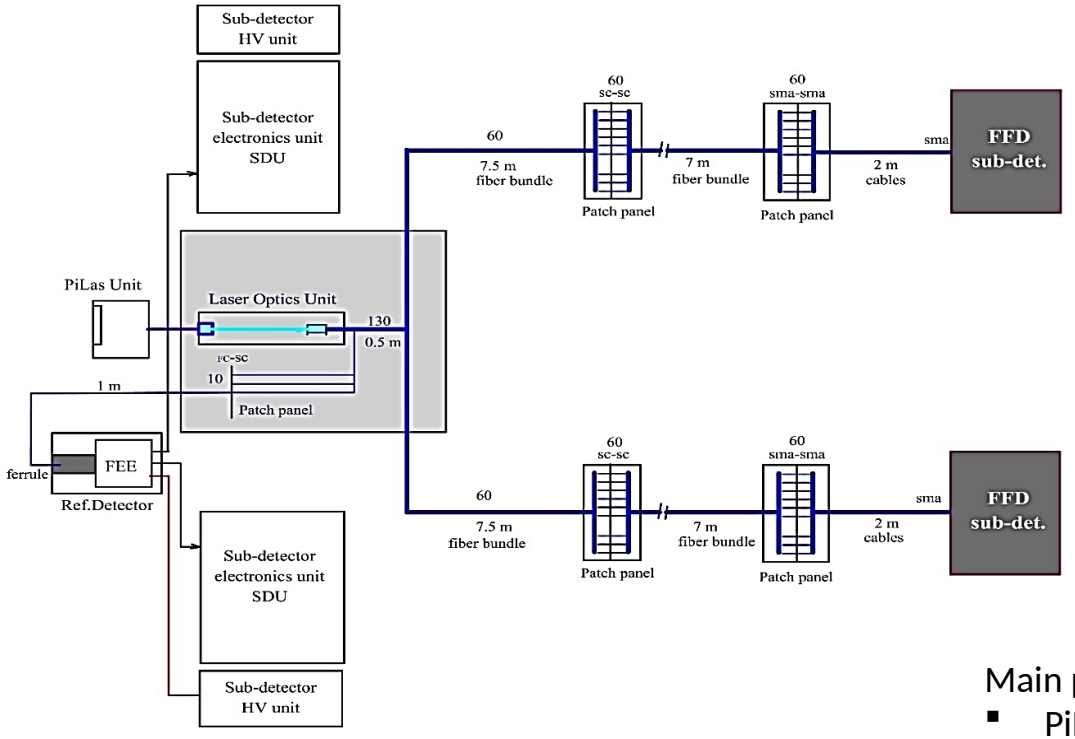
2019 - Prototyping and testing

2020 - Final design, production, and tests

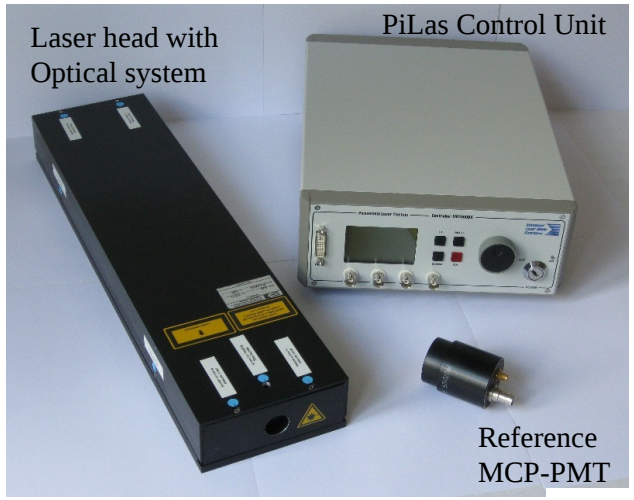
Laser calibration system

1) precision time calibration of FFD channels
2) monitoring the detector operation

Based on PiLas laser with 30 ps pulse width and 405 nm wavelength. The laser and optical system were produced and delivered by Advanced Laser Diode Systems (Germany).



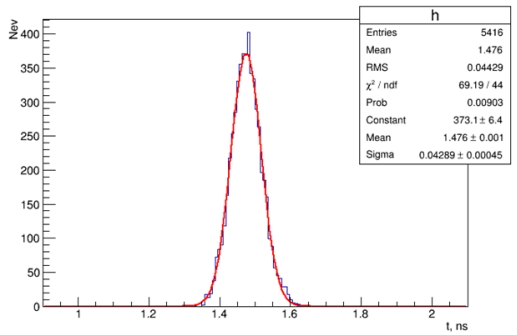
A scheme of the calibration system with PiLas laser



Ref. detector prototype

Main parts of the system:

- PiLas control unit (exist)
- Box with laser head and optical system (exist)
- Quartz fiber bundles (exist)
- Optical cables and patch boxes (in plan 2019)
- Reference photodetector (exist)



Time resolution measured with 2 detectors on BM@N beam line

Cable system

FFD modules and reference detector

- HDMI cables, 42 units (LVDS pulses, LV)
- Coaxial cables, 202 units (analog pulses)
- HV cables, 42 units

Sub-detector electronics

- Molex cables, 10 units
- Coaxial cables, 202 units

Trigger electronics

- Molex cable, 2 units

Laser system

- Optical cables, 100 units

Status:

2018 - all types of cables were tested

2019 - purchase of cables

Detector control system

The Detector Control System (DCS) provides control and monitoring of

- HV power supplies for MPC-PMTs
- LV power supplies for frond-end electronics
- FFD module operation
- SDUs and VU logic operation
- laser calibration
- local DAQ for calibration and monitoring of the FFD

The DCS server communicates with the Tango server of MPD Slow Control System

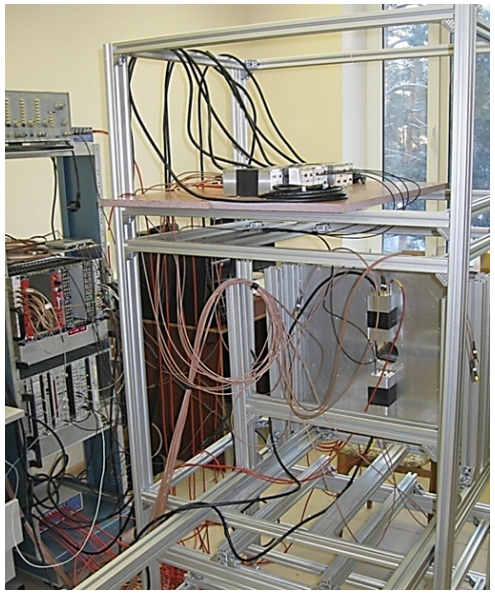
The first prototype of a FFD DCS web-server has been developed and tested.

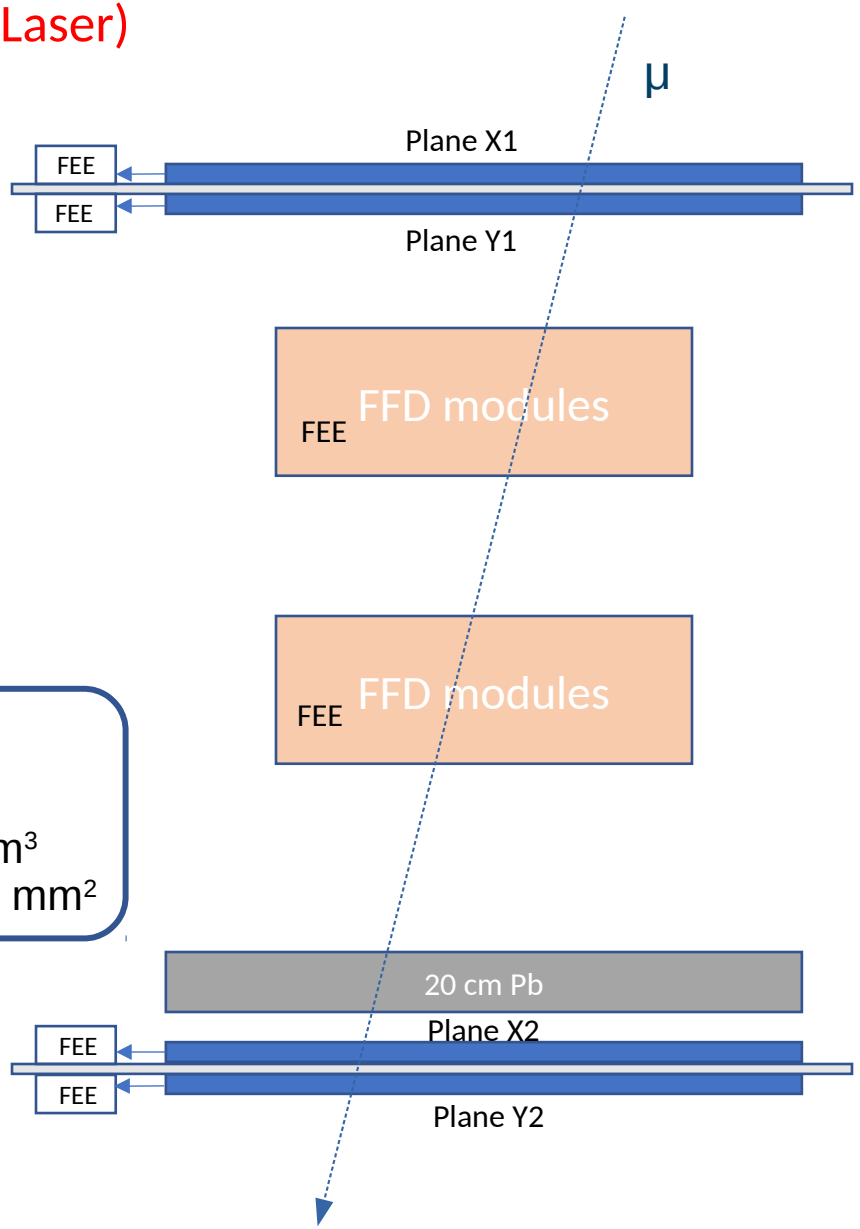
Plan

2019 - continue the development of DCS

2020 - DCS will be tested with all FFD sub-systems

FFD Test Stand (Cosmics + Laser)





Tests in 2019-2020:

- Arrays of FFD modules
- Trigger units
- TDC readout
- CAEN readout
- Laser System

XY Planes: Scintillator + SiPM

Overall XY size: 50 x 50 cm^2
Plane has 10 strips 50 x 5 x 1 cm^3
Strip is viewed by two SiPM 6x6 mm^2

FFD Test Stand Overview