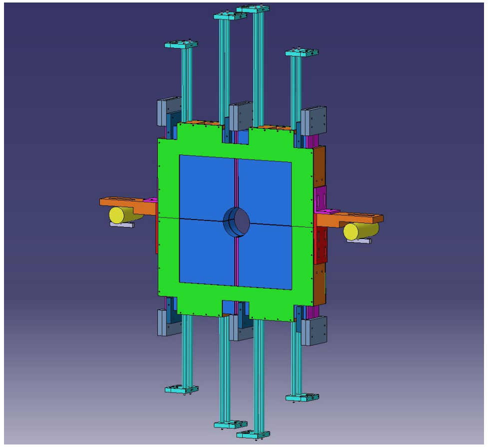
Forward Diffractive Detector

The upgrade of a forward physics detector in ALICE



Workshop EJČF 2020

Solangel Rojas Torres

13/01/2020

Content

- Introduction
- ALICE
- Fast Interaction Trigger
- Diffractive physics
- ALICE Diffractive detector
- Forward Diffractive Detector:
  - Placement
  - Layout
  - Construction
  - Test and Measurements
- Final Comments

Introduction

The ALICE experiment is making a significant **upgrade** of its detectors and systems during the second long shutdown (**LS2**) of the LHC.

During **Run-2** of the LHC the **ALICE Diffractive** (AD) detector was installed to **extend the pseudorapidity coverage** of ALICE for increase the capacities to trigger **diffractive** and **ultra-peripheral** events.

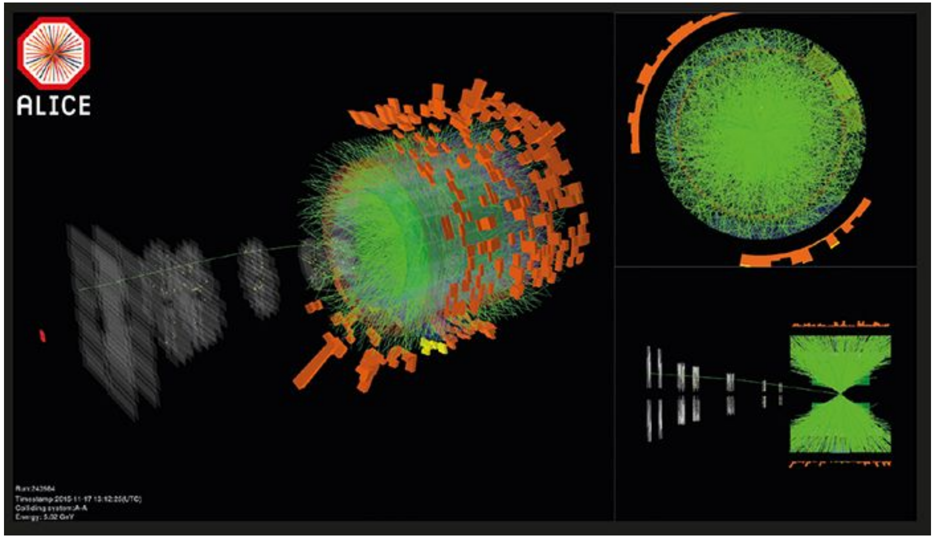
The **Forward Diffractive Detector** (FDD) is the **upgrade** of AD to fulfil the **new requirements** of the LHC conditions and fit in the new ALICE environment.

FDD keep the **same geometry** and **placement** of its predecessor but with **improvements in materials** used for its construction and will be part of **Fast Interaction Trigger** system.

ALICE

ALICE (A Large Ion Collider Experiment) is an experiment placed at point two of the LHC accelerator and was suited to study mainly the **Quark-Gluon Plasma** properties.

- The ALICE Collaboration has built a dedicated **heavy-ion** detector to exploit the unique physics potential of **nucleus-nucleus** interactions at LHC energies.
- The aim is to study the physics of **strongly interacting matter at extreme energy densities**, where the **formation of a new phase of matter, the quark-gluon plasma**, is expected.



B. A. et al, T. A. Collaboration, Upgrade of the alice experiment: Letter of intent, Journal of Physics G: Nuclear and Particle Physics 41 (8) (2014) 087001.

ALICE - LS2

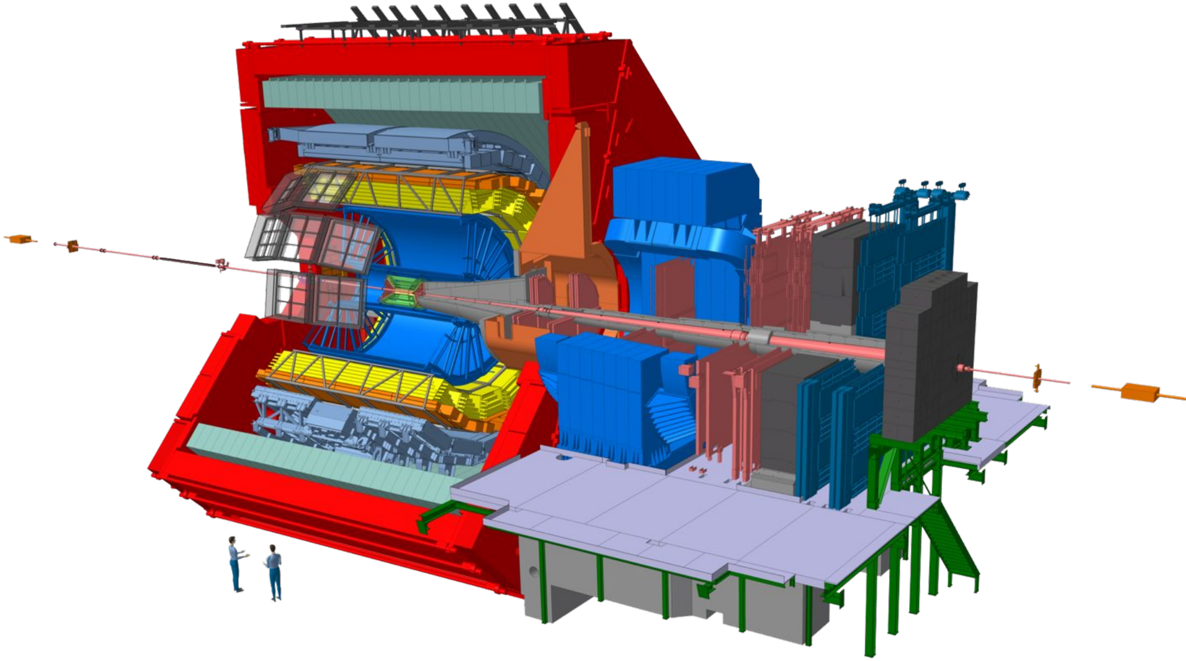
After the second **Long Shutdown** (LS2), the LHC will progressively **increase its luminosity** with:

Pb beams

- ❑ Collisions rate = 50 kHz
- ❑ Average Luminosity = $6\times10^{-27}\ cm^{-2}\ s^{-1}$

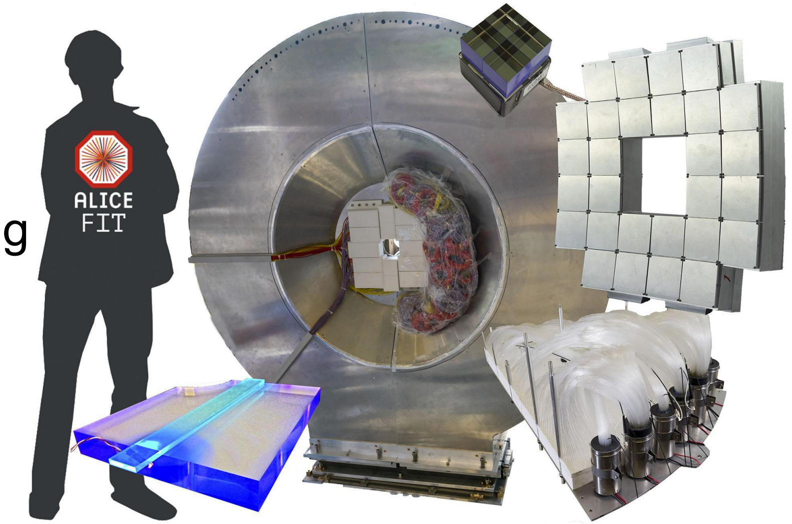
Protons beams

- ❑ Collisions rate = 1 MHz
- ❑ Average Luminosity = $10^{-34} cm^{-2}\ s^{-1}$



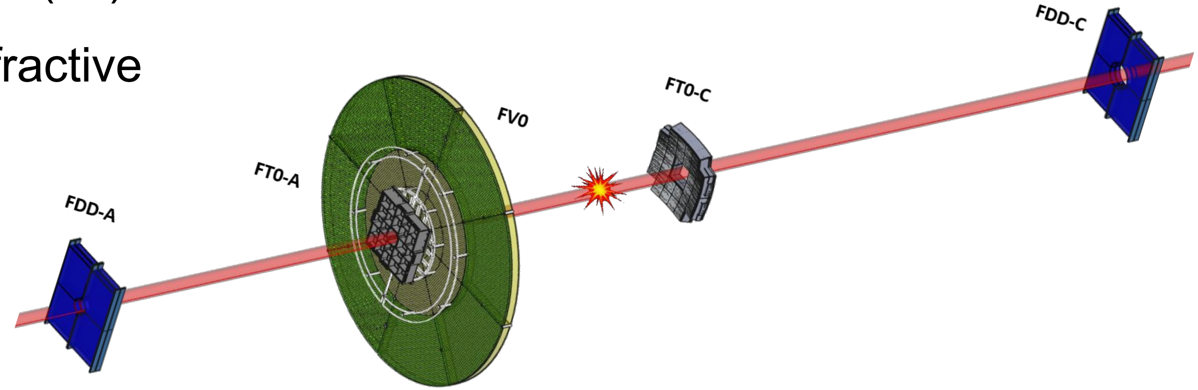
B. A. et al, T. A. Collaboration, Upgrade of the alice experiment: Letter of intent, Journal of Physics G: Nuclear and Particle Physics 41 (8) (2014) 087001.

Fast Interaction Trigger



The FIT system will be the MB trigger of the ALICE during the Run-3.

- **Multiplicity**: V0+ (LM)
- **Luminosity**: T0+, V0+ and **FDD** (L0)
- **Collision time** and **vertex**: T0+ (LM)
- **LHC background** (BG): V0+ and **FDD** (L0)
- **VETO** (UPC, electromagnetic and diffractive interactions): T0+, V0+ and **FDD** (L0)



https://indico.cern.ch/event/855860/contributions/3601710/attachments/1931954/3200080/JO_FIT_Triggers_231019.pdf

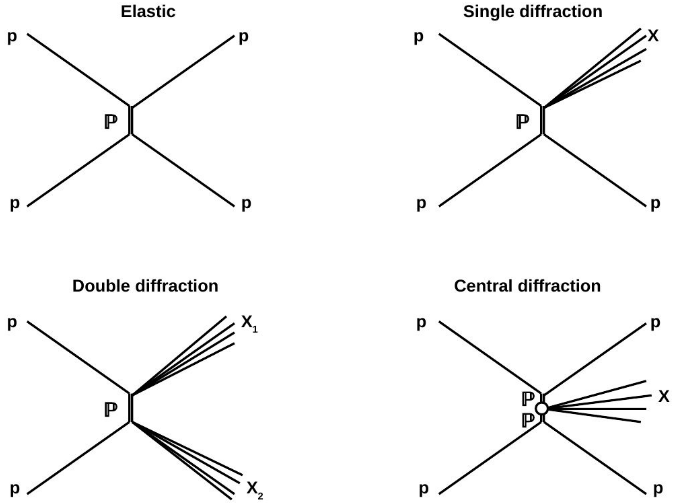
Diffractive physics

Diffractive Processes are driven by the strong force.

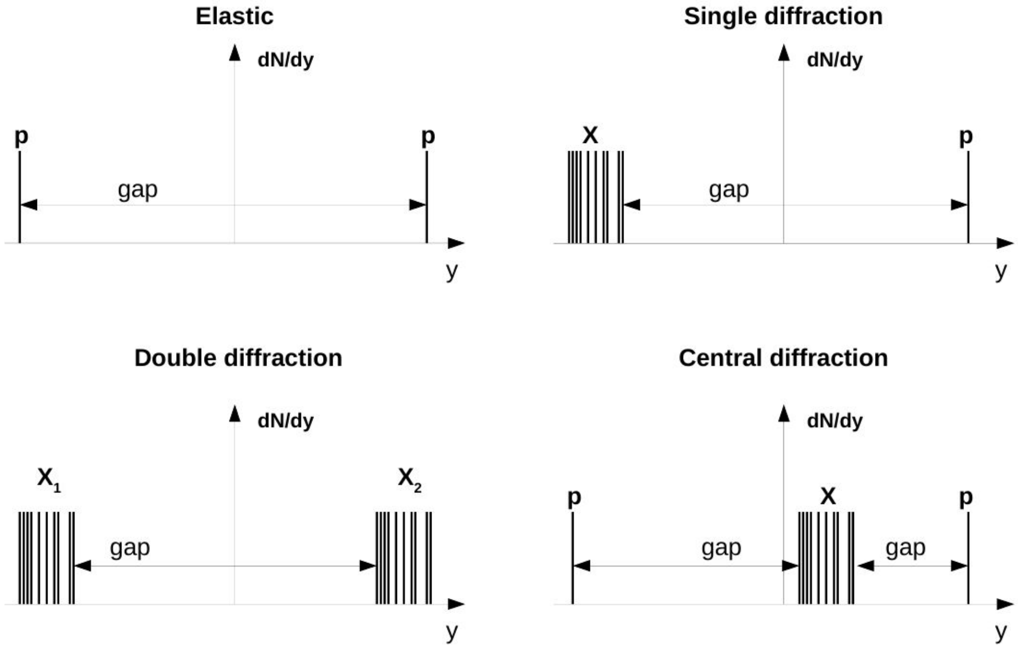
A feature of the diffraction processes is that though hard processes may be involved:

- One or both incoming particles either remain intact
- Dissociate into products emitted at very small angle

The **exchanged virtual particle (the Pomeron) carries no color**.



The characteristic signature of a diffraction event in a detector is the rapidity gap between the two diffractive systems.



Around of 30% of p-p interactions are diffractive processes.

G. H. Corral, Diffractive physics with alice at the lhc: the control of quantum collisions, Journal of Physics: Conference Series 624 (1) (2015) 012008.
T.-R. S., Diffractive Physics at DØ, Springer, Hadron Collider Physics2002doi:https://doi.org/10.1007/978-3-642-55524-4_20.

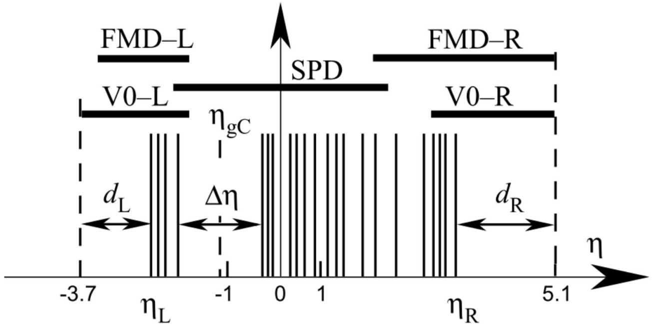
Diffraction in ALICE – Run 1

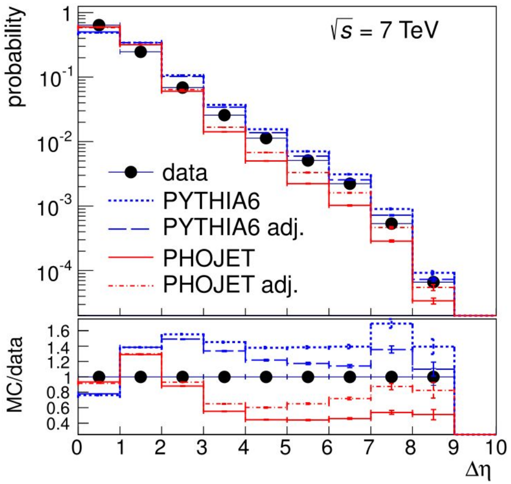
- Measurements of cross sections of **inelastic**, **single**- and **double-diffraction cross section.**
- **Proton-Proton** at three centre-of-mass energies:
  - sqrt(s) = **0.9**, **2.76**, and **7 TeV**

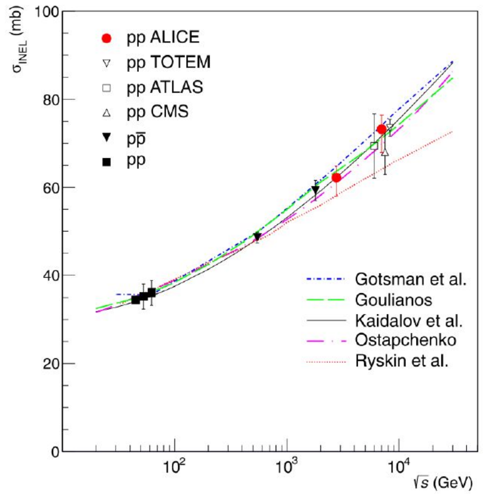
Using **V0** detector, **SPD** and the **FMD** for **trigger** information for the selection of **minimum-bias** events.

The **TPC** and the whole **ITS** were used in this study only to provide the **interaction vertex position**, from reconstructed tracks.

Covering a continuous acceptance over a pseudorapidity interval of 8.8 units.



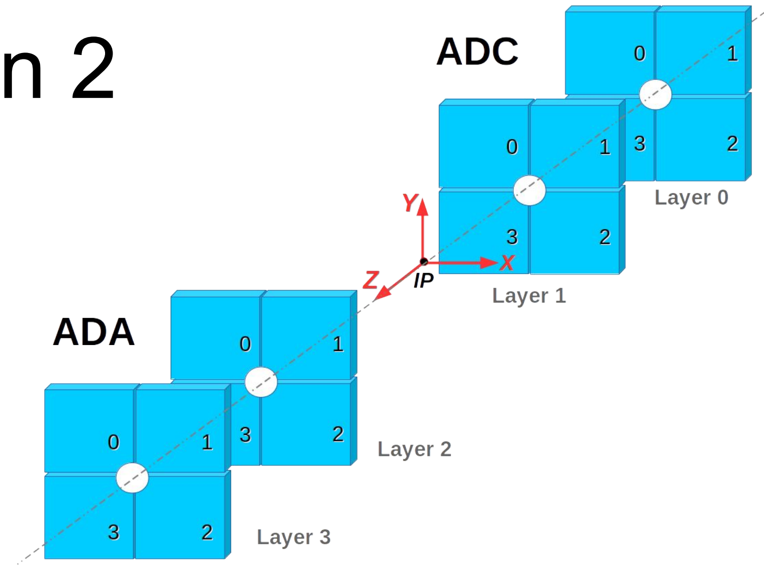


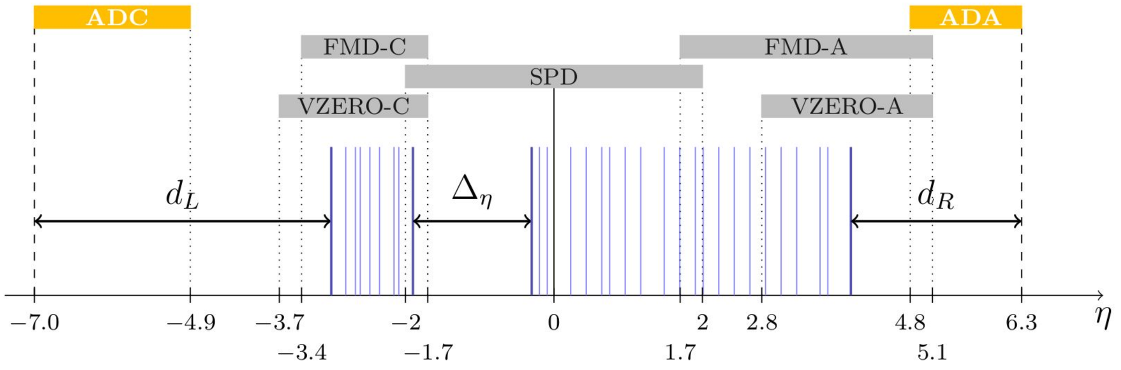


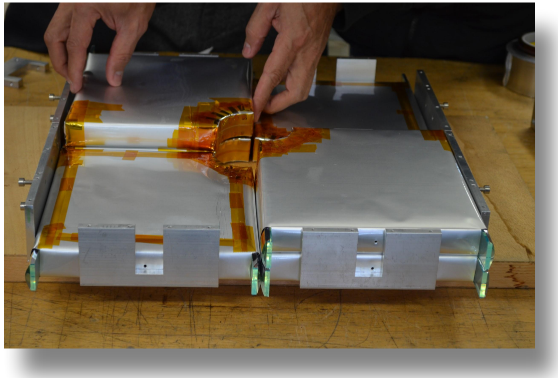
B. Abelev, et al., Measurement of inelastic, single- and double-diffraction cross sections in proton–proton collisions at the LHC with ALICE, Eur.Phys. J. C73 (6) (2013) 2456. arXiv:1208.4968, doi:10.1140/epjc/s10052-013-2456-0.

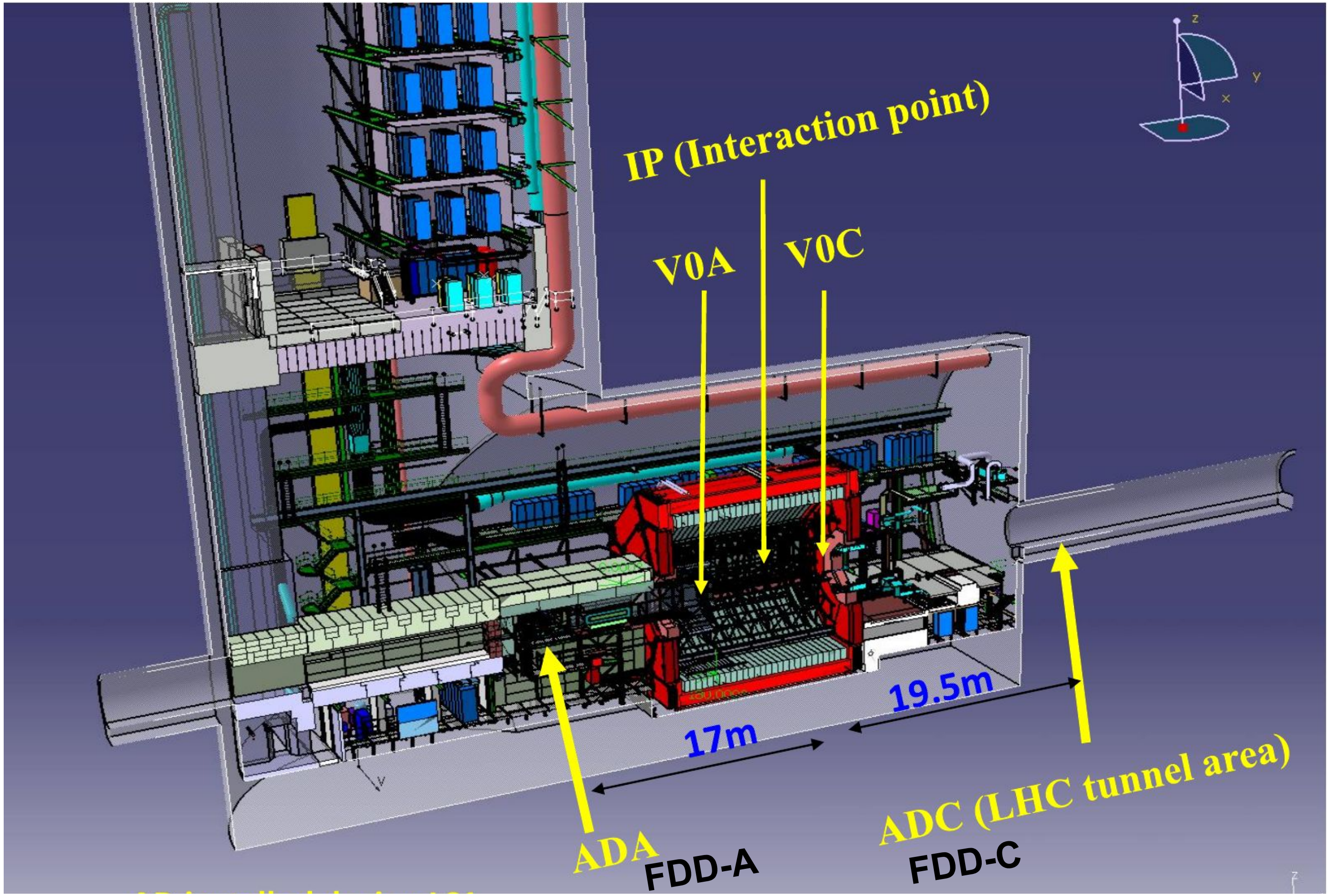
The ALICE Diffractive (AD) – Run 2

- Designed to **increase the forward coverage** to tag diffractive events produced in non frontal collision.
- It was designed, constructed and installed during **2014**.



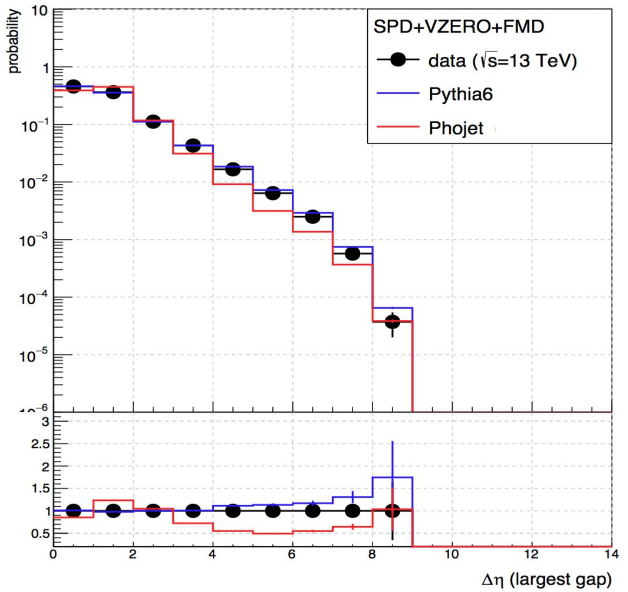


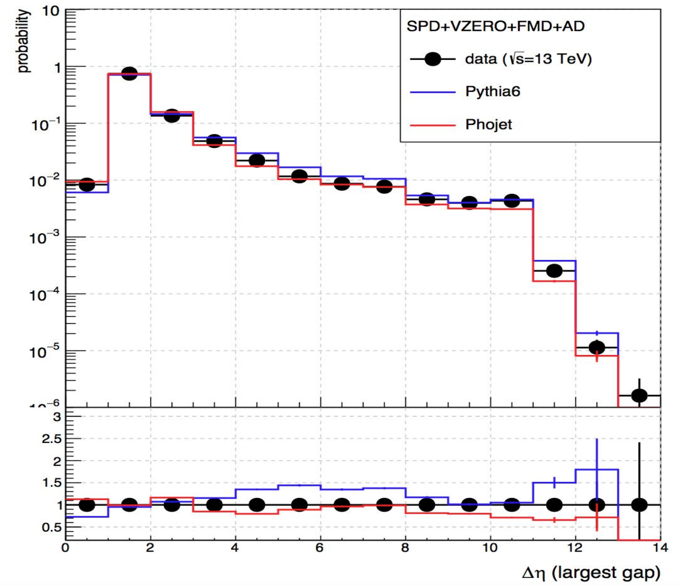



IP (Interaction point)
V0A
V0C
17m
19.5m
ADA
FDD-A
ADC (LHC tunnel area)
FDD-C

AD preliminaries

E. Calvo





Same analysis as in Eur. Phys. J. C 73 (2013) 2456

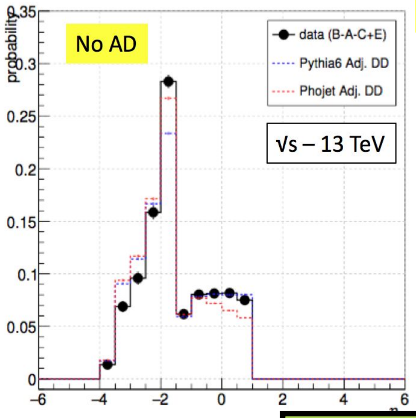
ALICE **internal-only** data: work in progress!

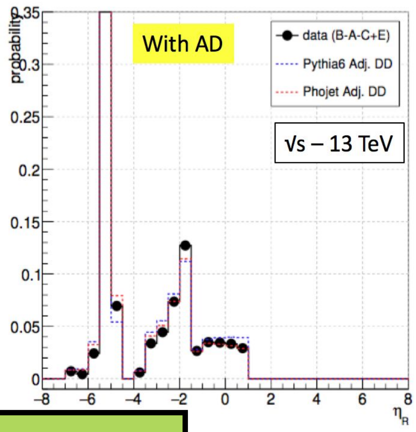
Distribution of the largest pseudorapidity gap in 2-arm events (DD), as defined in [Eur. Phys. J. C 73 (2013) 2456], showing on the **left the distribution without AD** and on the **right the distribution with AD**.

AD Upgrade for LHC Run 3 The ALICE Forward Diffraction Detector (FDD) DRAFT PROPOSAL, The FDD Collaboration.

AD preliminaries

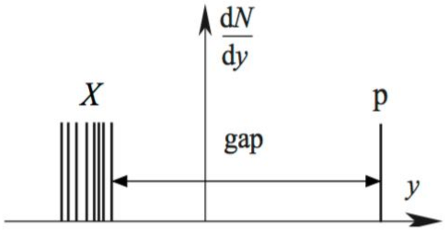
E. Calvo

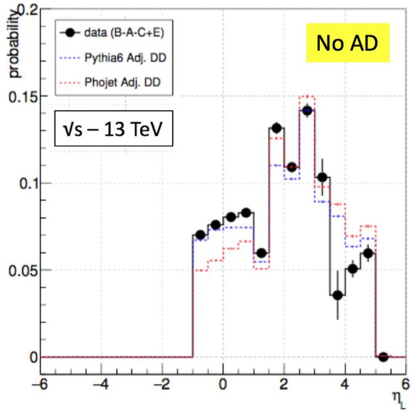


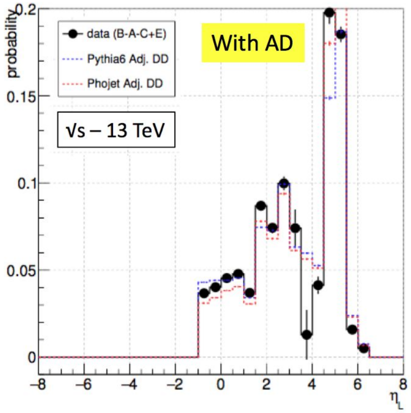


ALICE **internal-only** data: work in progress!

SD on C side







SD on A side

Same analysis as in Eur. Phys. J. C 73 (2013) 2456

AD Upgrade for LHC Run 3 The ALICE Forward Diffraction Detector (FDD) DRAFT PROPOSAL, The FDD Collaboration.

AD paper contribution

AD as been used as veto detector for an ultra-peripheral paper.

https://doi.org/10.1016/j.physletb.2019.134926

Physics Letters B 798 (2019) 134926

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Coherent J/ψ photoproduction at forward rapidity in ultra-peripheral Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV

ALICE Collaboration *

ARTICLE INFO

Article history:
Received 19 April 2019
Received in revised form 15 August 2019
Accepted 6 September 2019
Available online 10 September 2019
Editor: M. Doser

ABSTRACT

The ALICE collaboration performed the first rapidity-differential measurement of coherent J/ψ photoproduction in ultra-peripheral Pb-Pb collisions at a center-of-mass energy $\sqrt{s_{NN}} = 5.02$ TeV. The J/ψ is detected via its dimuon decay in the forward rapidity region ($-4.0 < y < -2.5$) for events where the hadronic activity is required to be minimal. The analysis is based on an event sample corresponding to an integrated luminosity of about 750 μb^{-1}. The cross section for coherent J/ψ production is presented in six rapidity bins. The results are compared with theoretical models for coherent J/ψ photoproduction. These comparisons indicate that gluon shadowing effects play a role in the photoproduction process. The ratio of ψ' to J/ψ coherent photoproduction cross sections was measured and found to be consistent with that measured for photoproduction off protons.

Work in progress

- "Coherent rho0 photoproduction in ultra-peripheral Pb-Pb collisions at 5.02 TeV" (*see David Horak presentation)*
- "Single Diffraction, Double Diffraction and Inelastic Cross Sections in pp collisions at 13 TeV" *(Ernesto Calvo V.)*
- "Coherent photoproduction of J/Psi and Psi(2s) in ultra-peripheral Pb–Pb collisions at 5.02 TeV" *(see Roman Lavicka presentation)*

Forward Diffractive Detector

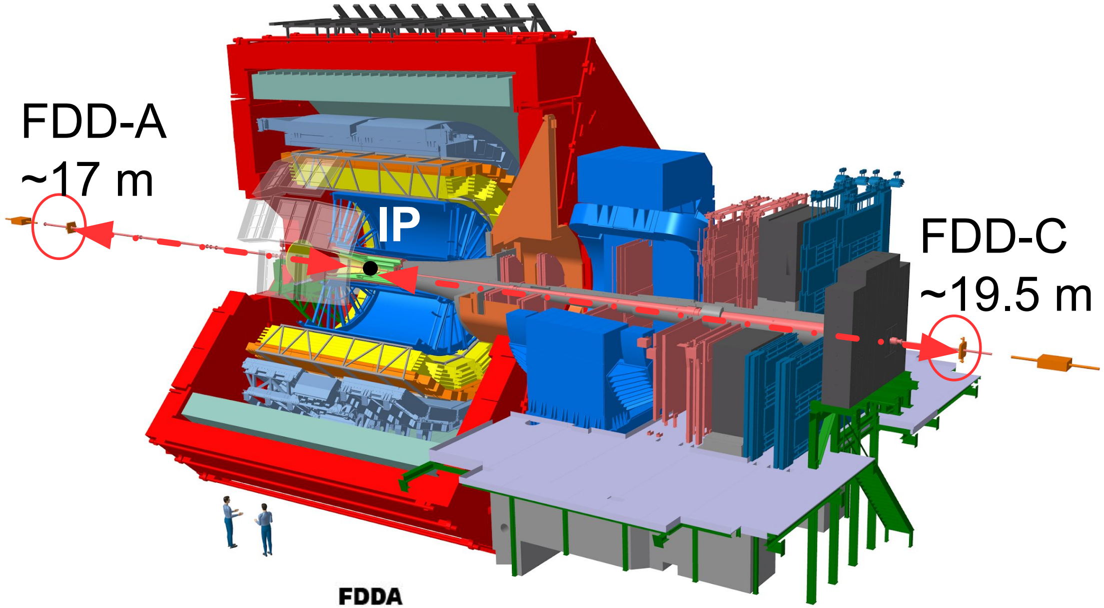
Upgrade of **AD -> FDD**

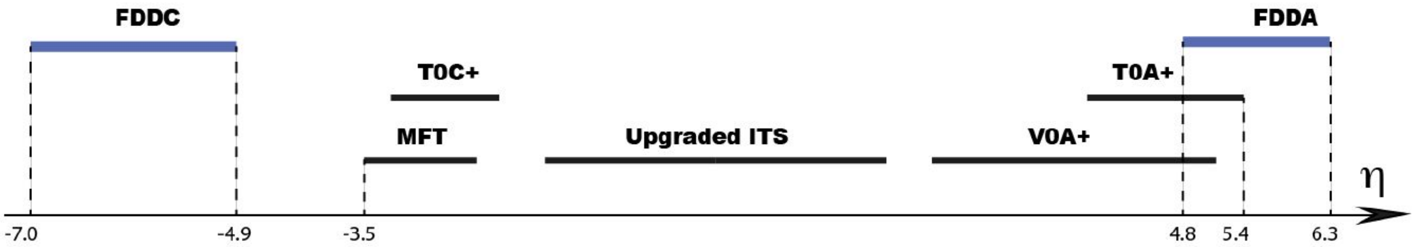
- 2 arrays: FDD-A & FDD-C.
- Same geometry as AD.
- Each 2 layers of 4 scintillators/PMT -> total 16 channels.
- Connected to FIT read-out.

Integrated into FIT detector

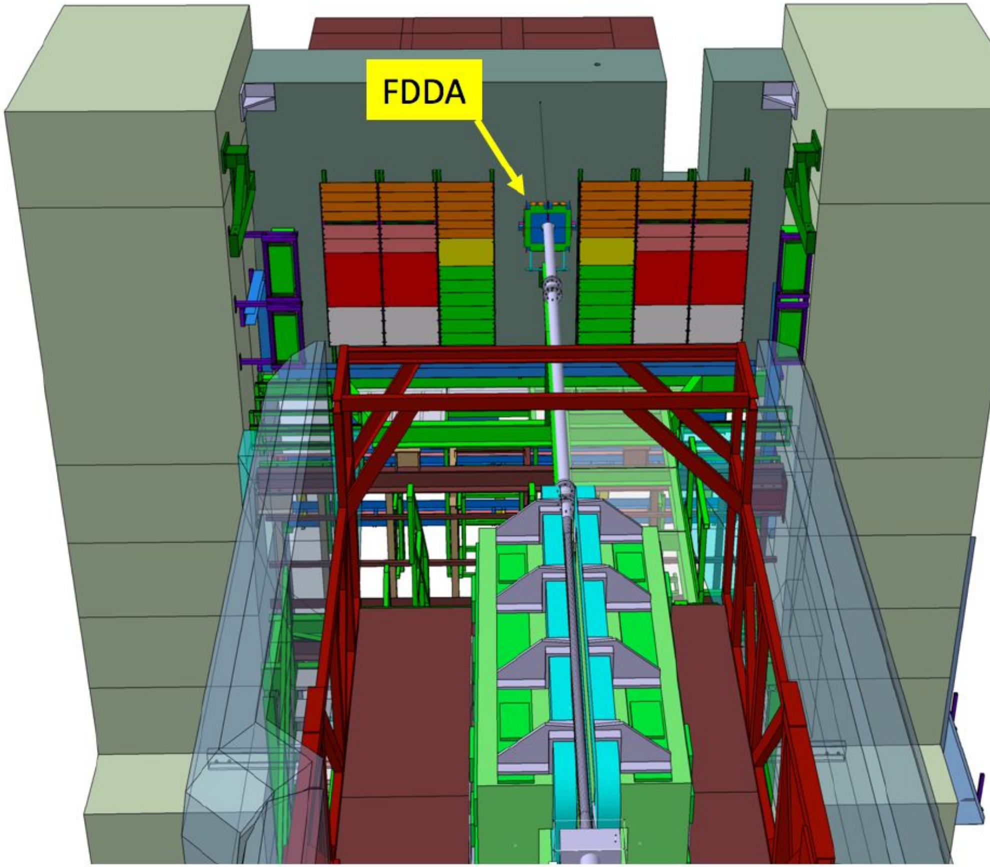
- Read-out, DCS, project coordination are common.

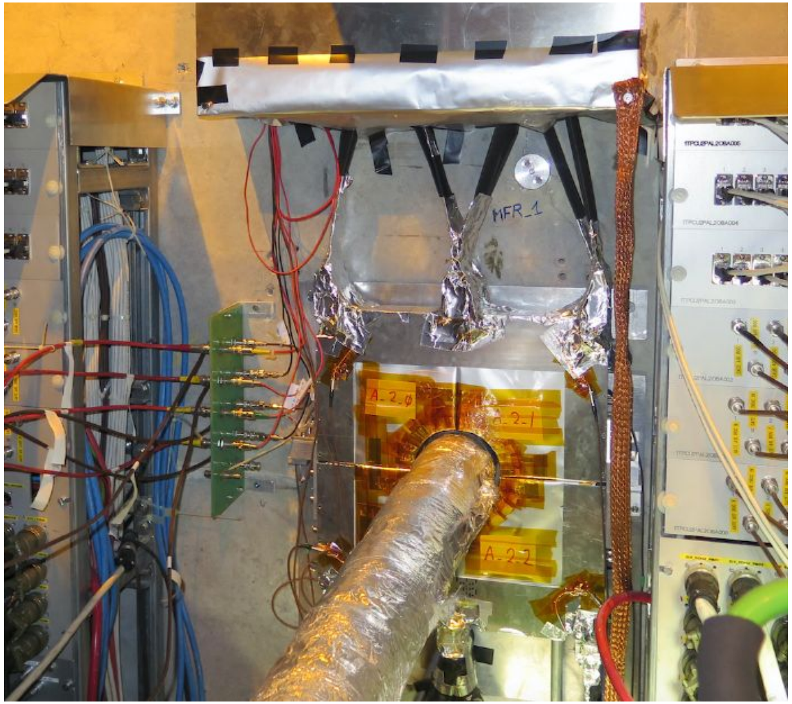
Pseudorapidity coverage: 4.7<η<6.3 and -6.9<η<-4.9



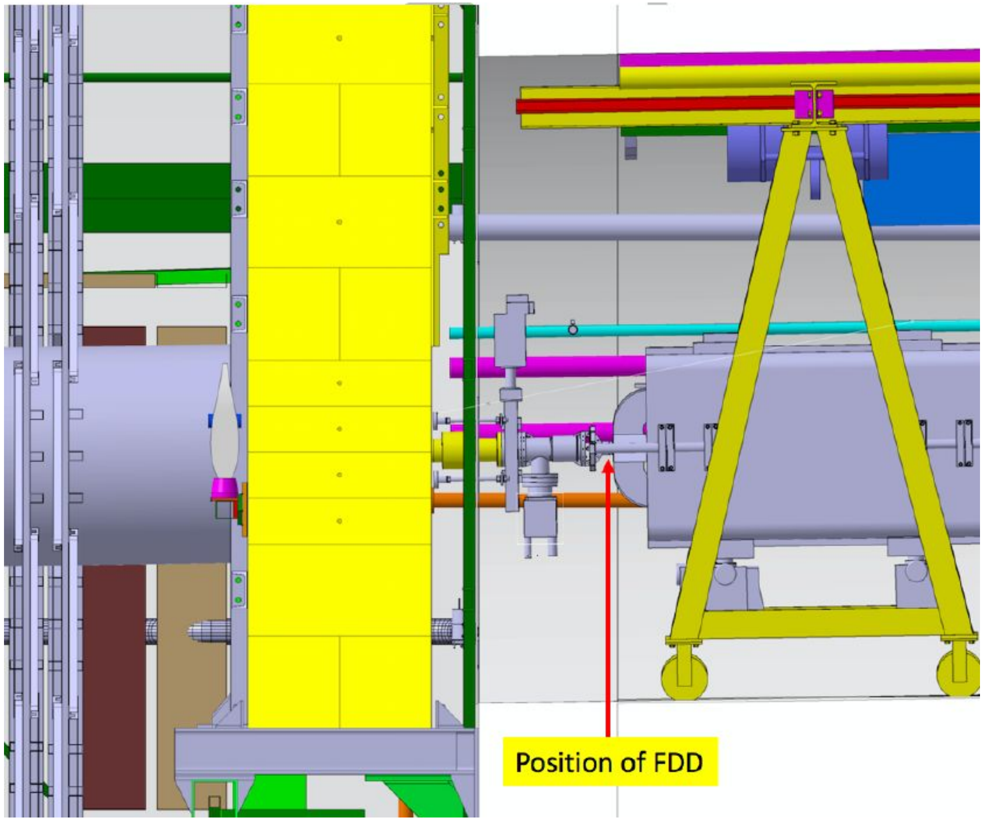


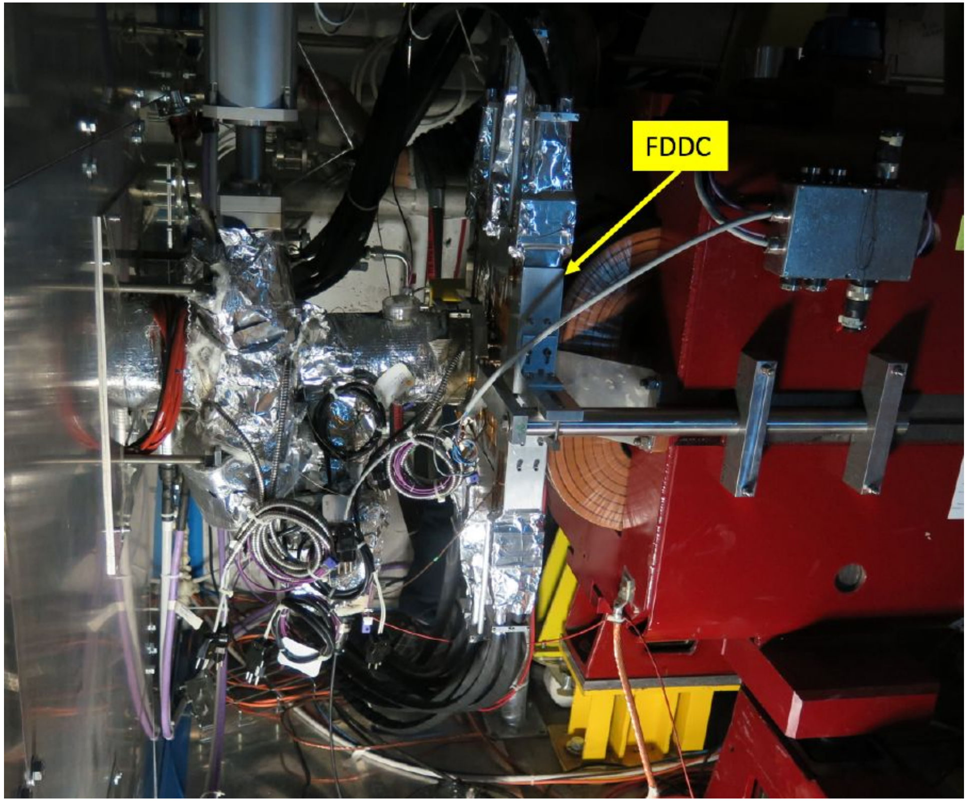
Placement of FDD-A





Placement of FDD-C

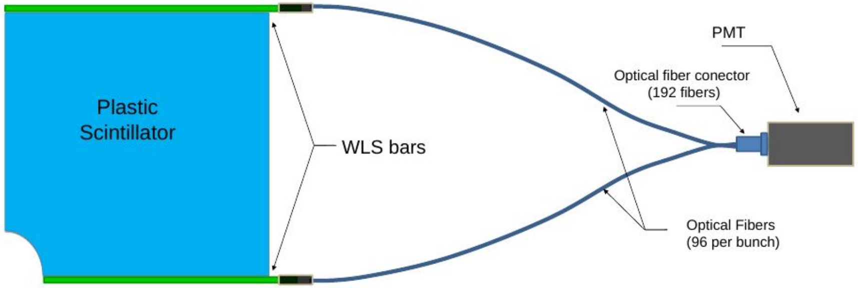


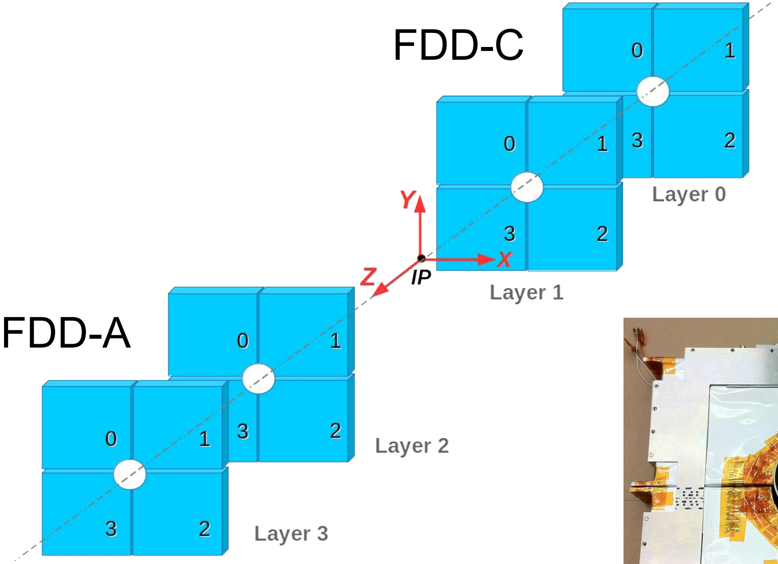


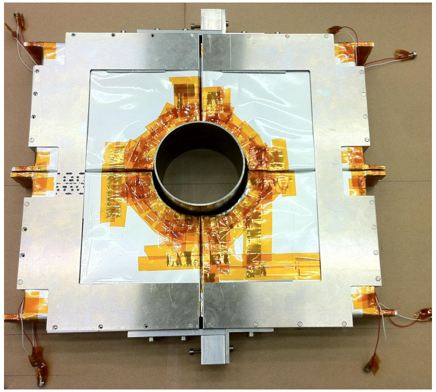
Forward Diffractive Detector - Layout

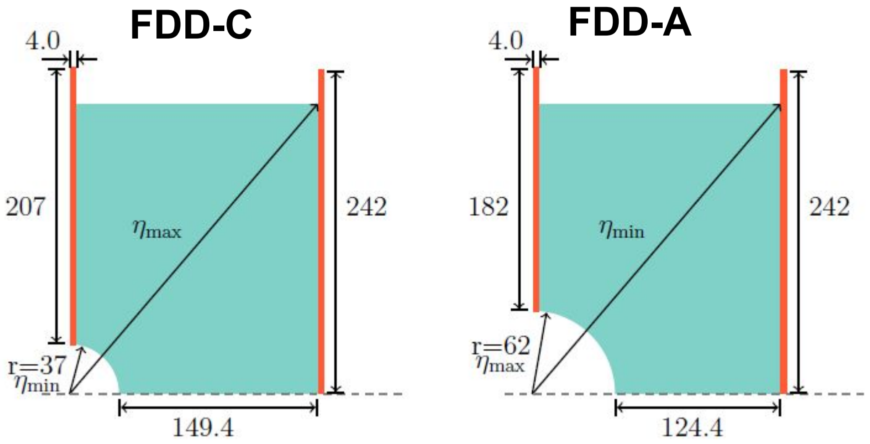
Materials:

- Plastic scintillator: Bicron **BC-420**
- WLS bars: LuminnoTech **NOL-38**
- Optical fibers: Kuraray **PSM-Clear**
- PMTs: Hamamatsu **H8409-70** (19 dinodes)

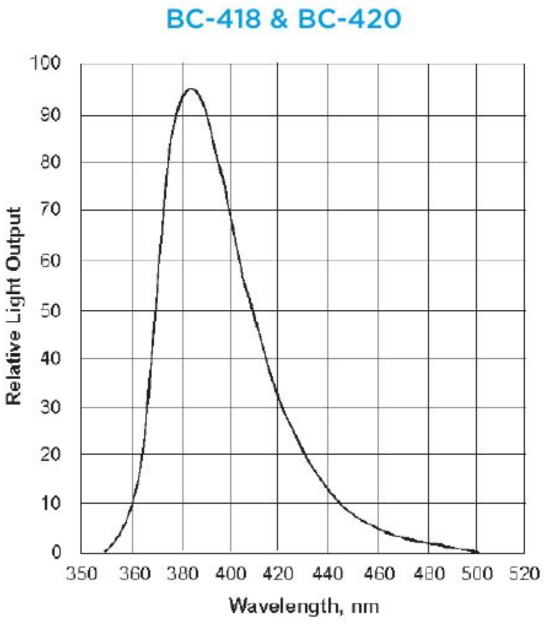






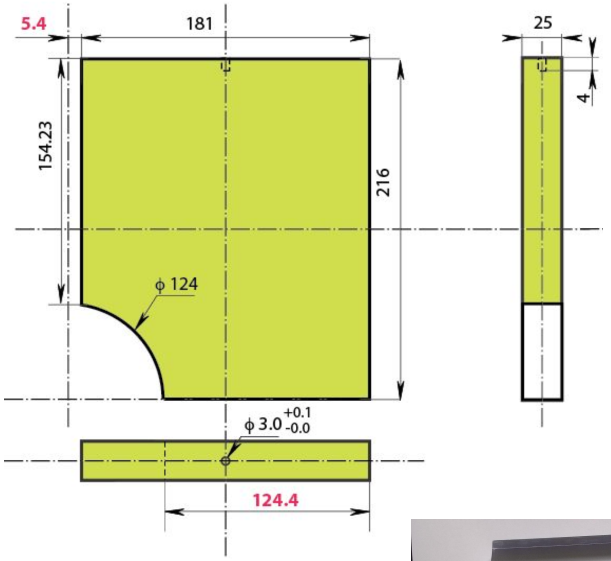


Layout: Plastic scintillators, BC420

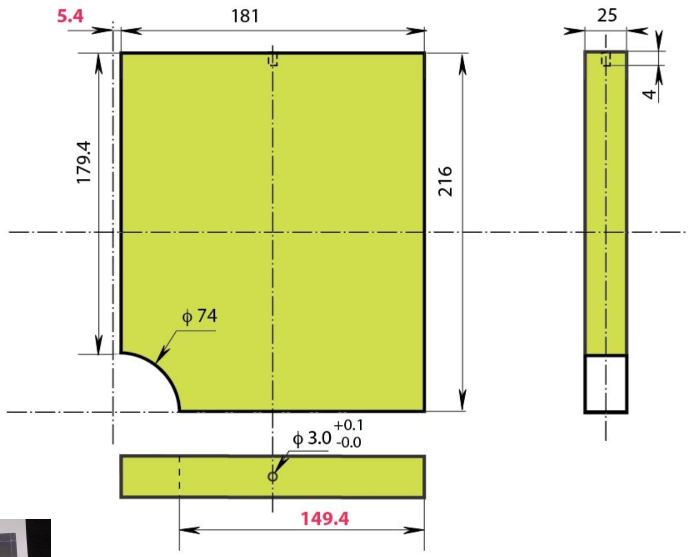


Peak of emission: 390 nm

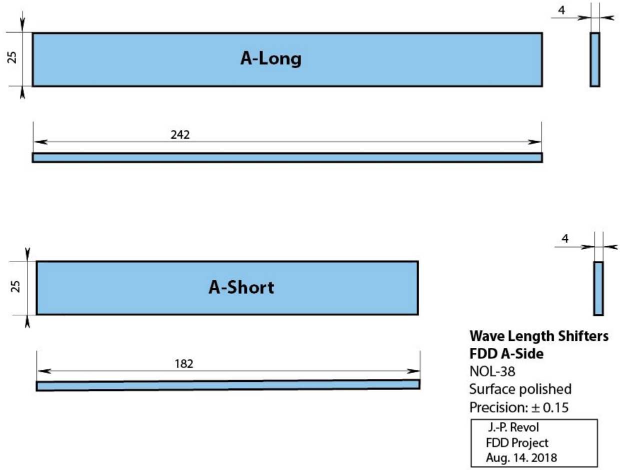
A-side

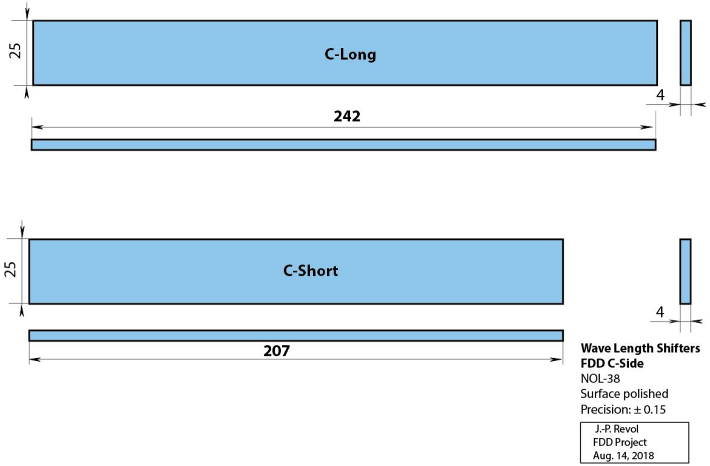


C-side

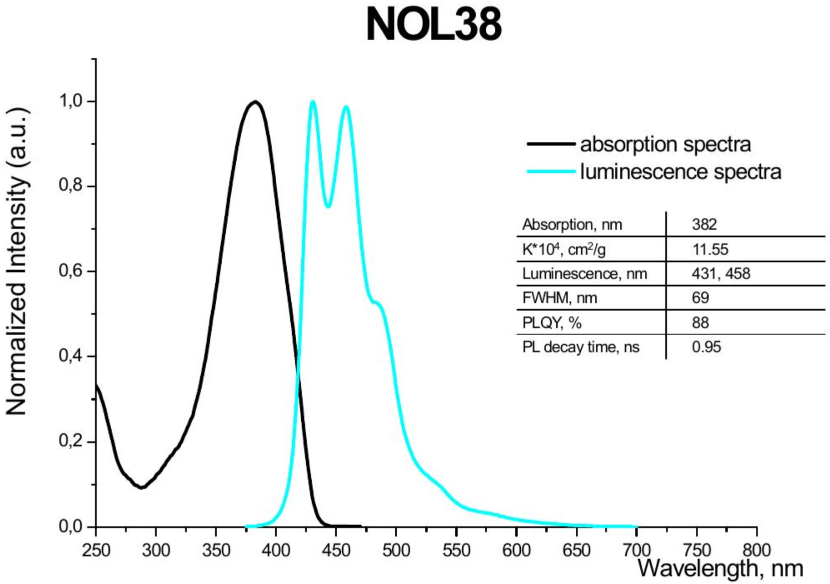


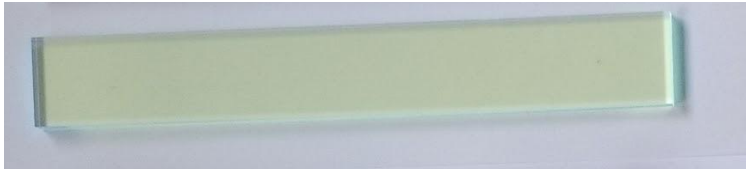
Layout: WLS bars



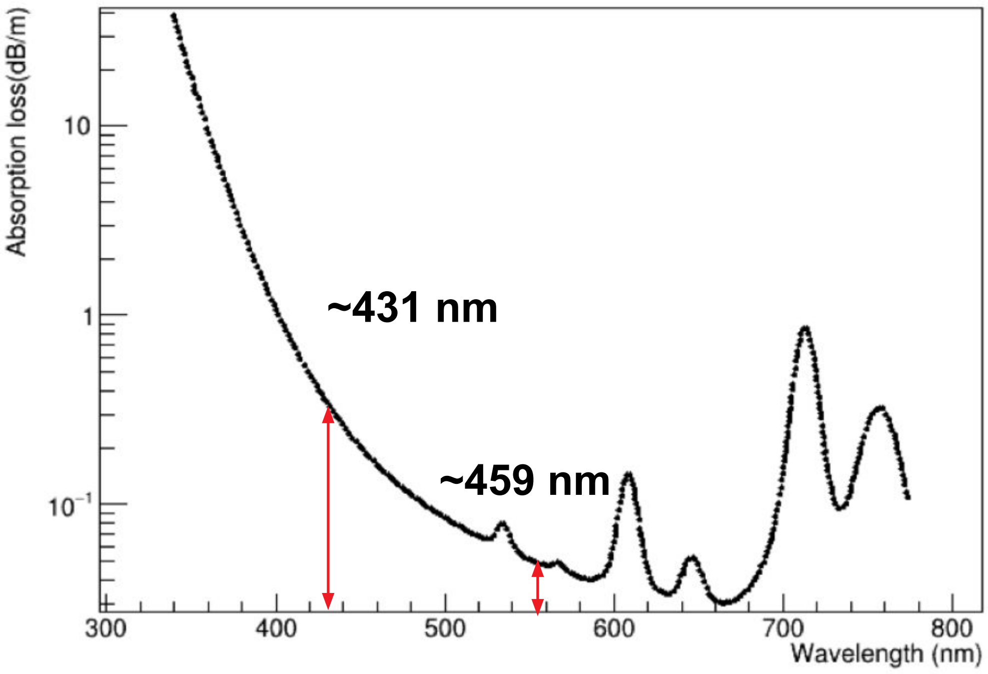


Model: BC499-90
NOL-38 from LuminnoTech
Time decay: **1 ns**,
Luminescence nm: 431 and 458

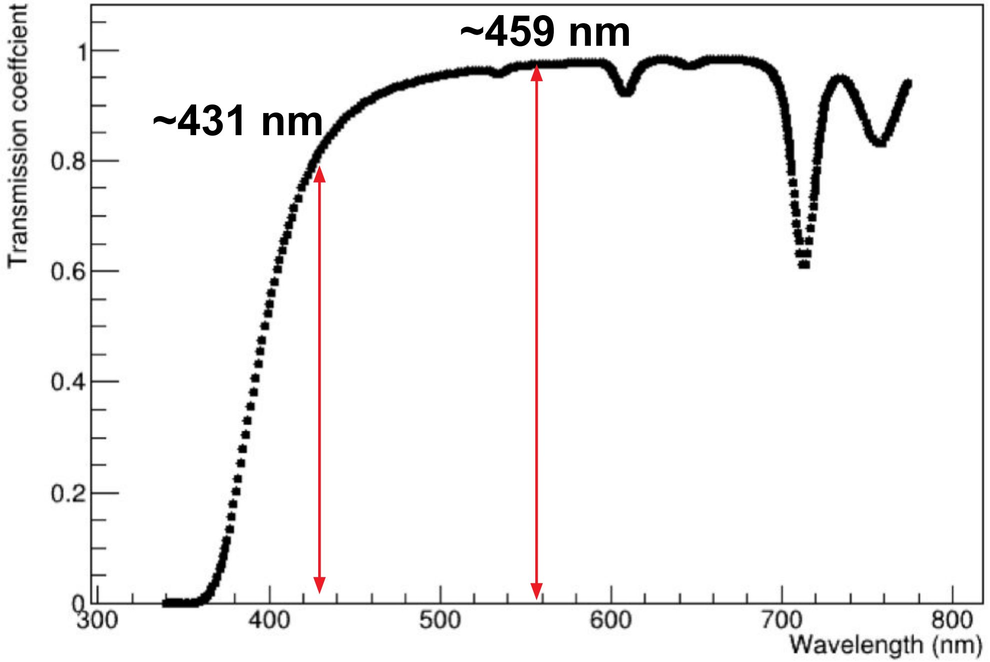




Optical fiber – Absorption and transmission



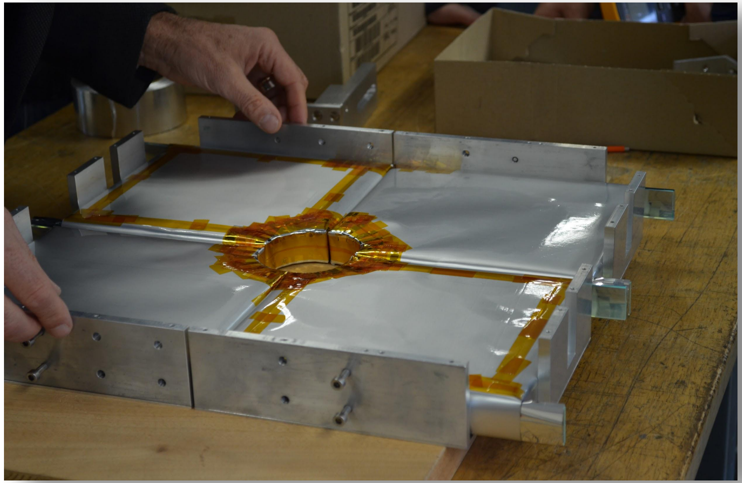
Absorption spectrum as a function of photon wavelength.

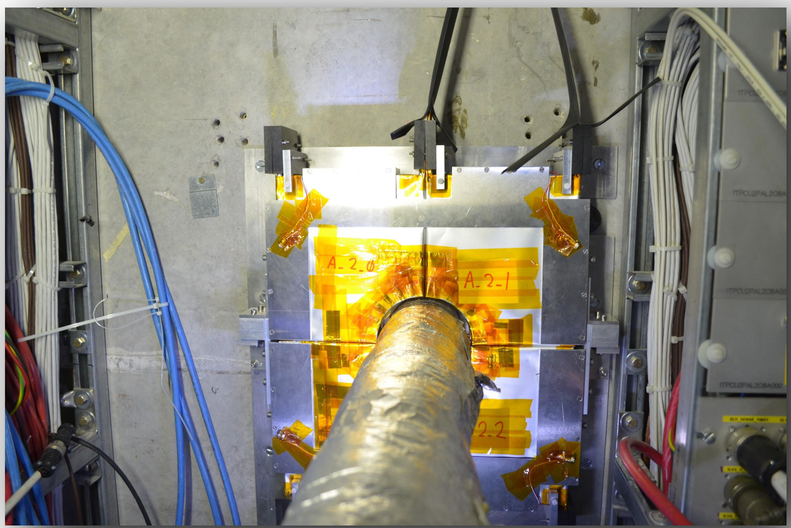


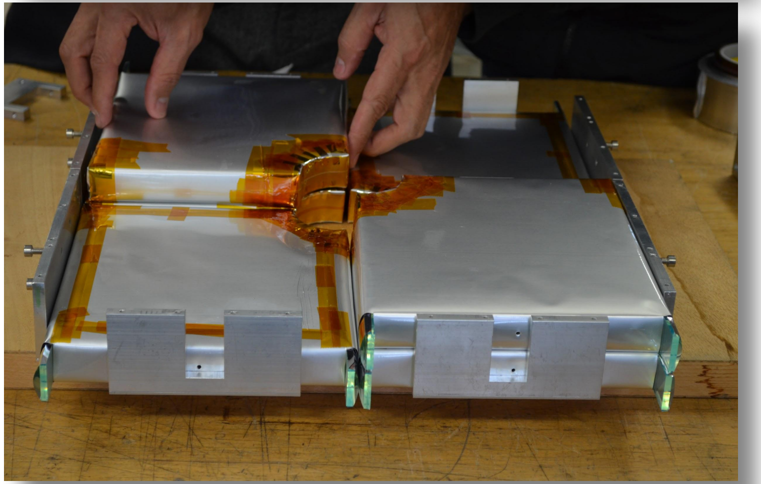
Transmission coefficient, or probability distribution for the transmission of photons along the clear fibers. The data correspond to the C side, where **fibers are 250 cm long.**

Construction procedure: FDD

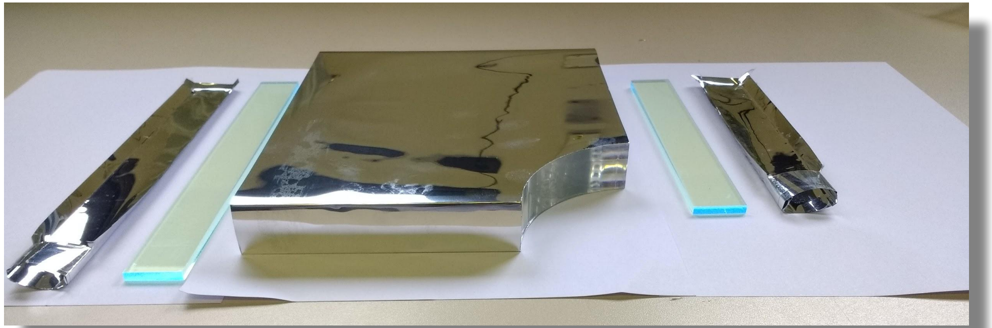
- FDD stations assembling
  a. Prepare WLS bar and attach it to the plastic.
  b. Wrap the module with Mylay foil and protective material.
  c. Place FDD pads into the support frame.
  d. Optical connectors construction.
  e. Fiber bundle preparation.
  f. Machining of PMT cases.
  g. Machining of PMT-Box.

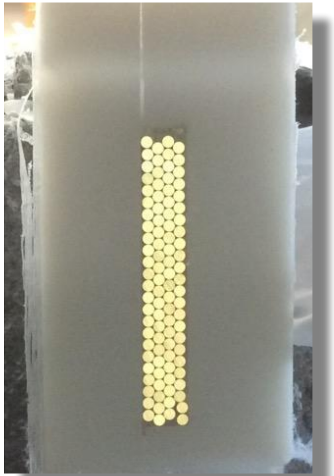


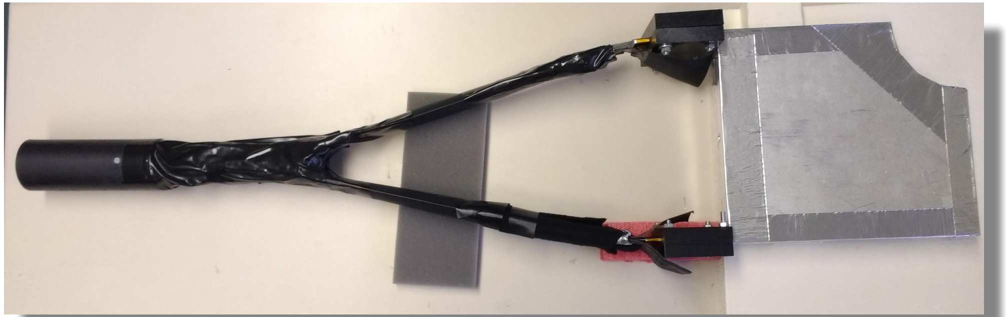


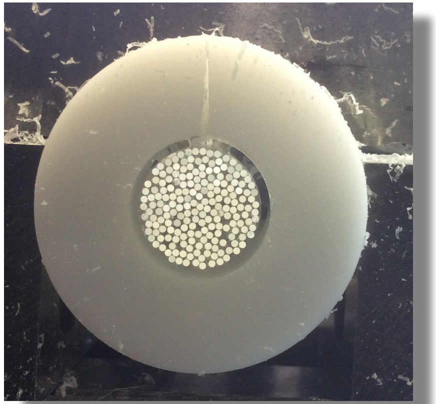


Construction procedure – Some pictures



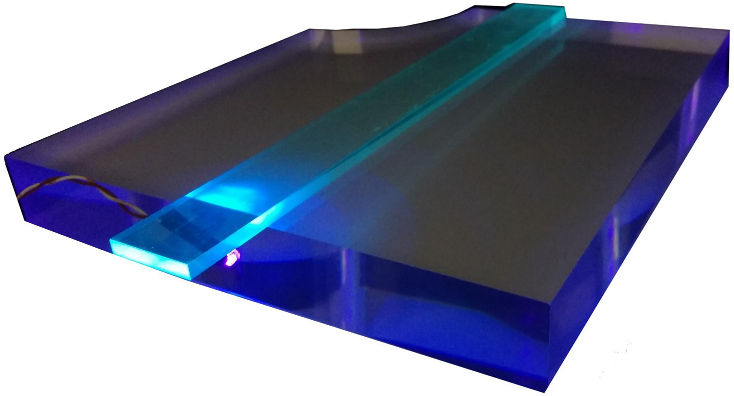




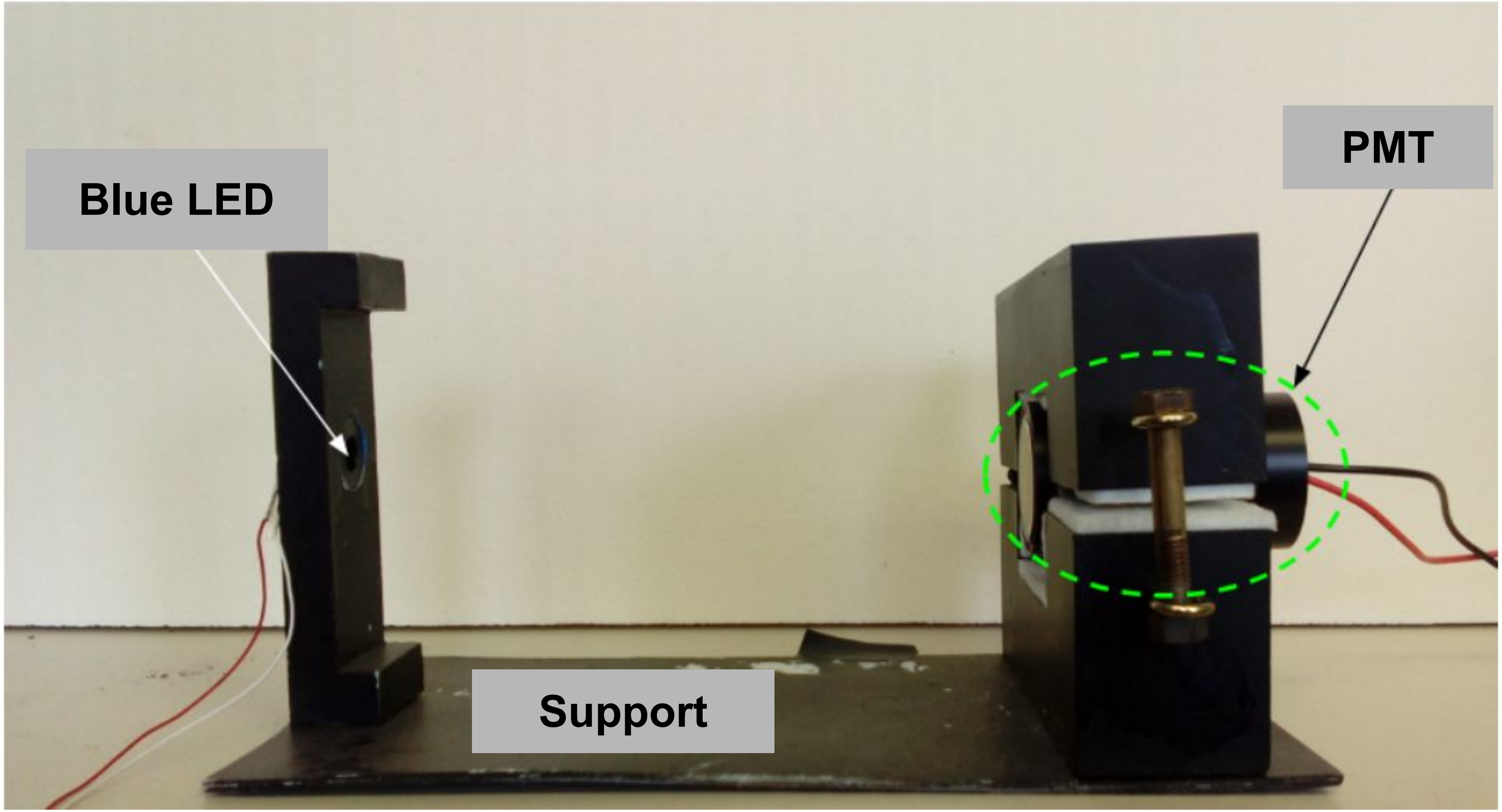


FDD prototype: Test and Results

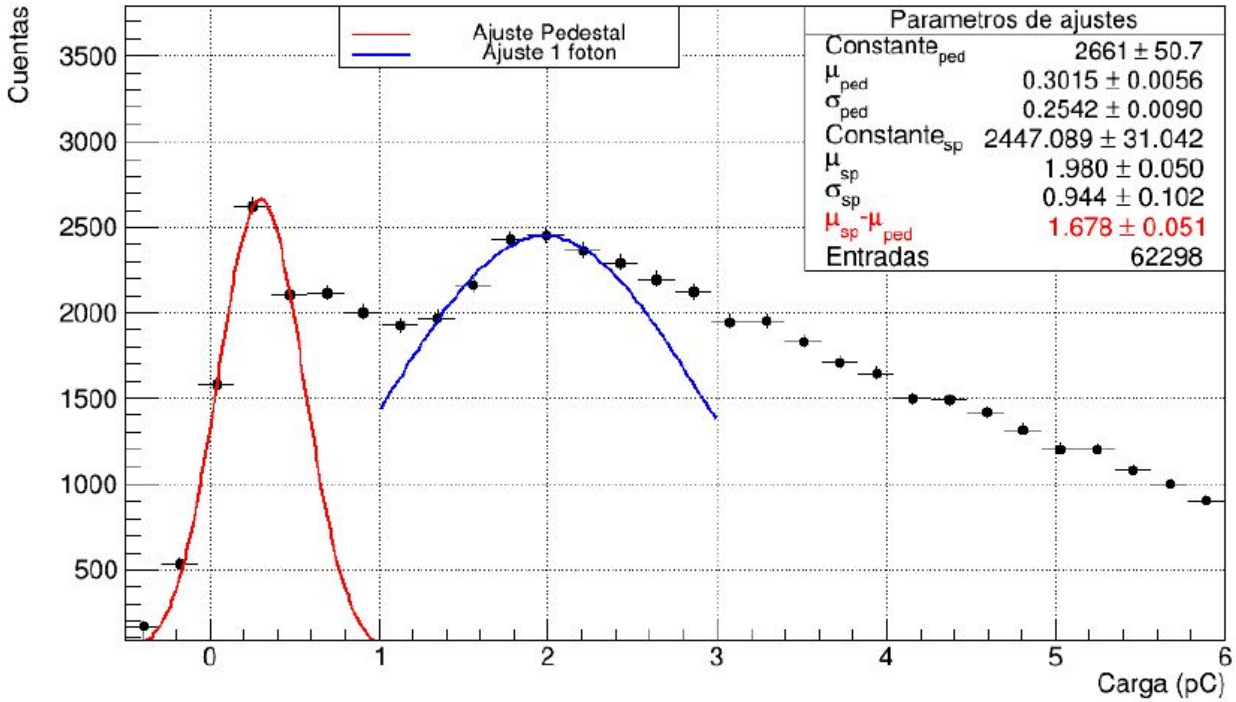
- Charge and time measurements of FDD prototype.
- Fit front-end electronic time and charge measurements.



Test and Results: Single photon calibration



Test and Results: Charge



- PMT model: **H8409-70**
- HV: **2300 Volts**

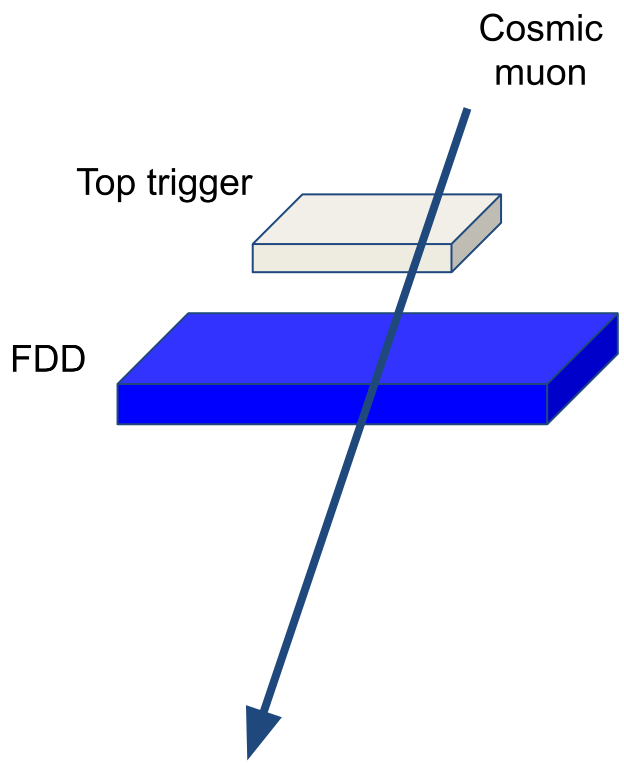
- Charge per photoelectron: **1.67 pC**

Photoelectrons/MIP: Standard electronics

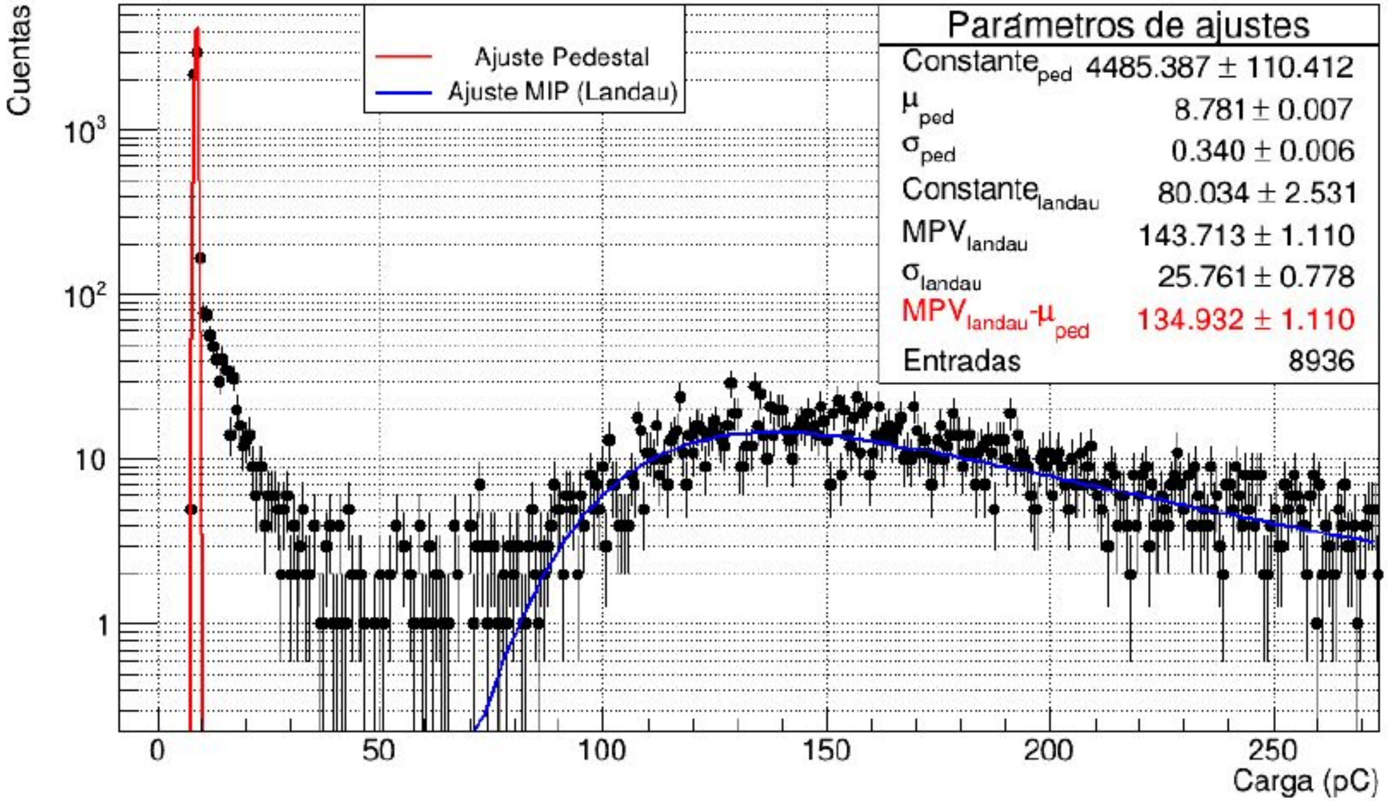
Digitizer:
VME CAEN **V1742**

Discriminator:
VME CAEN **V814**

PMT HV:
2500 volts



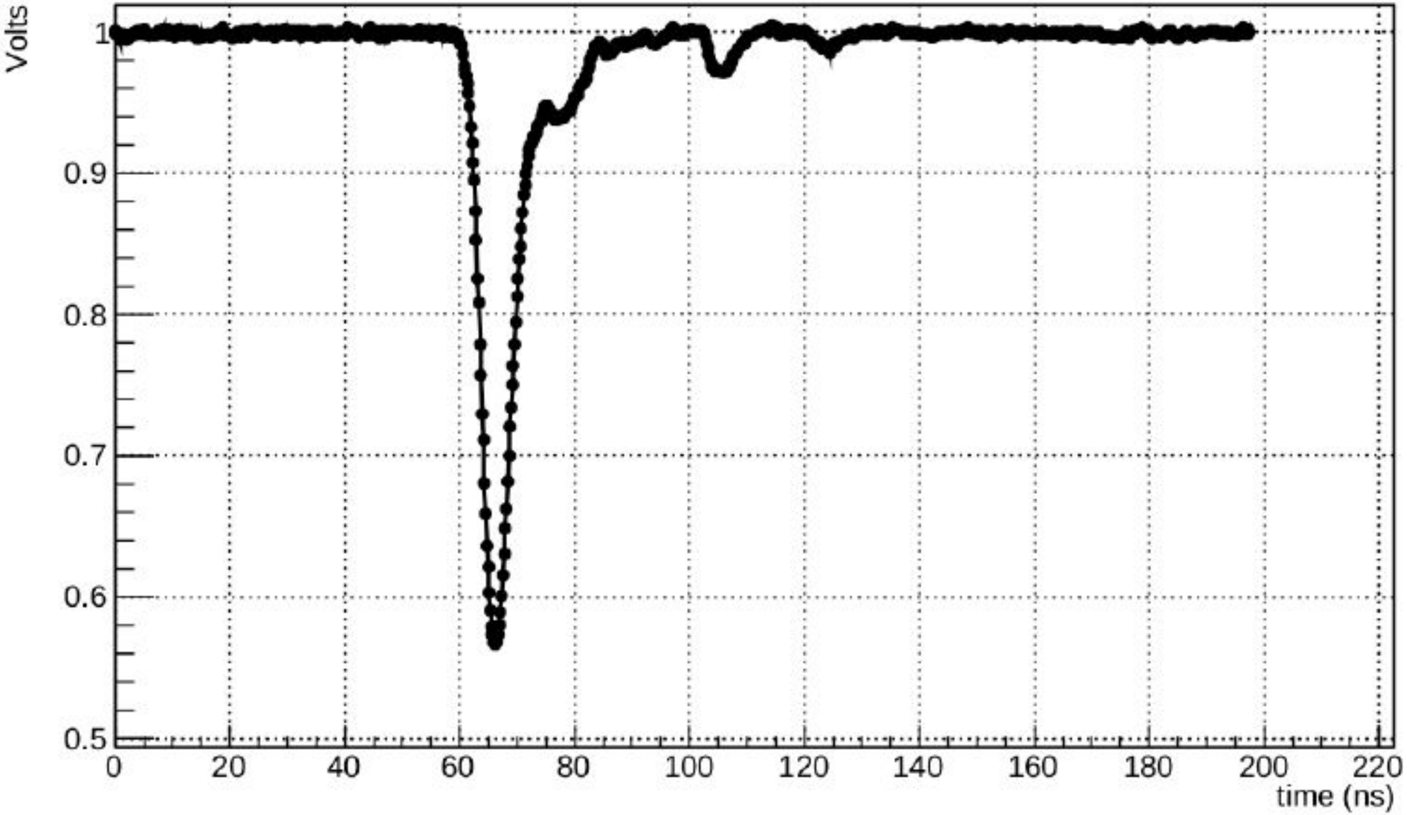
Test and Results: Charge for a MIP



- PMT model: **H8409-70**
- HV: **2500 Volts**

- Charge: **134.9 pC**
- No. phe: **81.32**

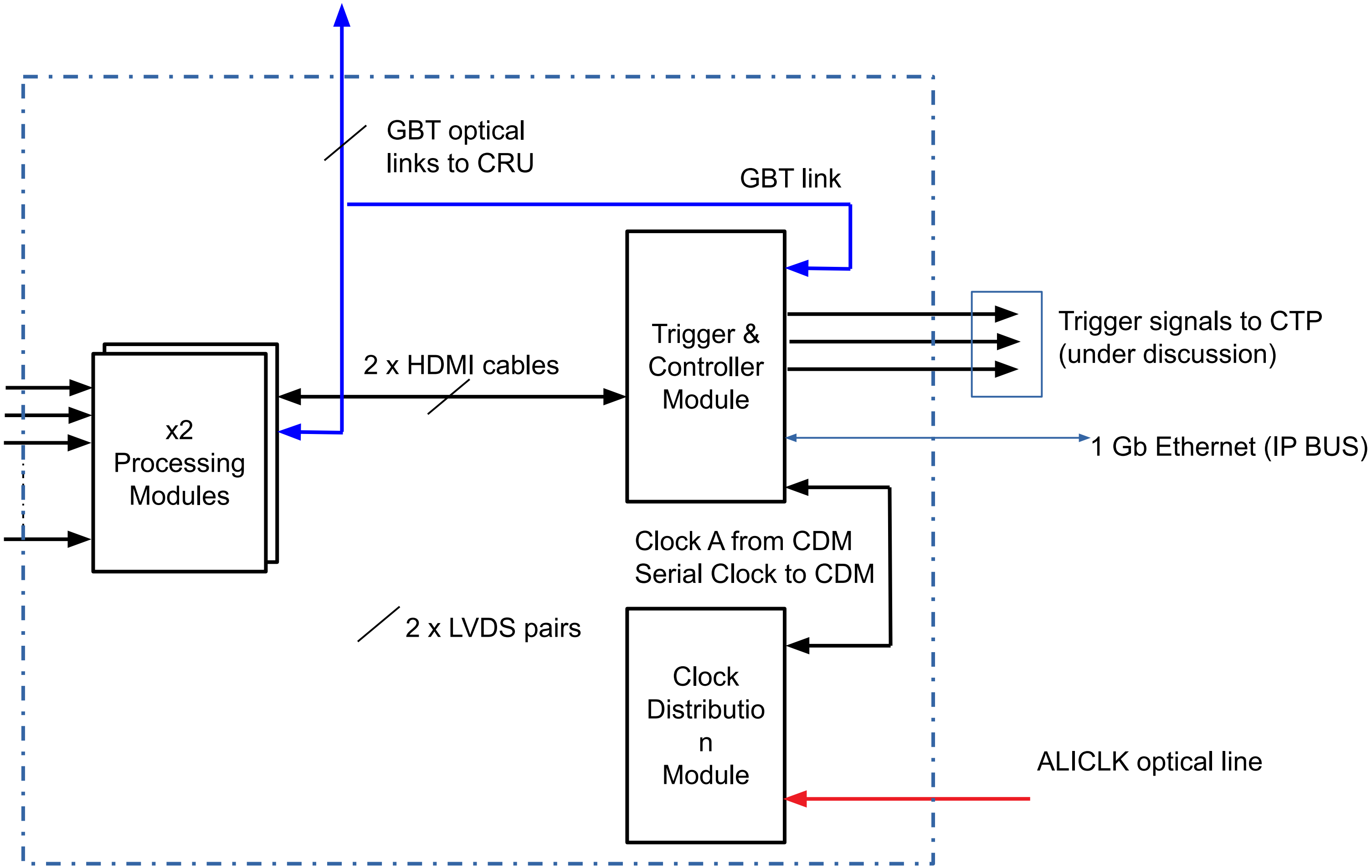
Typical pulse around the MPV.



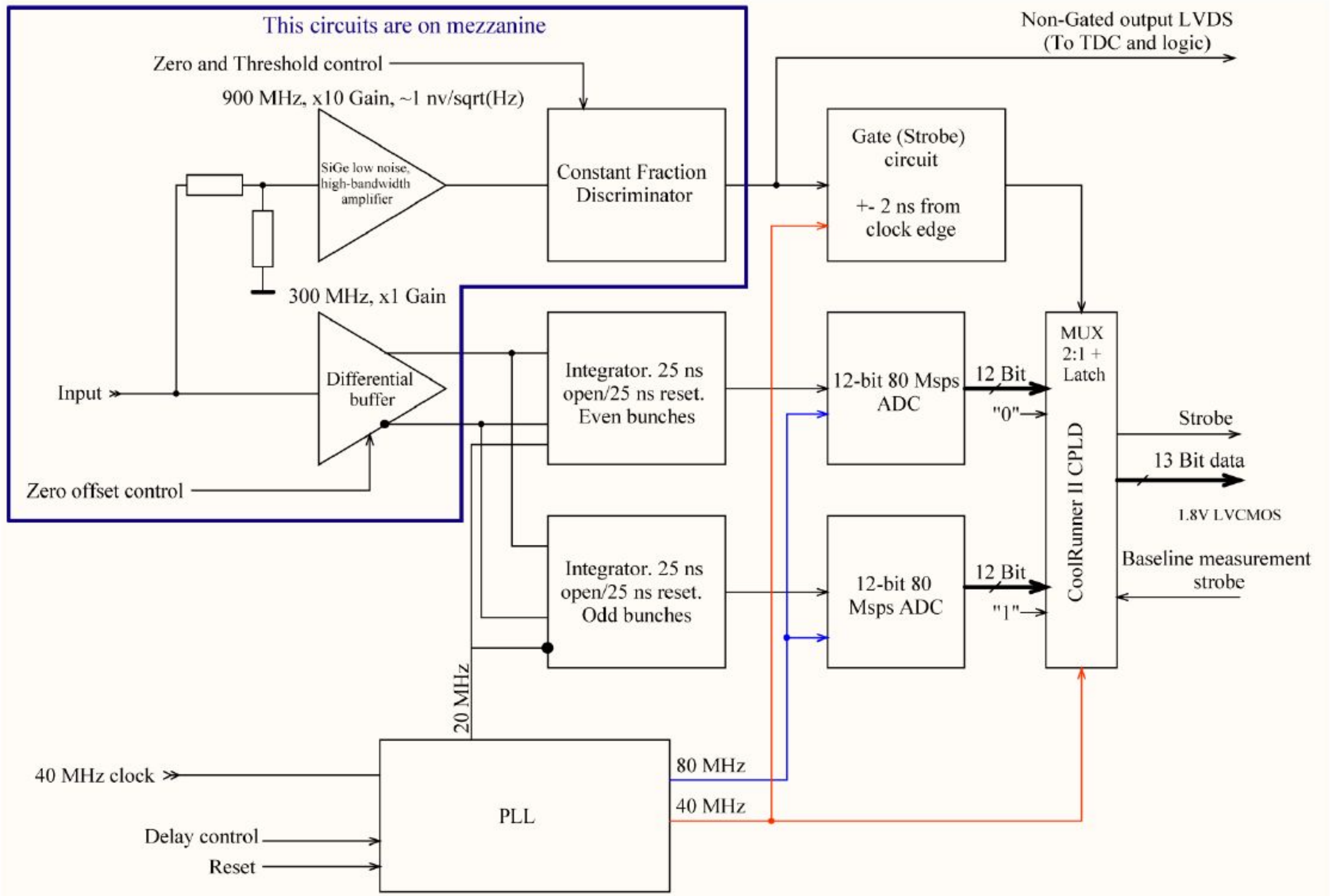
The amplitude: **564 mV**.

Note: directly from PMT.

FIT Front-End Electronics

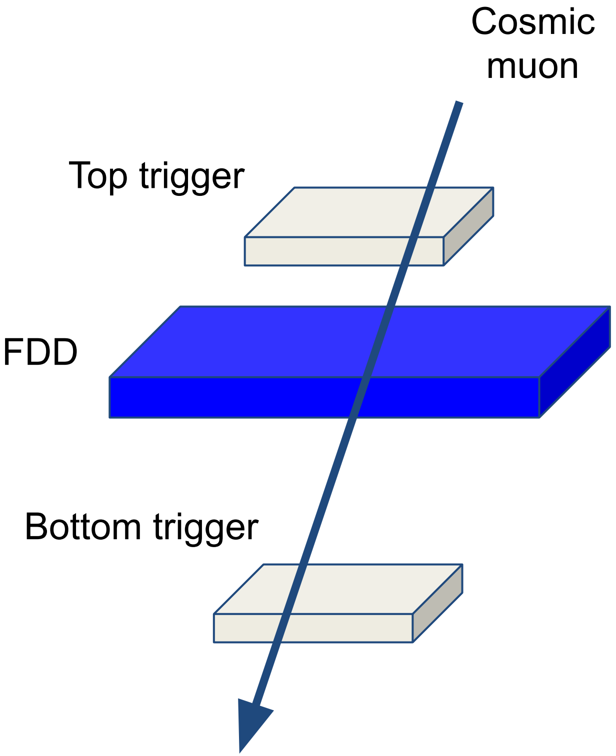


Processing Module

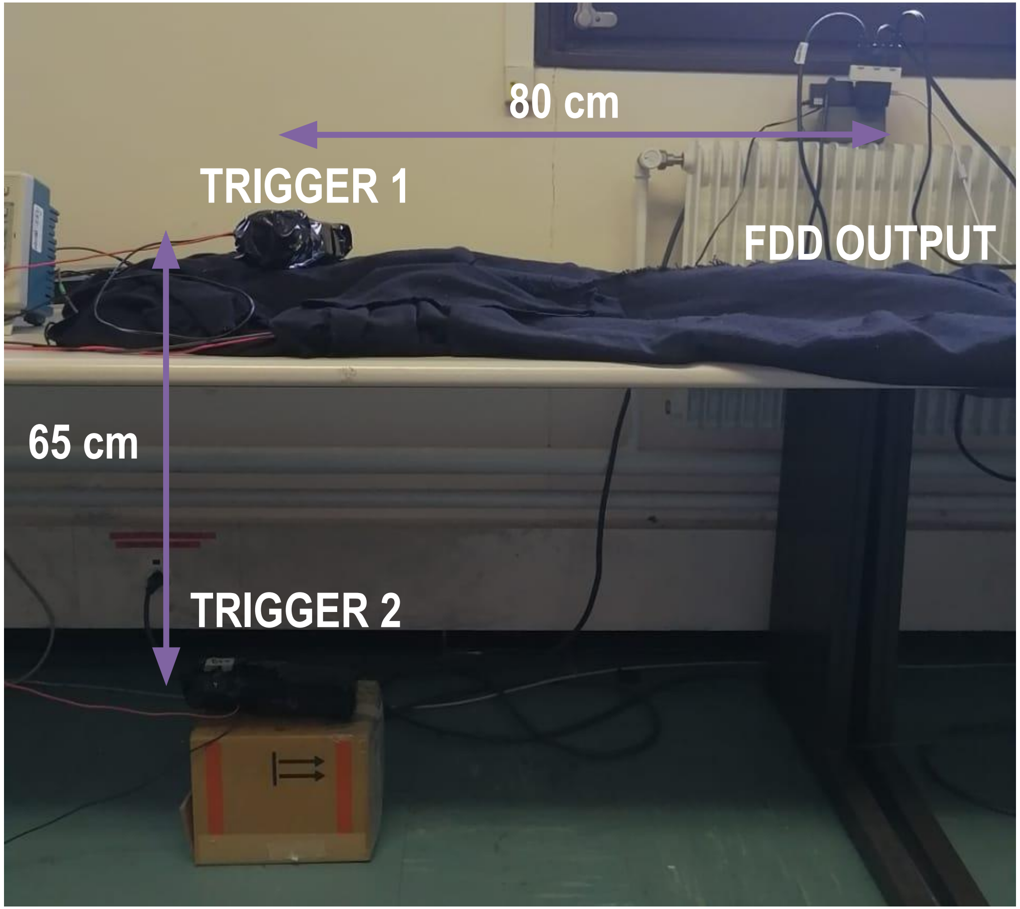


FIT Front-End Electronics test

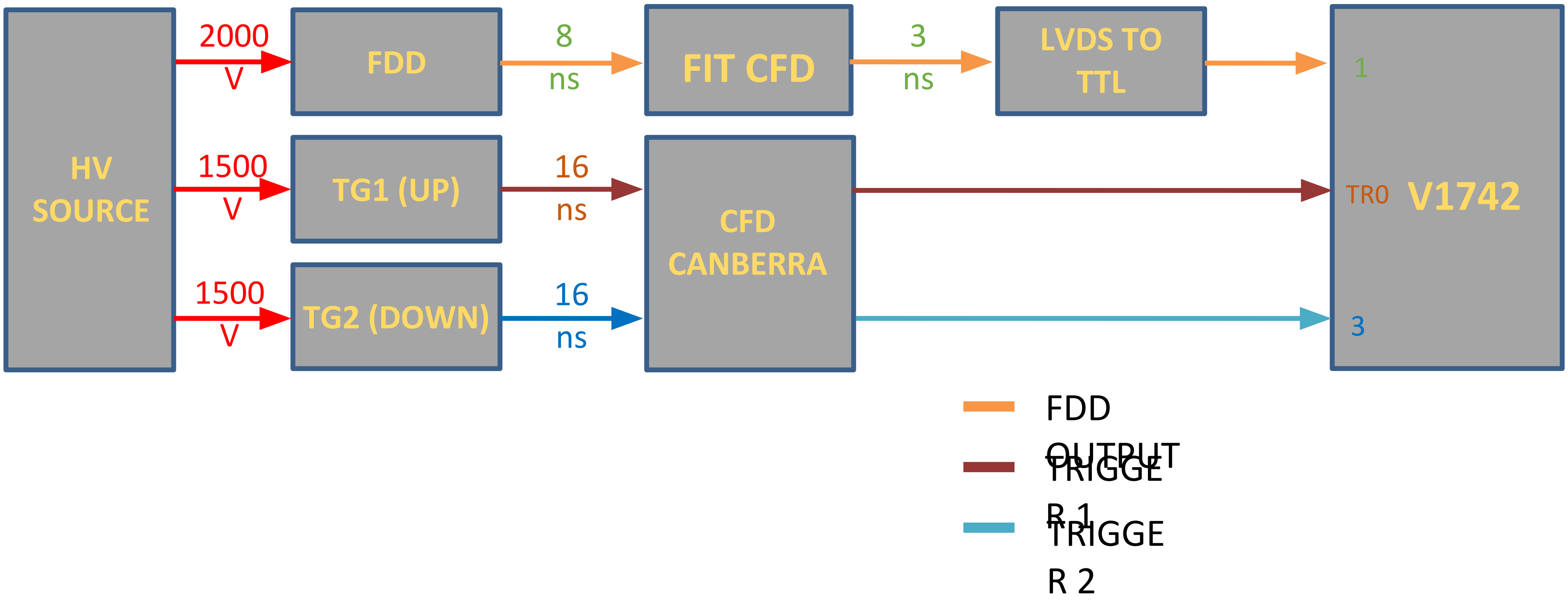
- PMT model: **H6153-70** (AD)
- To measure the time resolution we use two scintillators to **trigger cosmic muons**.
- **FDD prototype** under test was placed between two scintillators, **Top and Bottom**.
- The analogs signals from the triggers were sent to a commercial CFD.
- This logic pulses were sent to the **V1742 digitizer** (5 Gsamples/s)



Detectors configuration

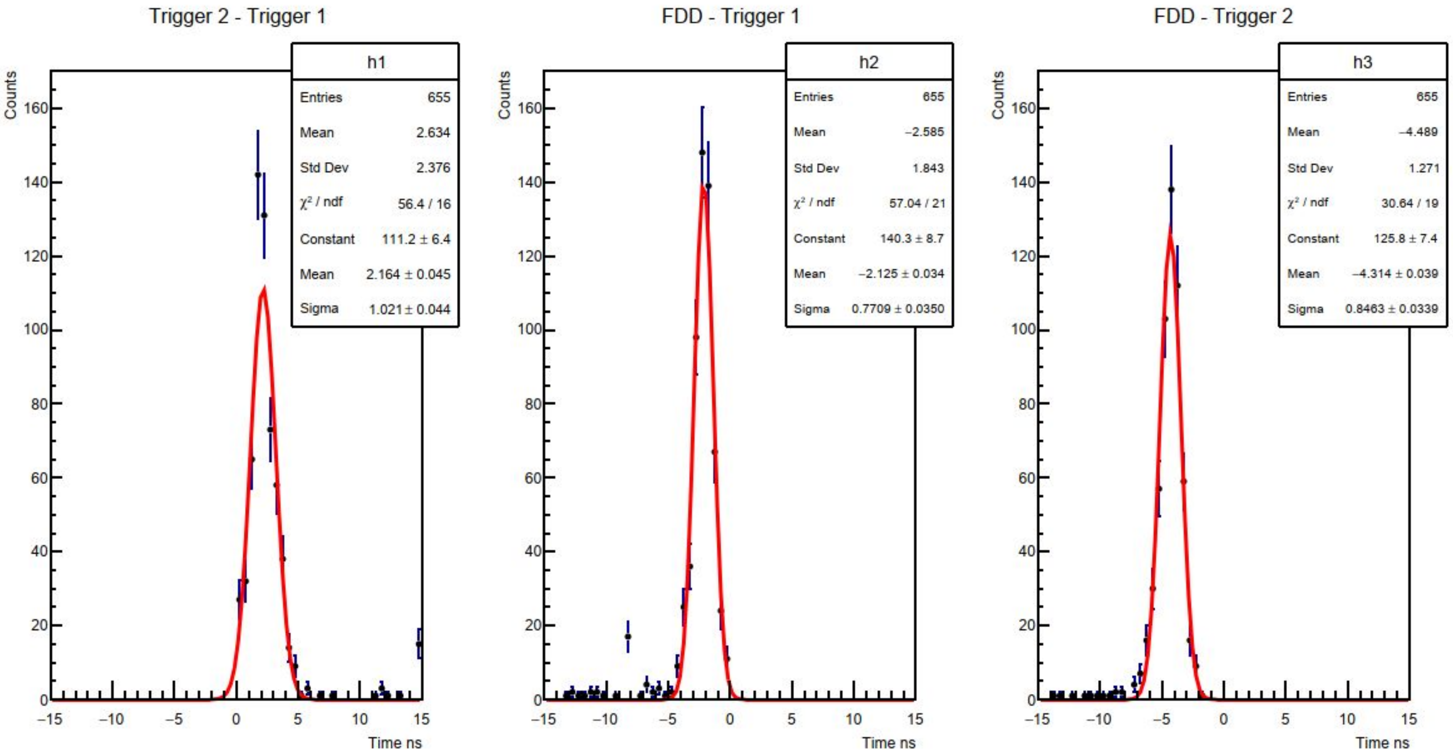


Connection of diagram



FIT Front-End Electronics test: **Time**

FDD time resolution: 0.367 ± 0.148



Final Comments

- Since the **AD detector worked successfully during Run 2**, we expect that with the upgrade, we can achieve the **characteristics required** for the new LHC conditions.
- The **degradation in the pseudorapidity coverage** in the new configuration of ALICE, make **FDD most important** to contribute to the coverage.
- We will make more studies in order to have the **complete characterization of the new detector**.
- In the next months will be measured its properties using a Laser and a different signal cable in order to **have a 25 ns pulse width**.
- We will **calibrate and characterize the PMTs** for the installation.
- New equipment has arrived to the laboratory of physics faculty, therefore, we can test the prototypes either at CERN or in the university laboratory.

Thanks for your attention!