ALICE: Luminosity monitoring and measurement

OUTLINE

- Luminosity goals
- ALICE Detectors for luminosity
- Beam gas – beam-beam trigger
- Efficiency Simulations
- Precision in luminosity measurement
- ALICE-ZDC and LHC-Luminometer
- Online Vertex determination
- Luminosity / Beam quality monitoring
- Summary

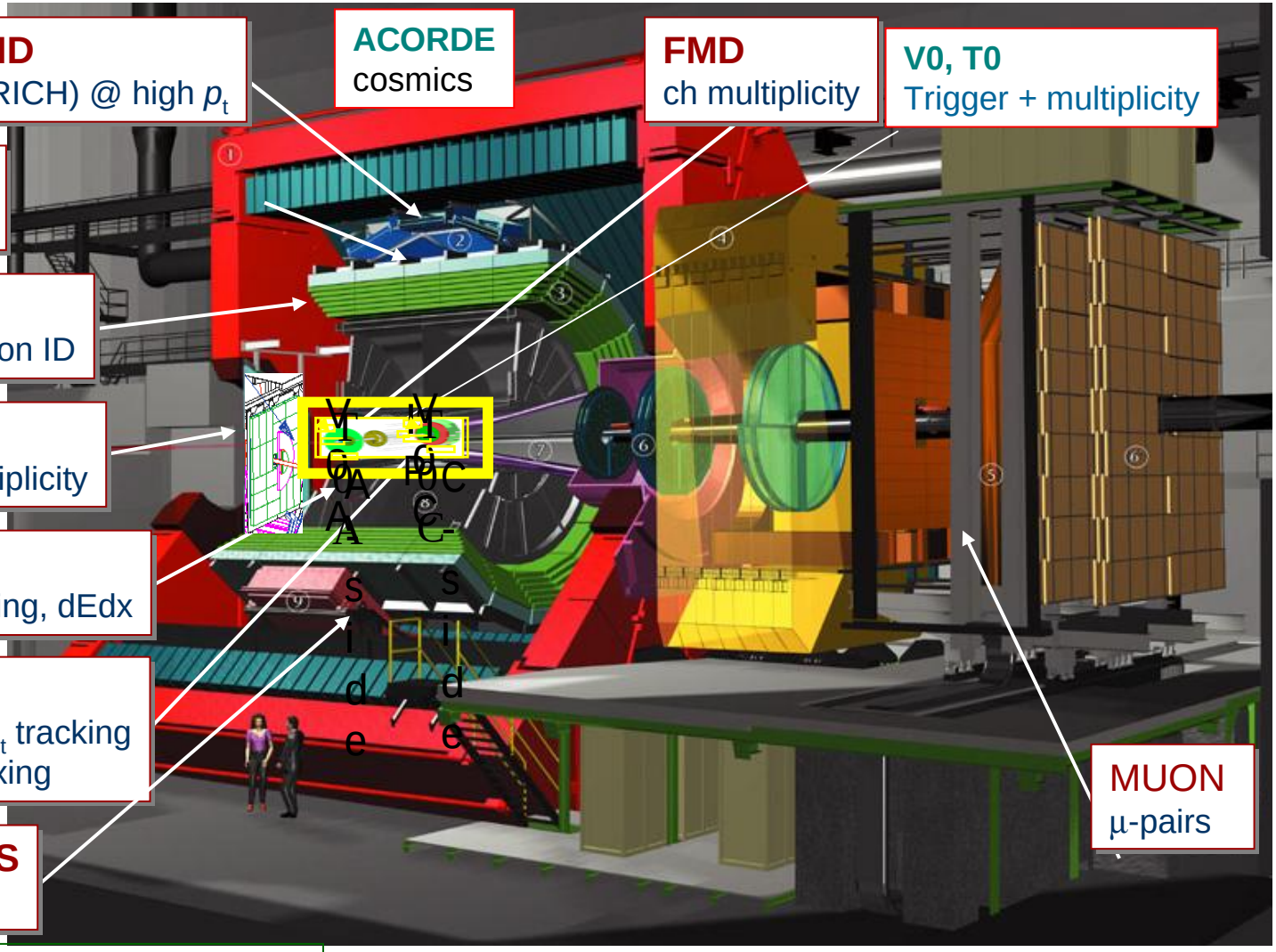
Joint LHC Machine - Experiments Workshop
January 26, 2007

Tapan Nayak
For the ALICE Collaboration

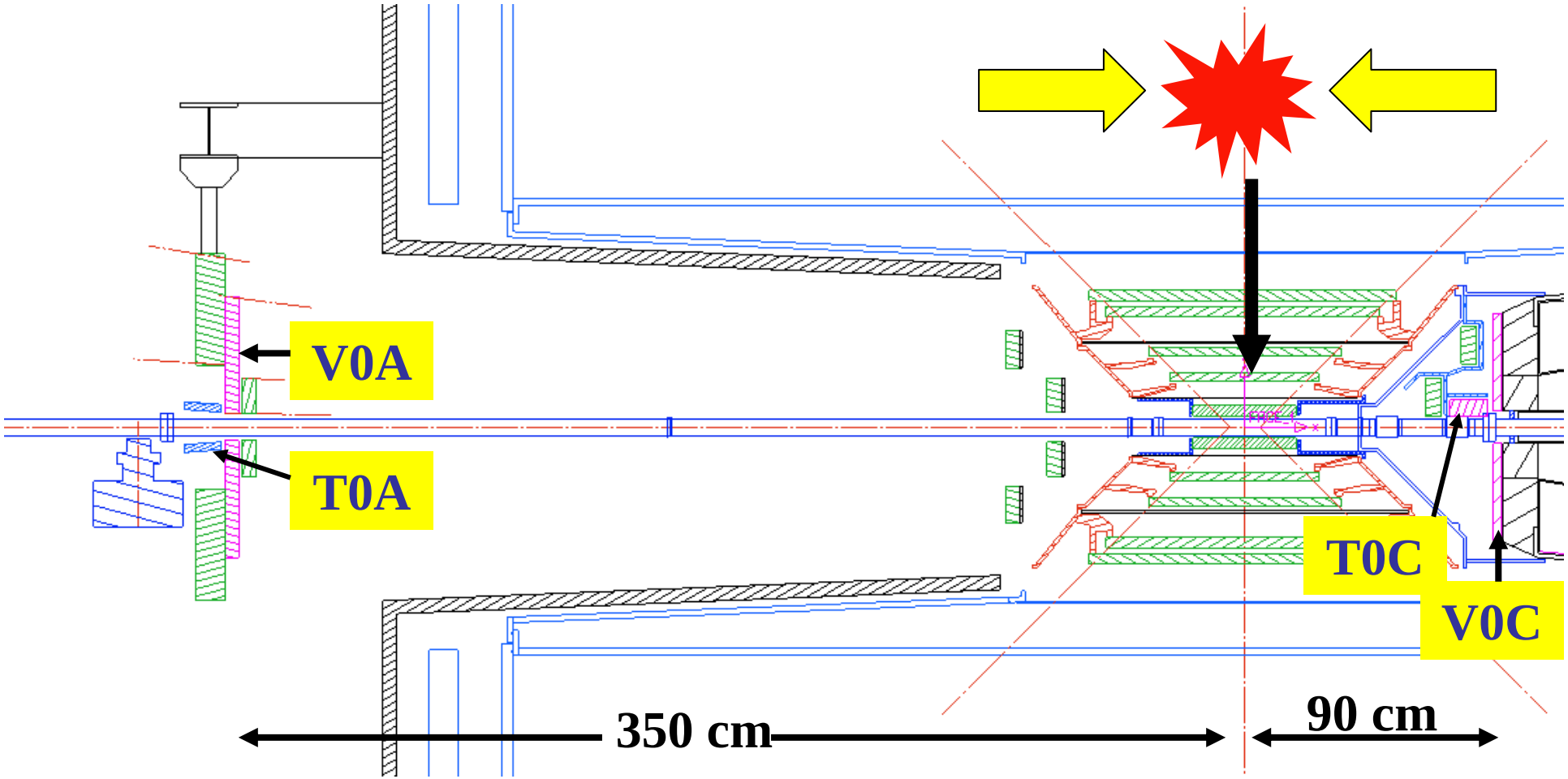
Luminosity goals in ALICE

- Luminosity measurement using:
  - ALICE - V0
  - ALICE - T0
  - ALICE - ZDC (for heavy ions, pp(?))
  - LHC Luminometer placed in front of ZDC
- ONLINE monitoring of luminosity:
  - Luminosity estimated from measured rates
  - Online display, monitoring and archiving
  - Feedback to LHC: needed for beam tuning, optimizing beam conditions and establishing proper running conditions.
  - L_{max} for ALICE in pp: $3x10^{30}$ cm^{-2} sec^{-1} (200 kHz rate limit as TPC drift time is 90μsec) => Very important to monitor and give feedback to LHC
- Luminosity OFFLINE:
  - Calculation of absolute luminosity with all corrections
  - Estimation of uncertainty in luminosity
  - Available for physics

ALICE at LHC Point-2

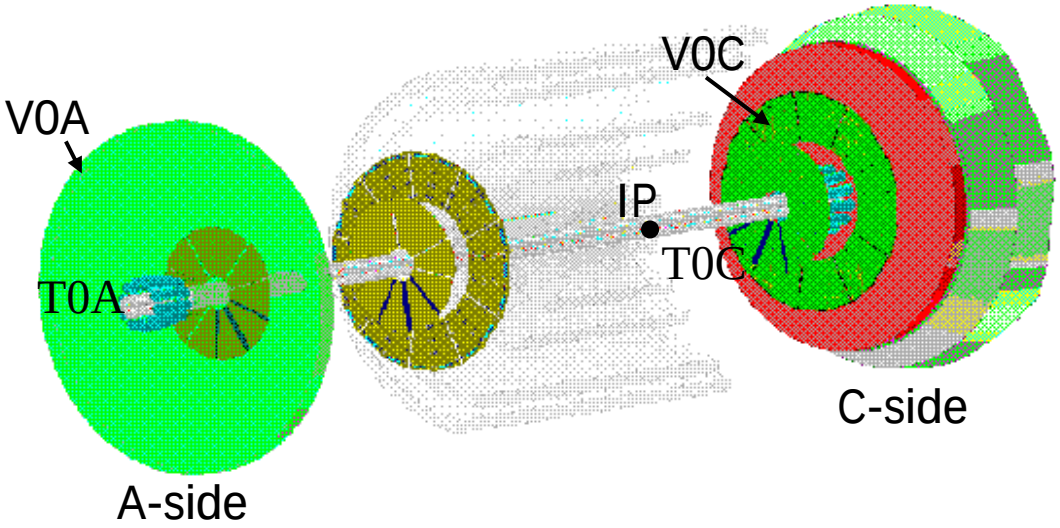


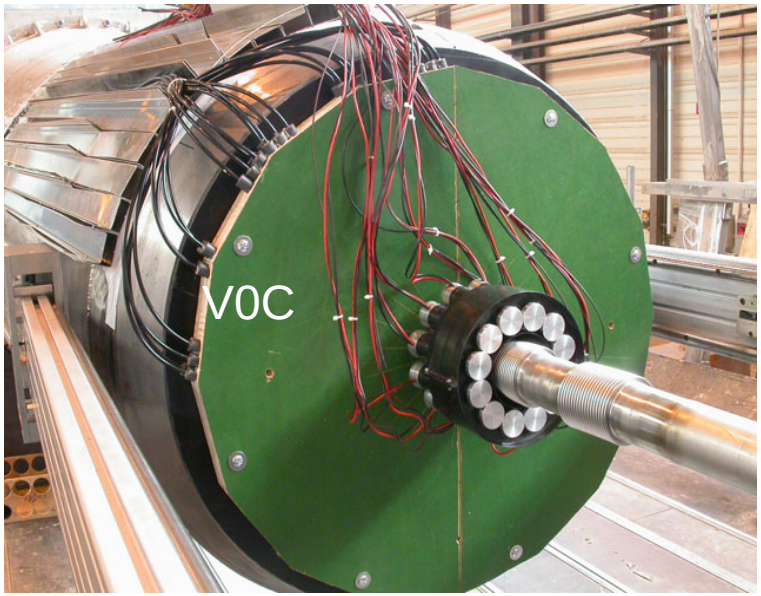
V0 and T0 positions in ALICE

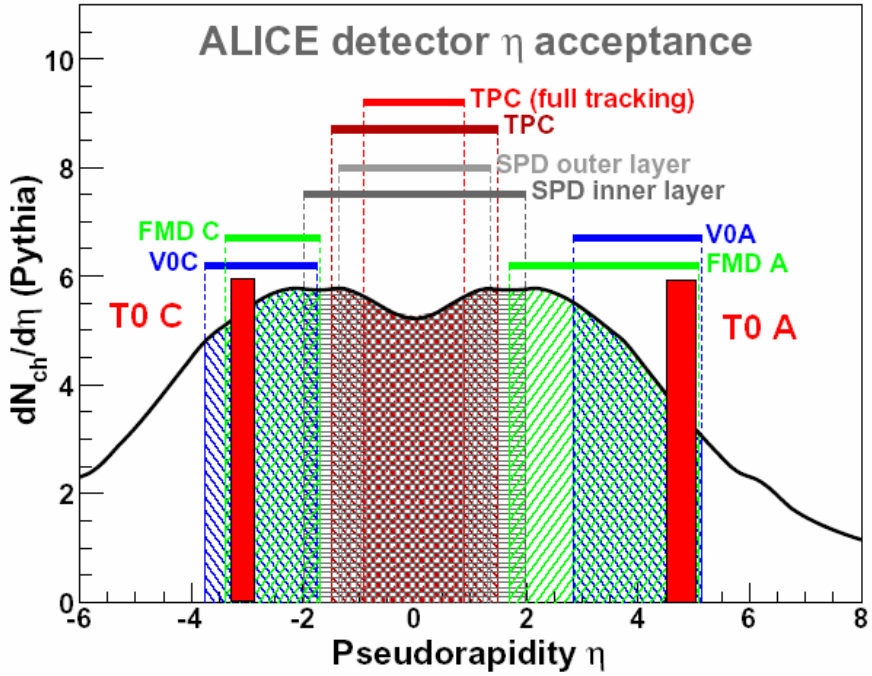


V0A @ -340 cm, T0A @ -350 cm
V0C @ 90 cm, T0A @ 70 cm

V0 and T0 detectors in ALICE

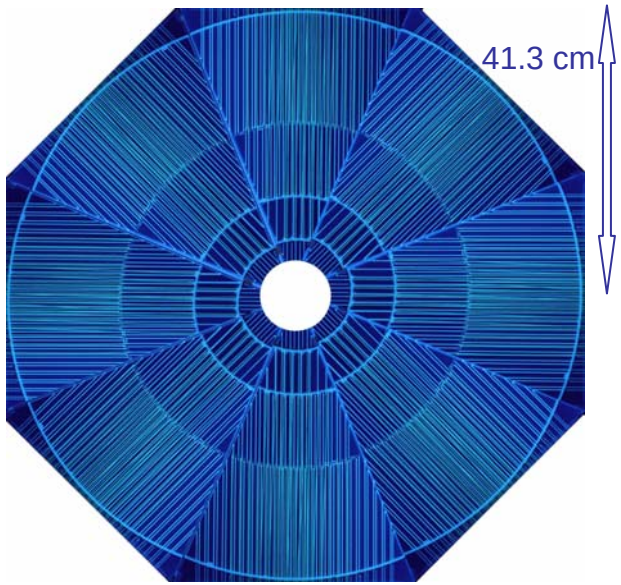




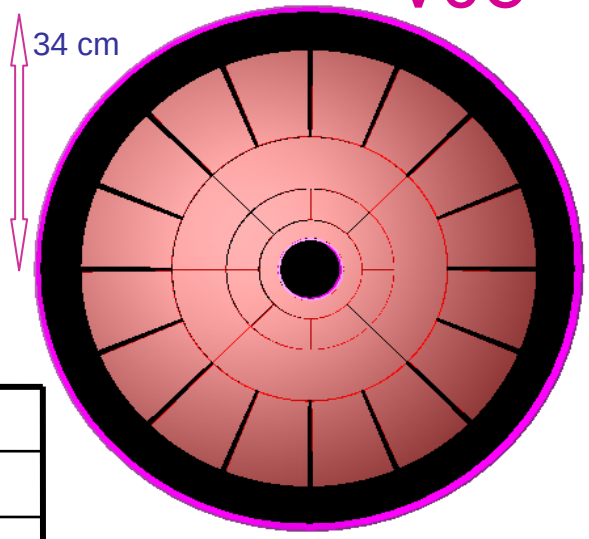


V0 detector

V0A



V0C



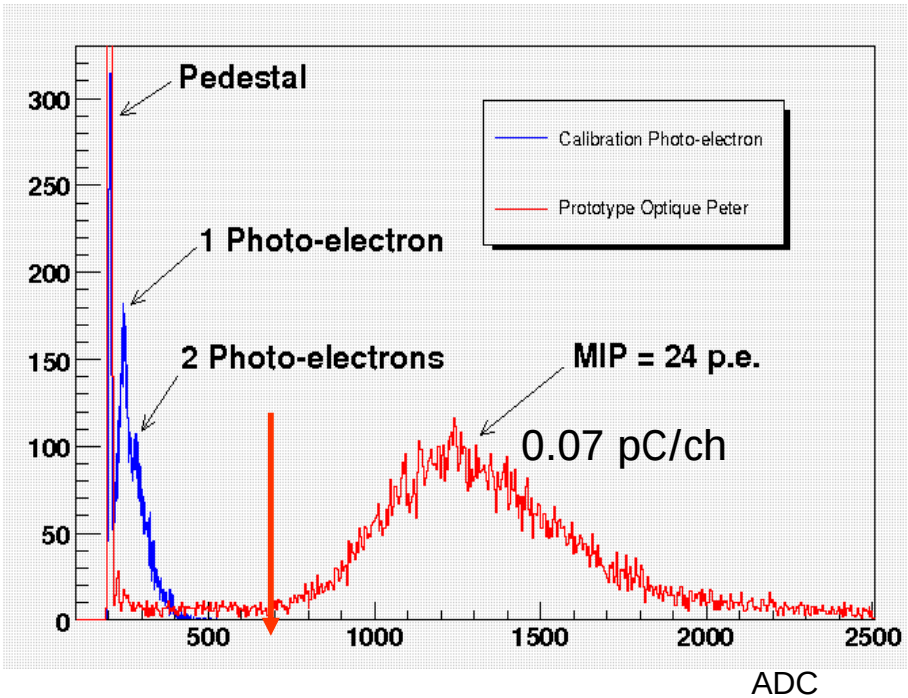
$\Delta\eta$ =>	V0A	V0C
Ring 1	5.1/4.5	-3.7/-3.2
Ring 2	4.5/3.9	-3.2/-2.7
Ring 3	3.9/3.4	-2.7/-2.2
Ring 4	3.4/2.8	-2.2/-1.7

Main Characteristics:

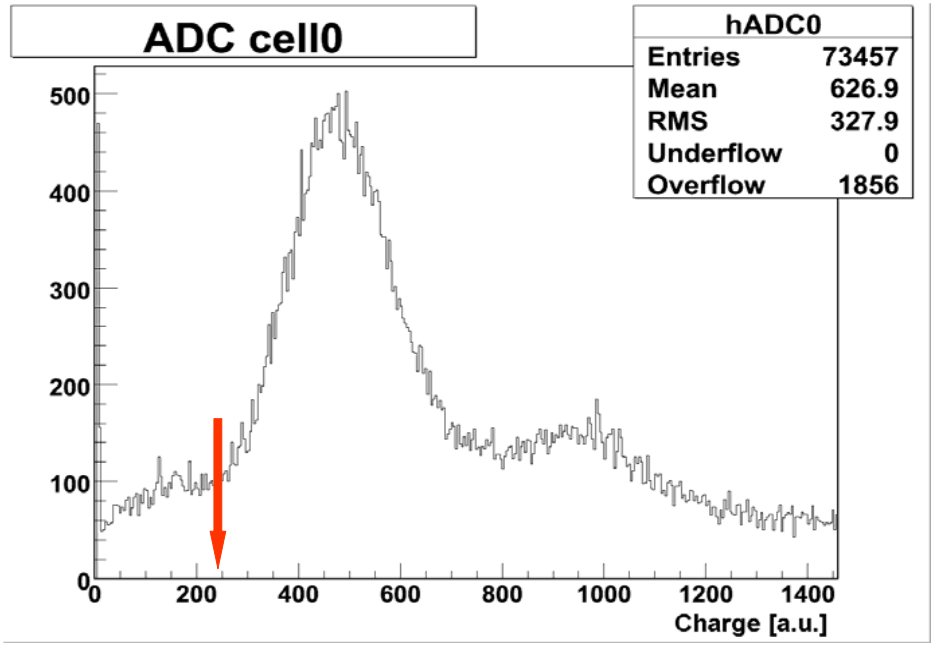
- 2 disks (V0A and V0C) on both sides of IP
- 2 x 32 channels in 8 sectors and 4 rings
- Each counter: Scintillator/fibres/ 16dyn. mesh PMT
- Time resolution of ~700ps
- Provides fast triggers
- Effective beam-gas filter
- Detector efficiency: 98% for MIP

Results from V0 cosmic tests

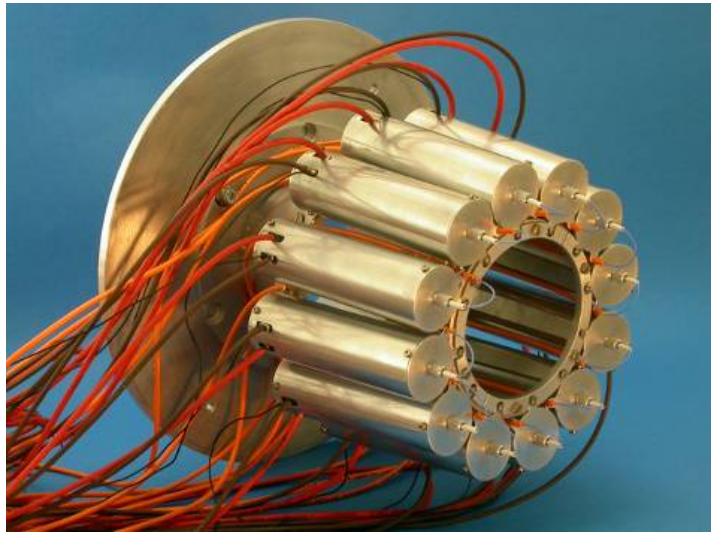
Cosmic ray Measurements

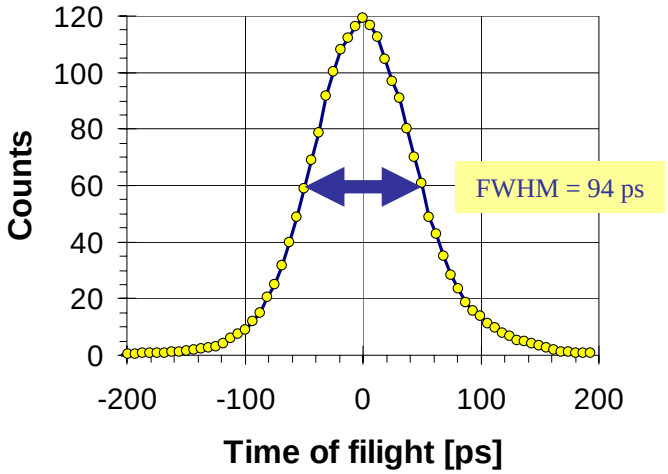


AliROOT simulation



T0 detector

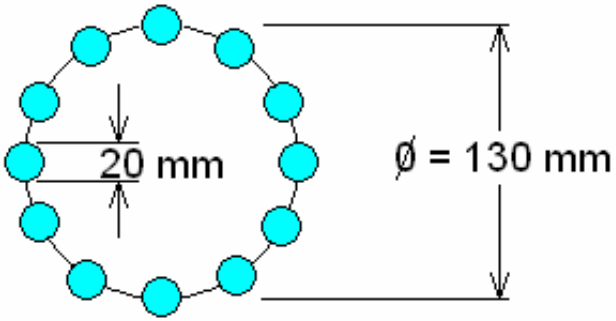




$$\sigma_{TOF} = \frac{FWHM_{TOF}}{2.35}$$

$$\sigma_{PMT} = \frac{\sigma_{TOF}}{\sqrt{2}}$$

$\sigma_{intrinsic}$ = 28 ps



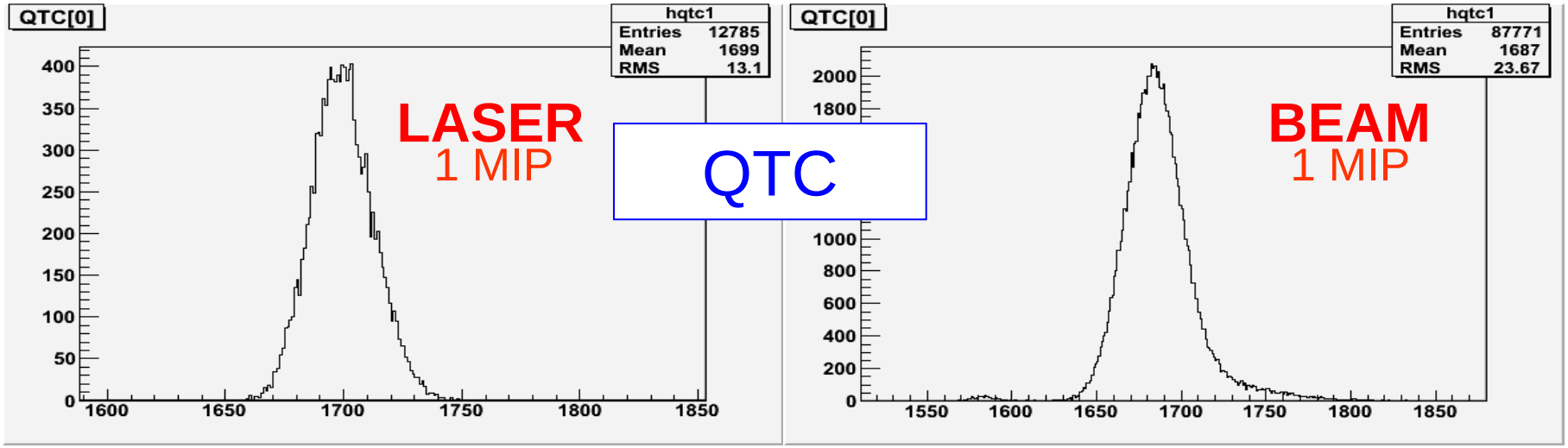
	T0-A	T0-C
$\Delta\eta$	5.0/4.5	-3.3/-2.9

Main Characteristics:

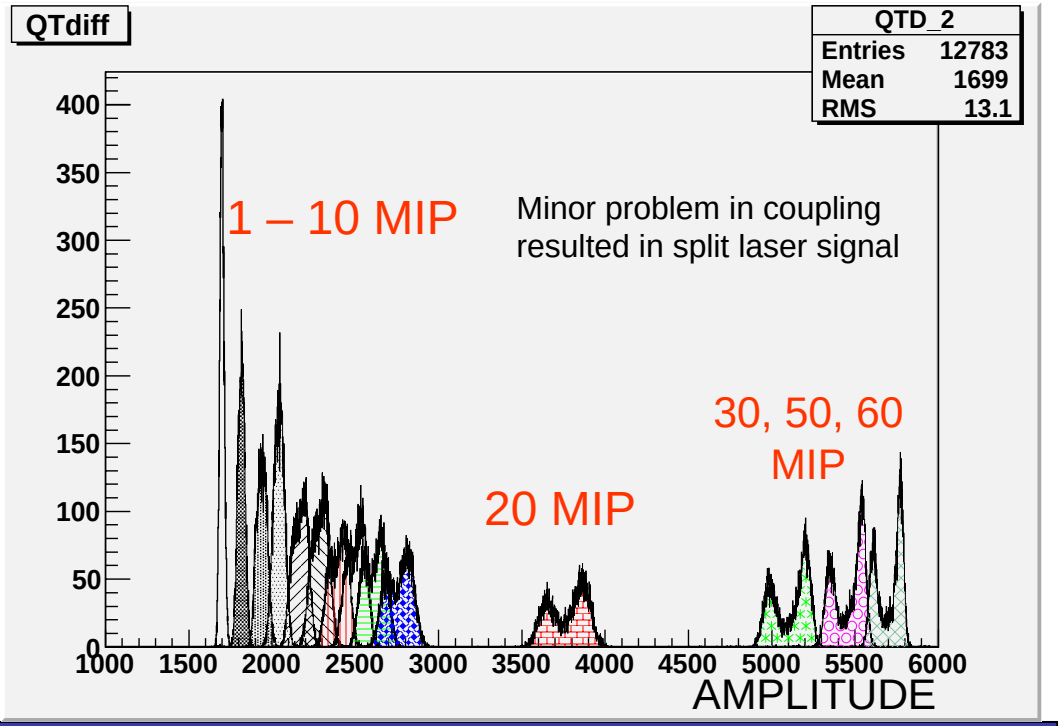
- 2 disks (T0A and T0C) on both sides of IP
- 2 x 12 channels
- Each counter: quartz radiator / PMT readout
- Time resolution of ~37ps
- provides fast triggers
- Good amplitude resolution
- Unidirectional
- Robust against potential instabilities

Disadvantage – small acceptance

Results from T0 tests

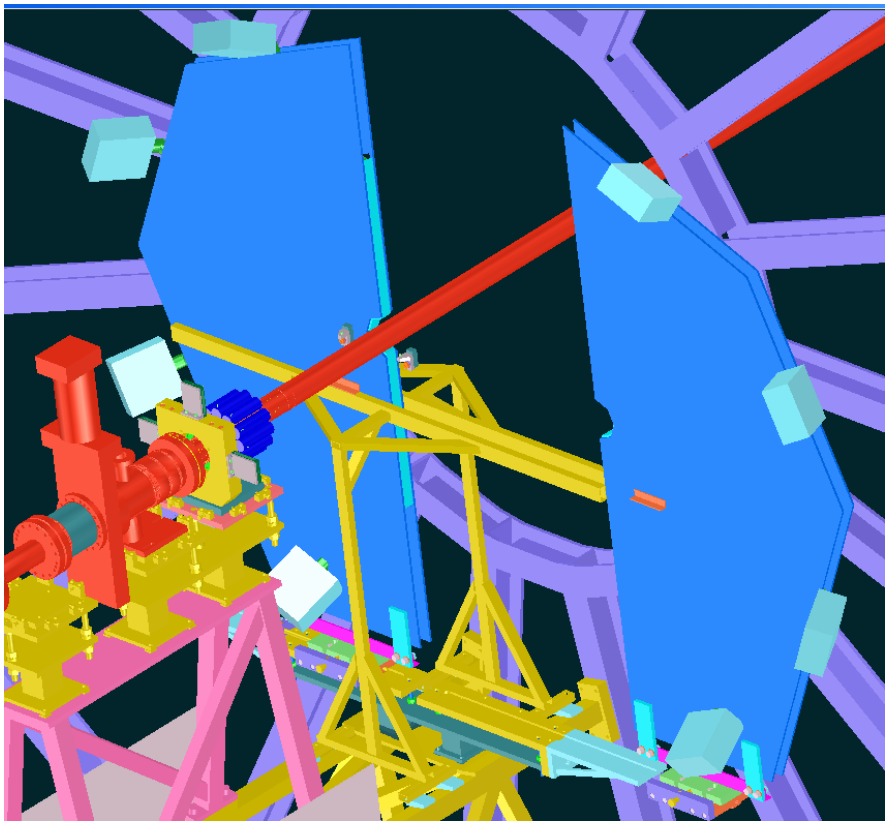


- The PMT pulse is analyzed by:
  - QTC (Charge to time converter)
  - LED (leading edge discriminator)
  - CFD (constant fraction discriminator)
- Time measurement:
  - CFD
  - LED (after slewing correction)
- Charge measurement:
  - QTC
  - LED – CFD signals

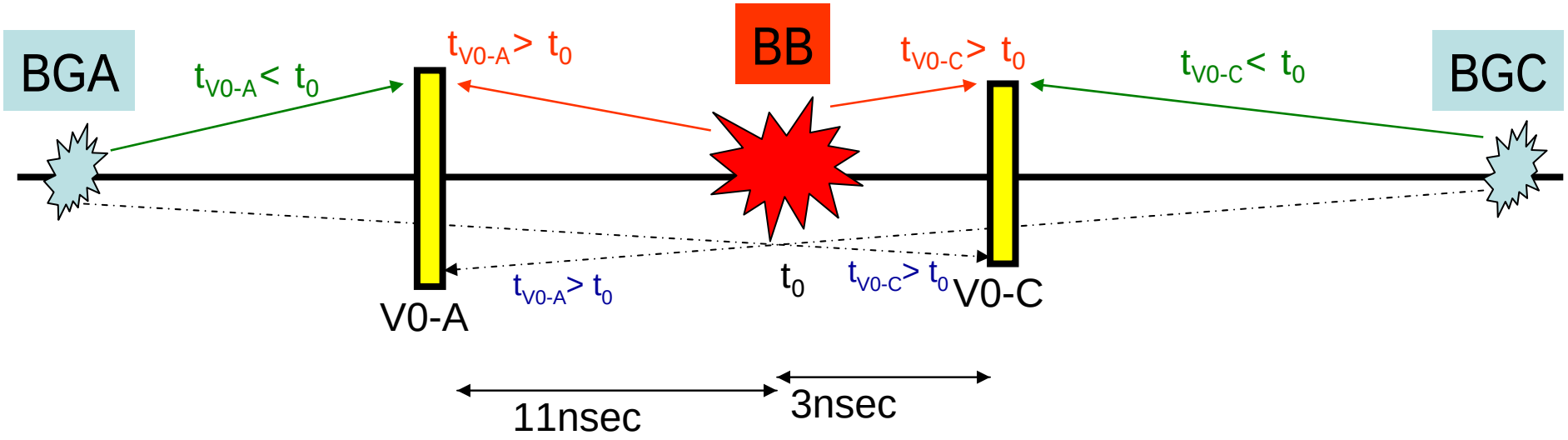


Detector alignment

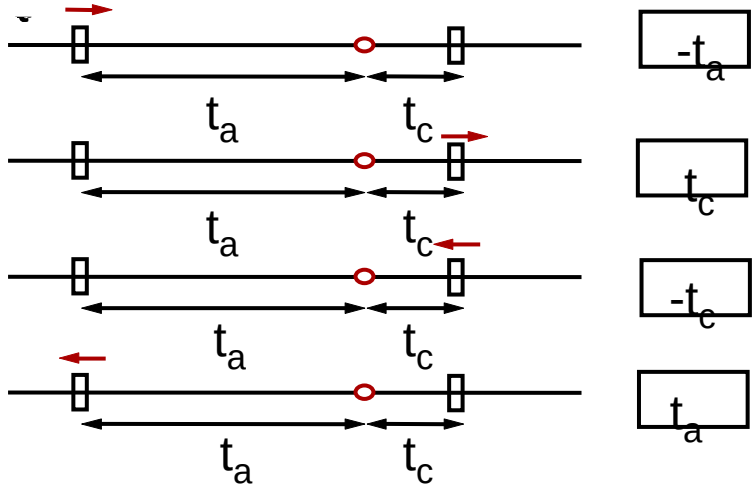
- The V0 & T0 detectors will be mechanically aligned with respect to beam pipe and not moved later during running periods
- Optical survey will be performed
- Six fiducial positions for each side will be provided for surveyors
- Survey precision: <1mm
- Survey update frequency: Once a year



Beam-beam and beam-gas interactions



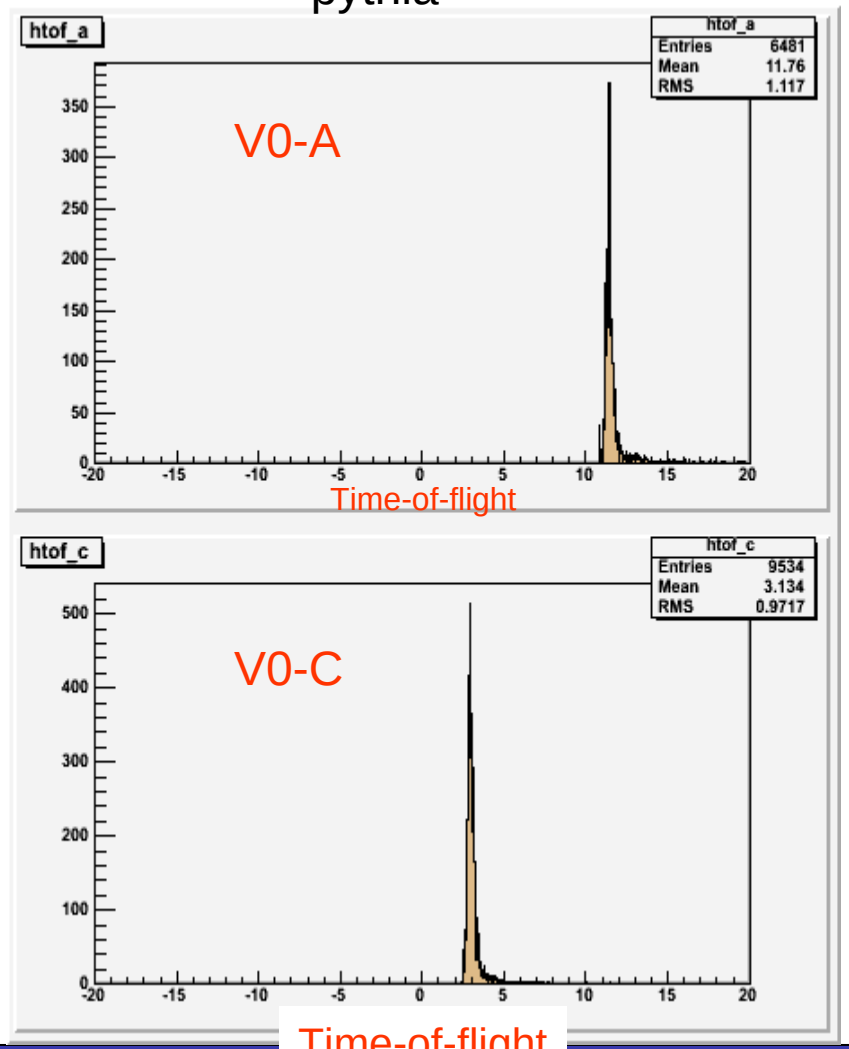
- For each bunch crossing, there are four possible times of interest when V0 might be hit
- The asymmetric arrangement of V0 helps



Beam-beam and beam-gas simulations

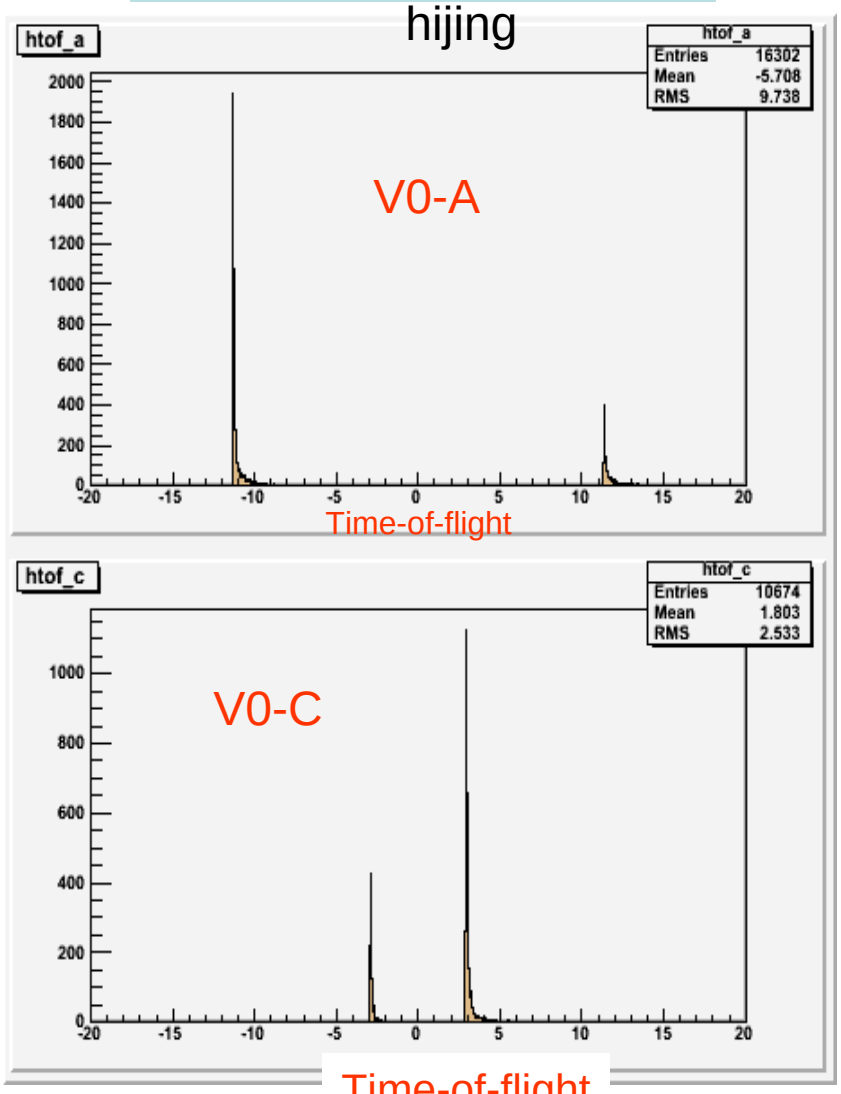
pp (beam-beam)

pythia

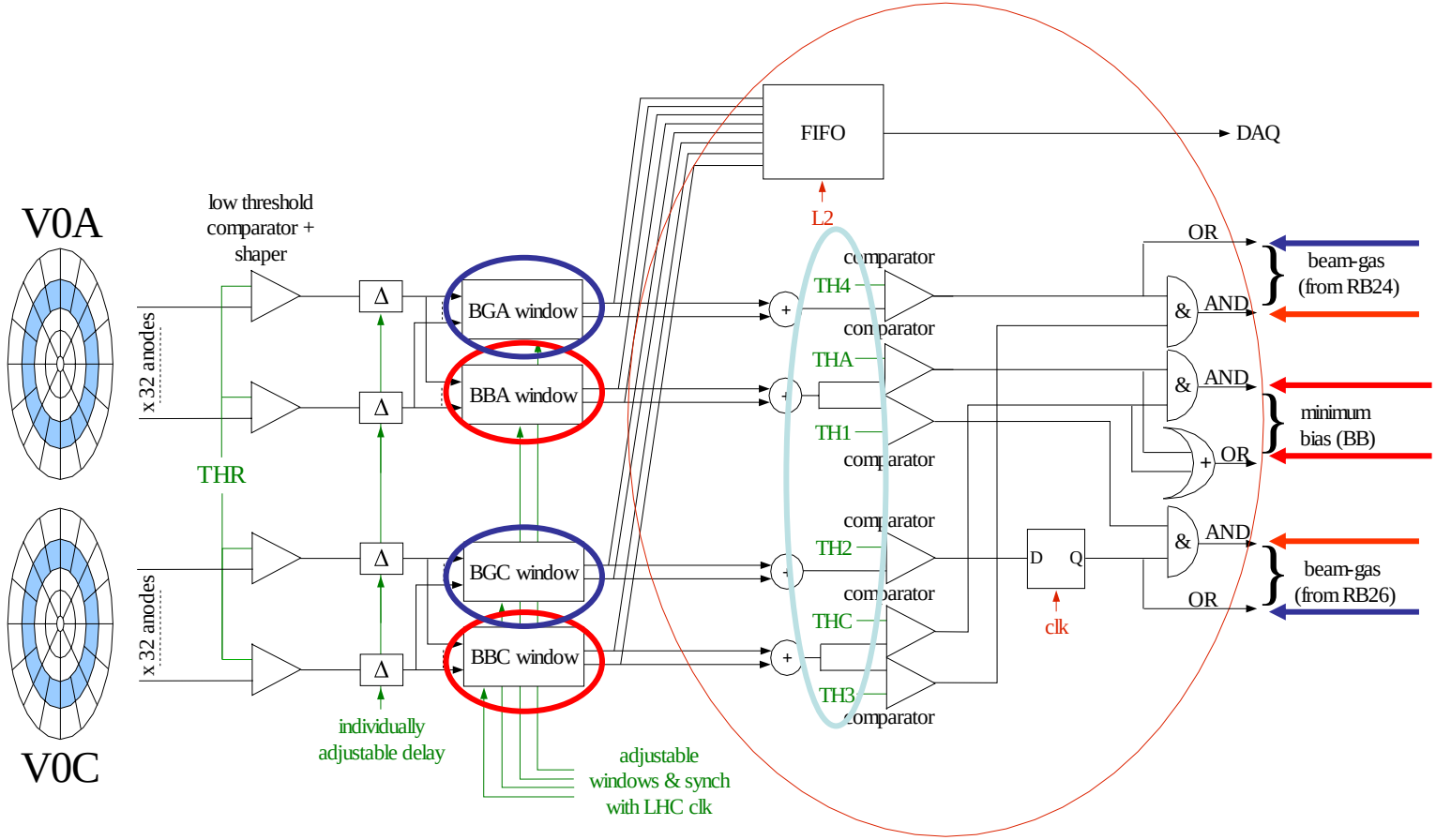


beam-gas (p+O)

hijing

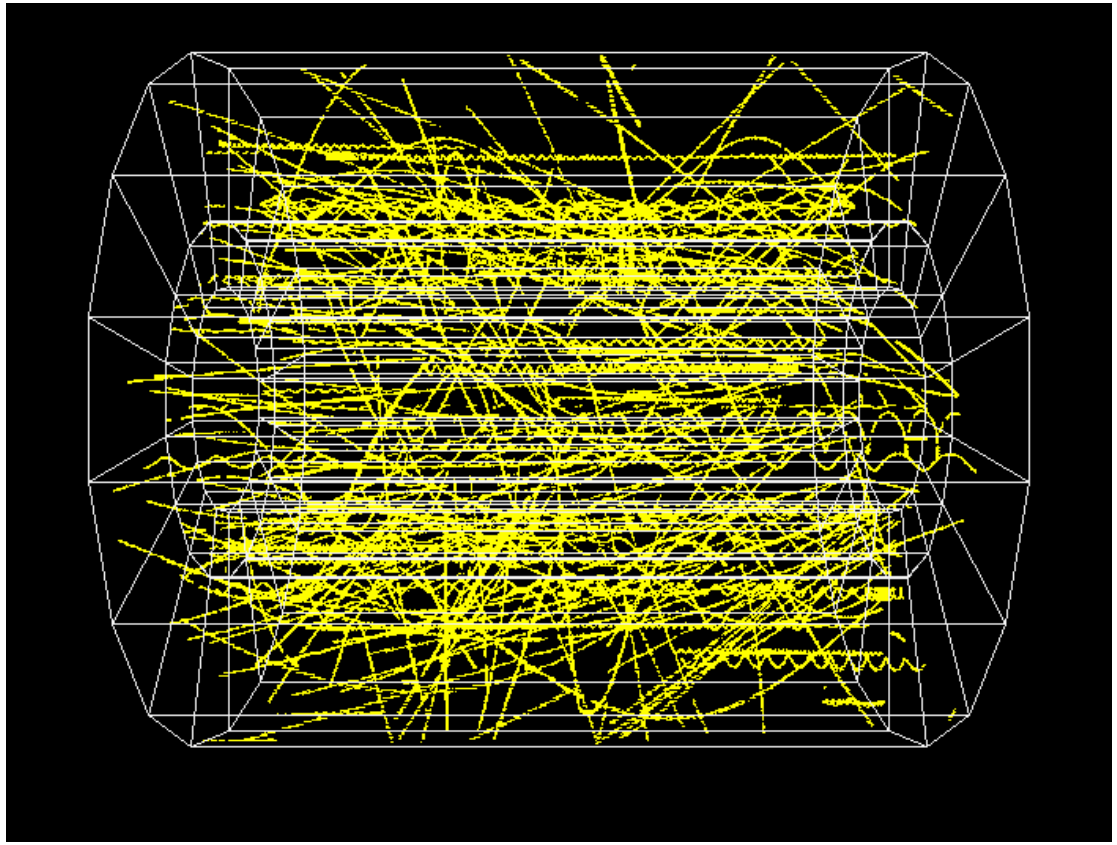


Beam-beam and beam-gas trigger



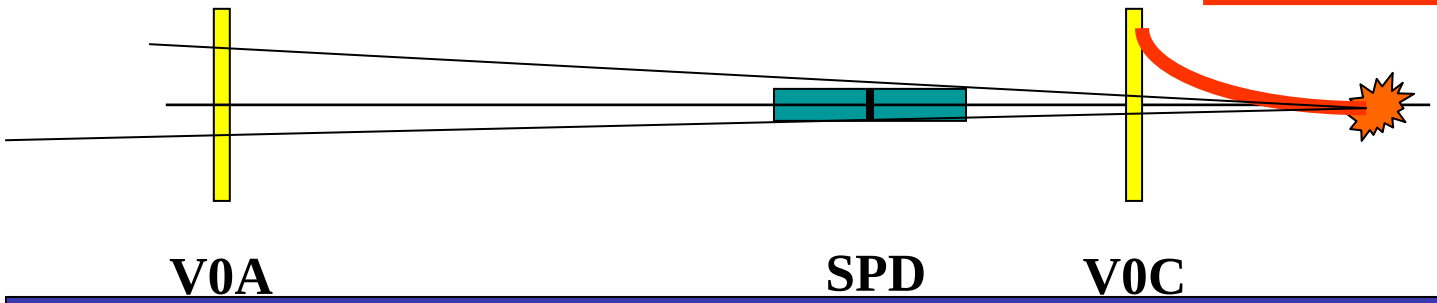
- Sources of inefficiences:
  - discrimination threshold on each PMT signal
  - observation windows applied on:
    BBA / BGA for V0A and BBC / BGC for V0C
  - threshold on the number of channels fired in each disk
  - Electronics deadtime

Hits in TPC from beam-gas



Hits in TPC from beam-gas:
- Generated using HIJING
- Beam from C (right) side
- Vertex before V0C
- trigger BBA & BGC

- We will setup both Beam-gas and Beam-Beam triggers during first commissioning runs.
- We like to request for running time with single beam.



Luminosity measurement

Luminosity relates the event rate to the interaction cross section:

$$R = L\sigma_{\text{int}}.$$

This expression is the relevant for obtaining instantaneous or relative luminosity:

- Scalars from V0A, V0C and T0A, T0C will be readout and monitored
- Cross checks between V0 and T0 (scaled for acceptances)

Absolute luminosity can be obtained over a period of time:

$$dN_{\text{evt}}/dt = L \,.\, \sigma \,.\, \underbrace{Acc \,.\, \varepsilon}_{\text{fraction of events detected}}$$

- Detailed simulations performed to find the efficiency factor.
- Cross section: initially calculated cross sections (Kaidalov *et al.*) to be used. Later on – cross sections will be obtained from TOTEM measurement.

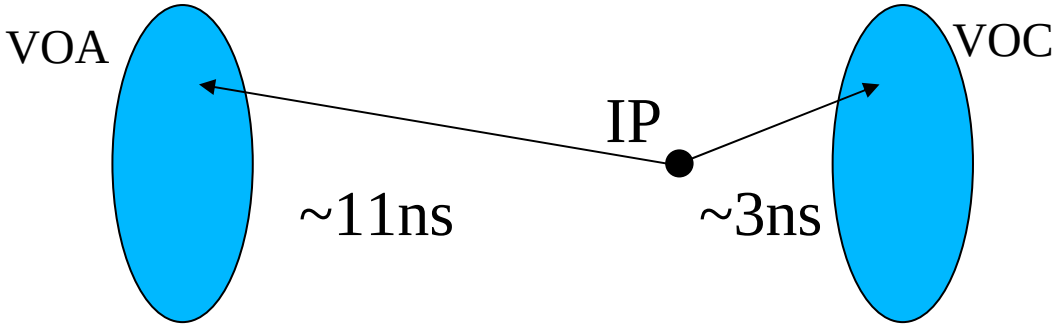
V0 simulation

Packages:

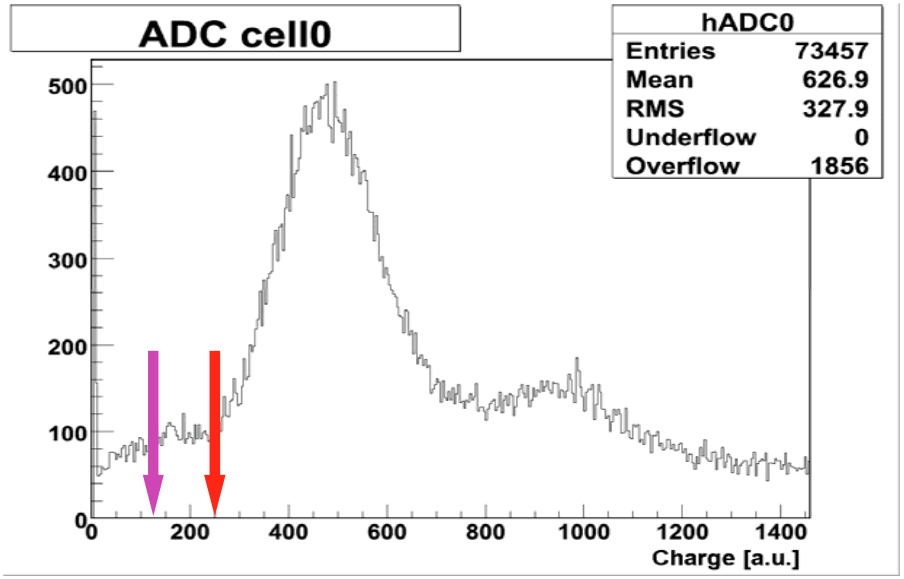
Full AliRoot simulation package

Event generation:

Pythia 6.214
pp collisions, minimum bias (kPyMb)
All environment (-> importance of secondary)
B=0.5 T when field ON
vertex smearing: 50 µm on x,y, 5.3 cm on z



CHARGE

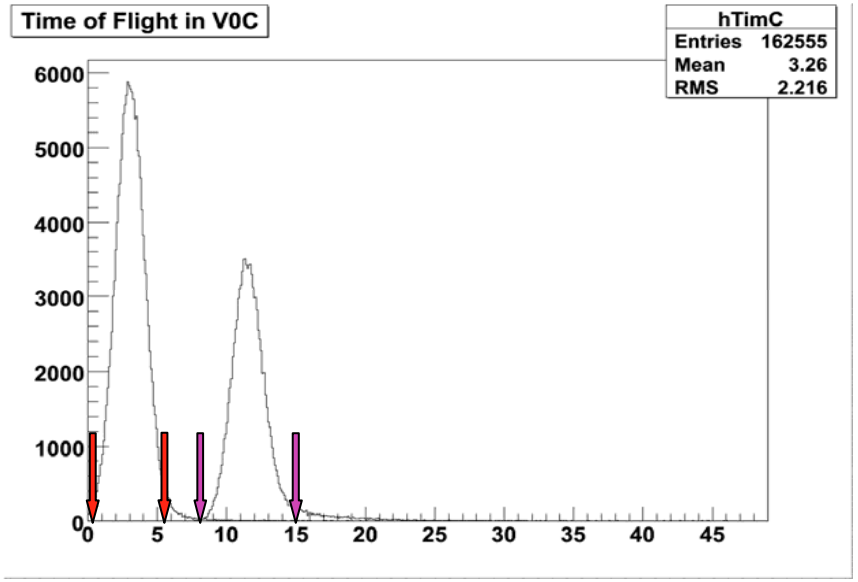


Cut at 2 sigmas

Cut at 3 sigmas

Matches well with cosmic data

TIME



Time resolution of 0.7 ns.

Efficiency Simulations

V0 Efficiencies (in %)

The numbers in the (..) parentheses are for non-diffractive processes.

	0.9TeV	2.2TeV	14TeV
V0-A	84.8 (98.6)	85.7 (99)	87.2 (99.2)
V0-C	83.6 (98.1)	84.2 (98.6)	87.1 (98.8)
V0 - OR	92.7 (99.8)	92.7 (99.9)	93.5 (99.9)
V0 - AND	**75.8 (96.9)**	**77.2 (97.8)**	**80.8 (98.1)**

T0 Efficiencies (in %)

with a threshold of 50 photoelectrons

	0.9TeV	2.2TeV	14TeV
T0-A	34.5%	38.9%	50.1%
T0-C	45.7%	50.8%	58.8%
T0 – OR	61.4%	65.4%	69.9%
T0 - AND	**18.8%**	**24.3%**	**39.0%**

Maximum Systematic Uncertainty: 3% from simulation.

Uncertainty in estimated Luminosity

1. Uncertainty in the calculated cross section. This number will be given later on by TOTEM.
2. Uncertainty from simulation: 3% maximum (with material effect taken into account)
3. From the measured numbers of Detectors (V0, T0 ….):
   - Detector acceptance / alignment
   - Stability in detector acceptance (with beam position ….)
   - Detector stability (e.g. PMT gain etc.)
   - Detector calibration (amplitude, time ….)

   being estimated ….
4. Beam spread in *x, y* (and also *z*):
   - what will be the spread for initial runs?
5. Backgrounds: beam gas, pileup, beam halo

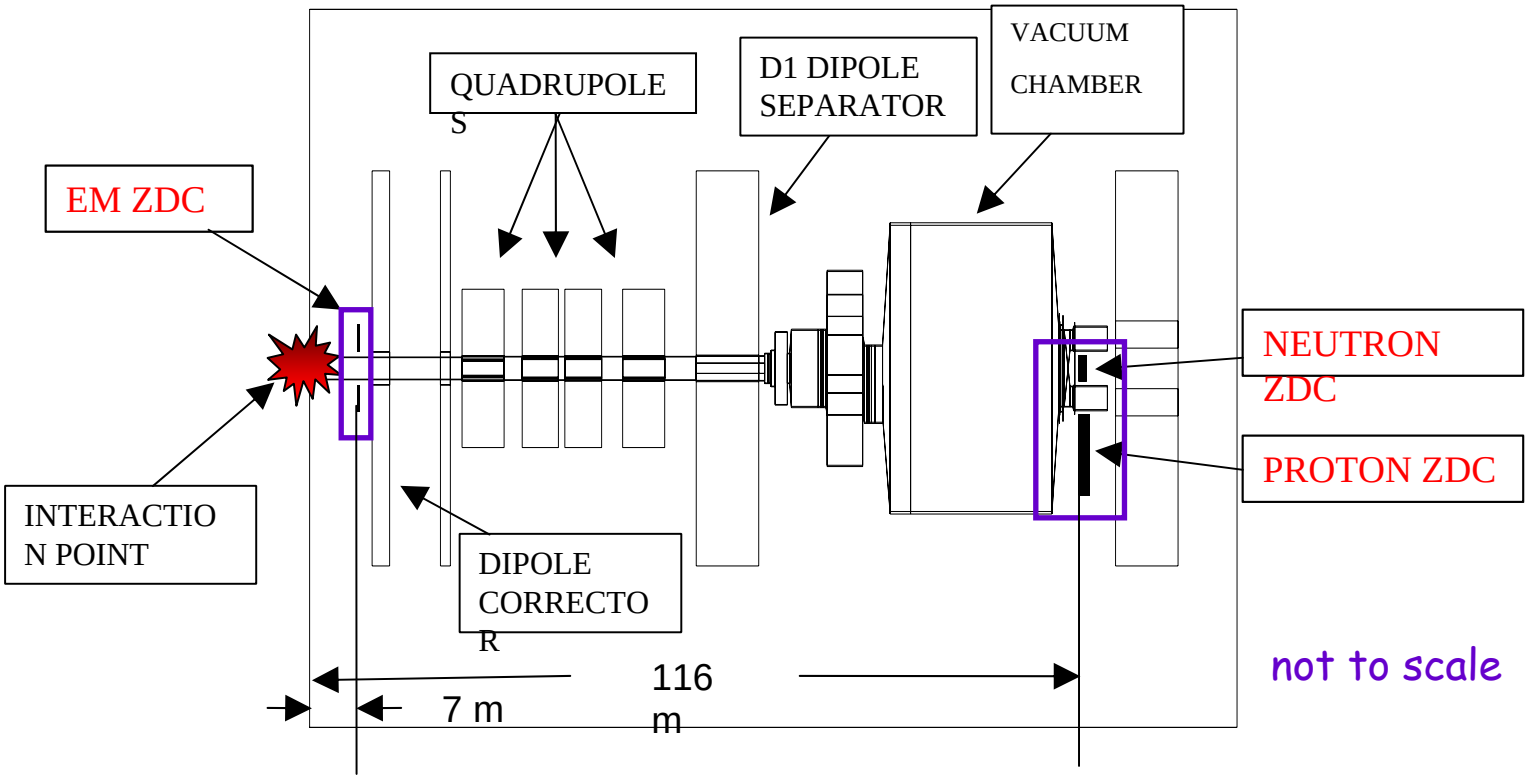
Aim:

- Initial: 10%
- Ultimate: 5%

Zero Degree Calorimeter

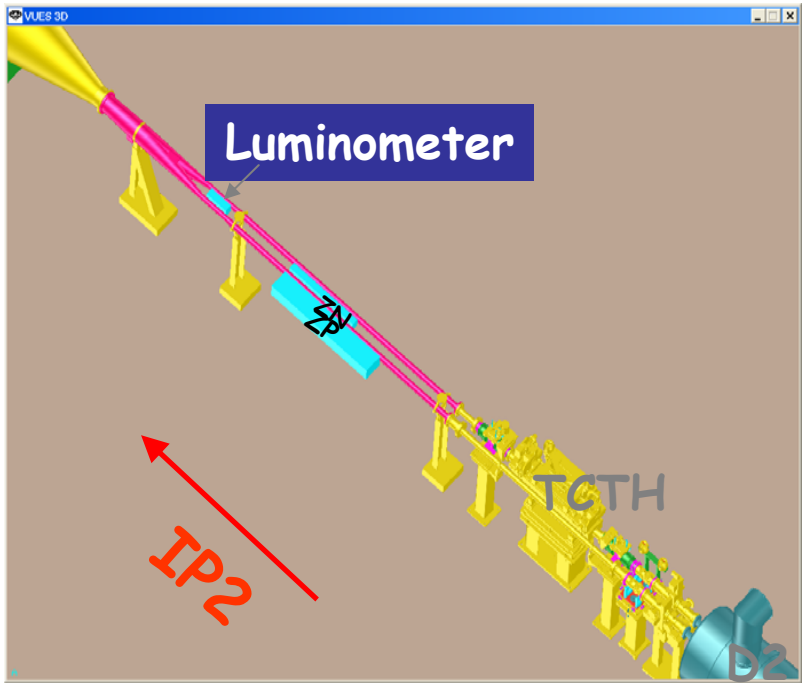
Already discussed yesterday

- Two sets of calorimeter located at opposite sides with respect to IP at 116m
- Each set of detectors consists of 2 hadronic "spaghetti" calorimeters:
  - ZN: for spectator neutrons, placed at 0° with respect to LHC axis
  - ZP: for spectator protons, positioned externally to outgoing beam pipe.

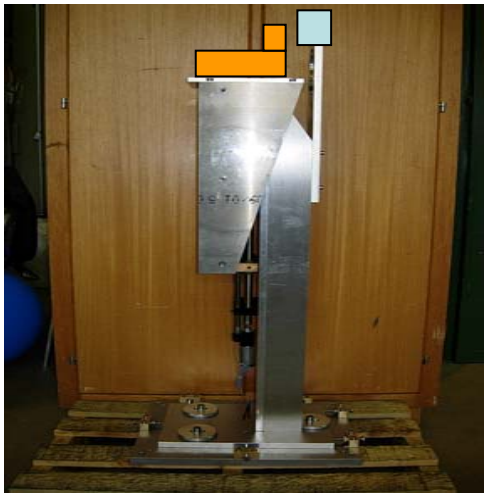


Integration of ZDC and Luminometer

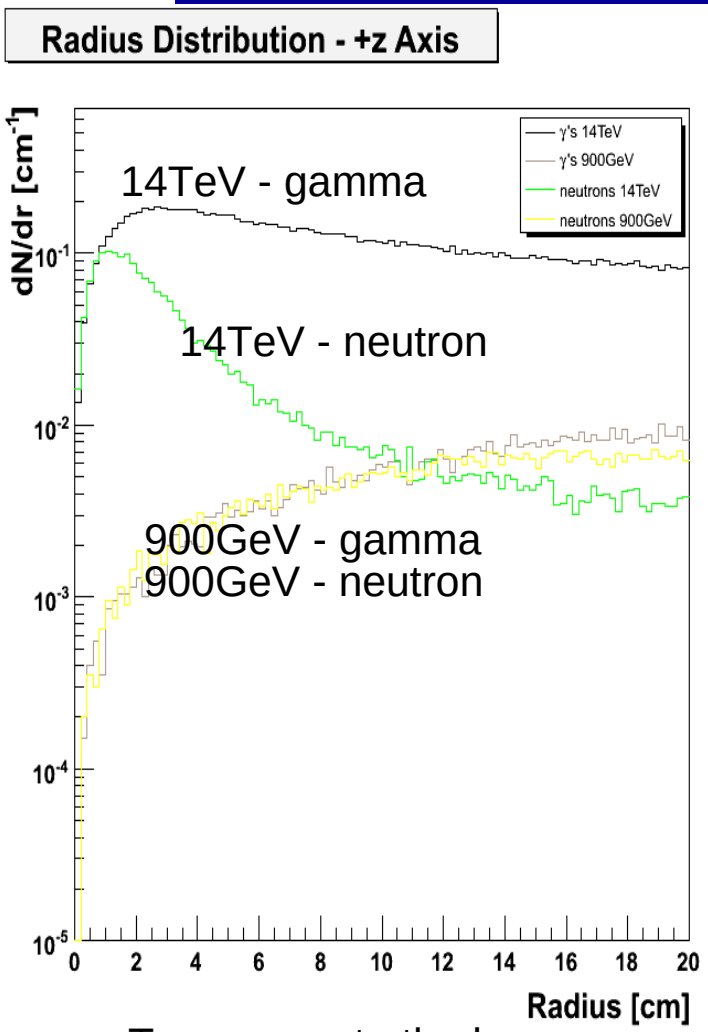
- We would like to have both the Luminometer and ZDC running for pp and heavy-ions.
- ZDC performance is shown to be not affected for heavy-ions for 3-4cm Cu converter of the Luminometer.
- Optimization of the converter thickness for p-p collisions is in progress.
- The compatibility depends on the converter thickness of the Luminometer.



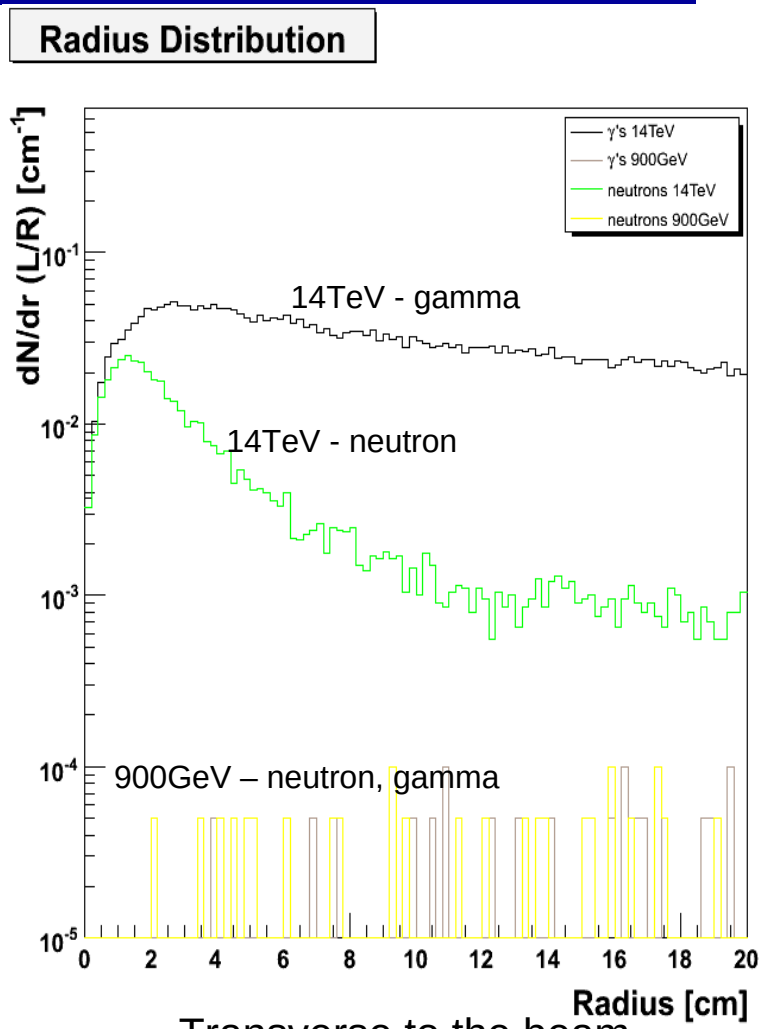
The Luminometer will be placed on a movable stand. Two converters will be placed. One can choose the converter thickness depending on p-p or heavy-ion runs.



γ *vs* neutrons: radius distribution



Transverse to the beam

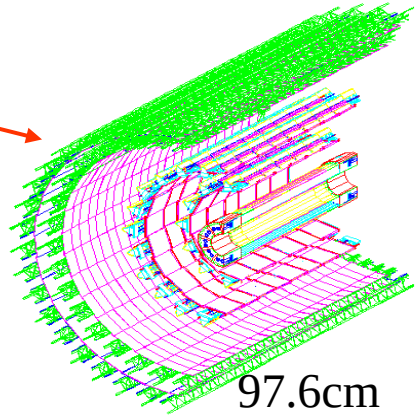


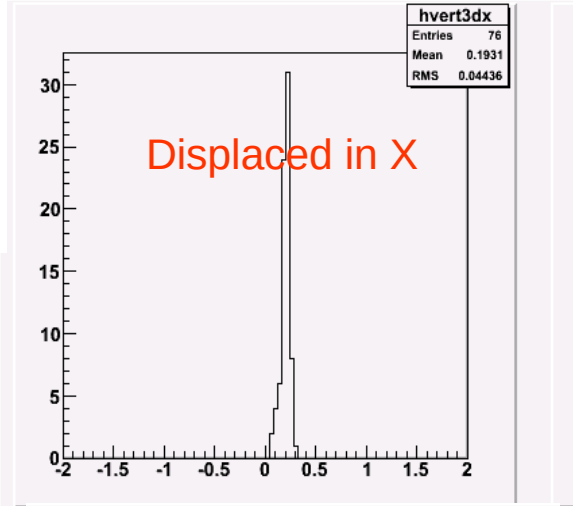
Transverse to the beam

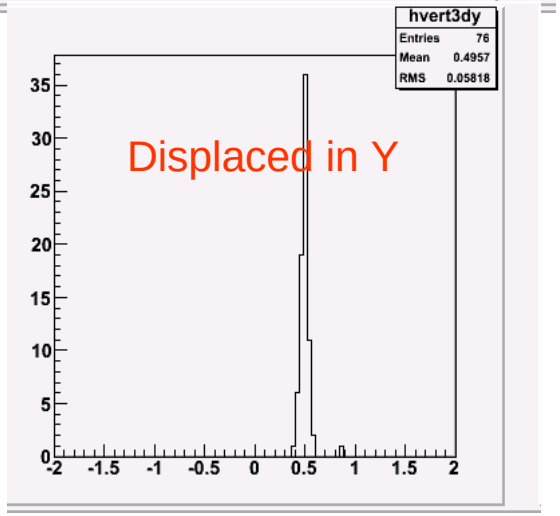
- Gammas can be measured => converter thickness can be reduced.
- Flux is down by factor 100 for 900GeV compared to 14TeV at the Luminometer position.

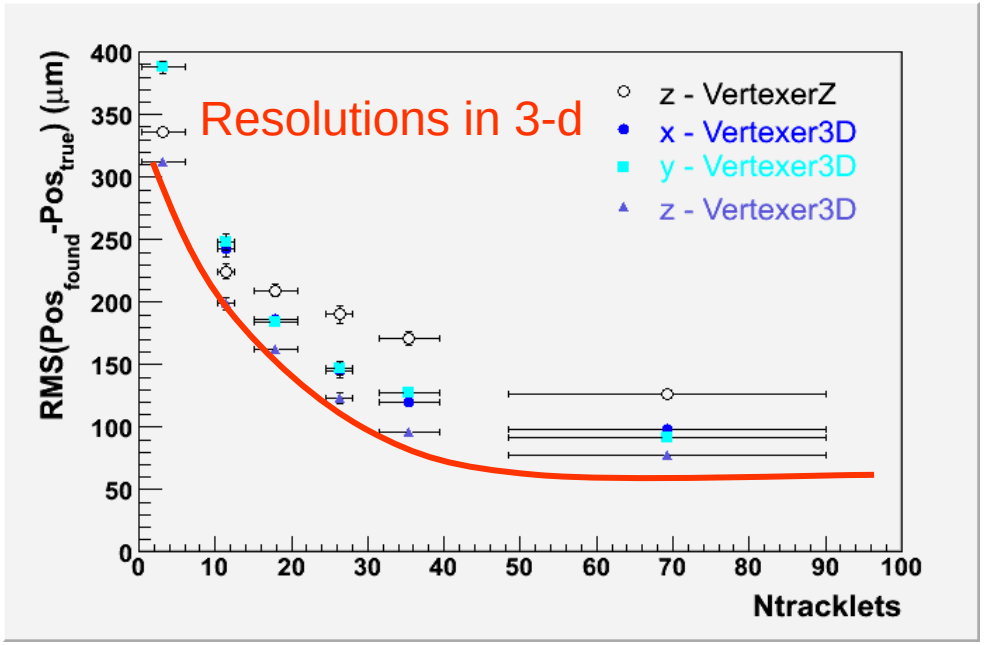
Primary vertex determination - online

- Primary vertex is determined ONLINE by using 2 silicon pixel layers of ITS
- This is important for:
  - Commissioning time and Initial running period
  - Sending information to LHC
  - Correct for displaced vertex

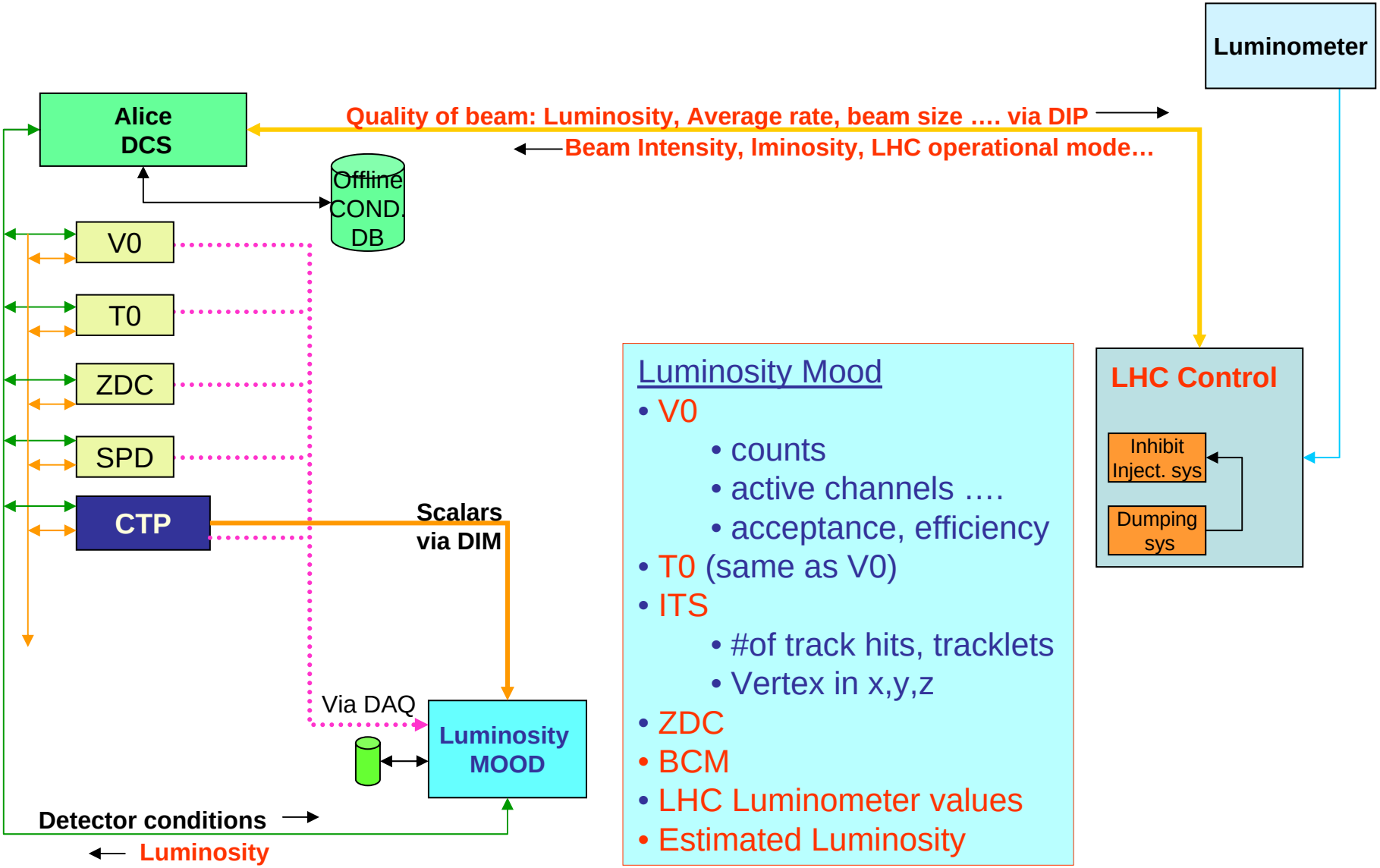








Beam Monitoring / Luminosity monitoring



Luminosity Mood

- V0
  - counts
  - active channels ….
  - acceptance, efficiency
- T0 (same as V0)
- ITS
  - #of track hits, tracklets
  - Vertex in x,y,z
- ZDC
- BCM
- LHC Luminometer values
- Estimated Luminosity

Mandate given by the Organisers of the workshop

During the LHC commissioning and start-up phase (2007-2008) we will need to optimize the procedure to adjust the luminosity at the 4 IPs. In addition, we will need to monitor the luminosity and we will probably make the first attempt to measure the absolute luminosity in order to evaluate the performace of the LHC.

The aim is to review how both the experiments and the machine are planning to proceed and what information they will make available to speed up the process. In particular:

1) How is the machine planning to optimize the luminosity at the 4 IPs? Will the experiments be able to help the machine in optimizing the luminosity in particular during the commissioning phase? If yes, what measurement can they provide and at what rate?
2) How the machine and the experiments are planning to monitor the luminosity and measure it? What measurements will be made available both from the machine side and the experiments side?

ALICE to LHC:

- **Luminosity / Rates**
  - **Estimate of Luminosity**
  - **Minimum Bias trigger rates**
  - **Beam-gas rates (Left and Right)**

- **Position and size of luminous region**
  - **$\langle X \rangle$, σ_X**
  - **$\langle Y \rangle$, σ_Y**
  - **$\langle Z \rangle$, σ_z**

Questions:

- Beam conditions during initial running period
- Beam displacement in transverse direction
- Beam stability in transverse direction

Summary

1. ALICE detectors:
   - V0 & T0 will be installed in summer for luminosity monitoring during initial beam periods and beyond
   - ZDC will be installed in summer for pp(?) and heavy-ions
   - Work in progress for ZDC and Luminometer compatibility
   - Work on Beam condition monitors (BCM) for beam abort system is in progress
2. LHC Luminometer: very good progress so far - it is of our interest to have full functionality of the Luminometer from Day-1.
3. Triggers: beam-gas and minimum bias triggers will be setup during initial running periods
4. Online vertex determination will be performed - beam positions & spread.
5. Online monitoring of beam condition and luminosity will be in place.
6. Data exchange LHC <=> ALICE: getting ready.
7. Uncertainty in Luminosity: initially about 10%, and ultimately: 5%

Many Thanks for collaboration and help to:

- **V0 Team**
- **T0 Team**
- **ITS pixels team**
- **Beam Vertex team**
- **ZDC Team**
- **DCS group**
- **Trigger group**
- **DAQ and monitoring group**
- **Data exchange (LHC-ALICE) group**
- **ALICE Offline group**

- **Luminometer group**