ALICE ZDC

Responsabilities shared by the following Institute:

- ♦Universita' del Piemonte Orientale, Alessandria, Italy
- ♦INFN-Cagliari and Universita' di Cagliari, Italy
- ♦INFN-Torino and Universita' di Torino, Italy

Outline

- ***Aim of the project***
- ***Detector description***
- ***Status***
- ***Integration issues***
- ***Installation planning***

Aim of the ALICE ZDC

during H.I. runs:

- *Event characterization*:
  - Magnitude of impact parameter → **Centrality of the collision**
  - Orientation of impact parameter → **Reaction plane orientation**
- *Absolute luminosity*
  - by measuring the rate of **mutual e.m. dissociation** in the neutron channel

during pA runs:

- **Centrality of the collision**
  - by measuring the energy of gray and black nucleons (slow nucleons)

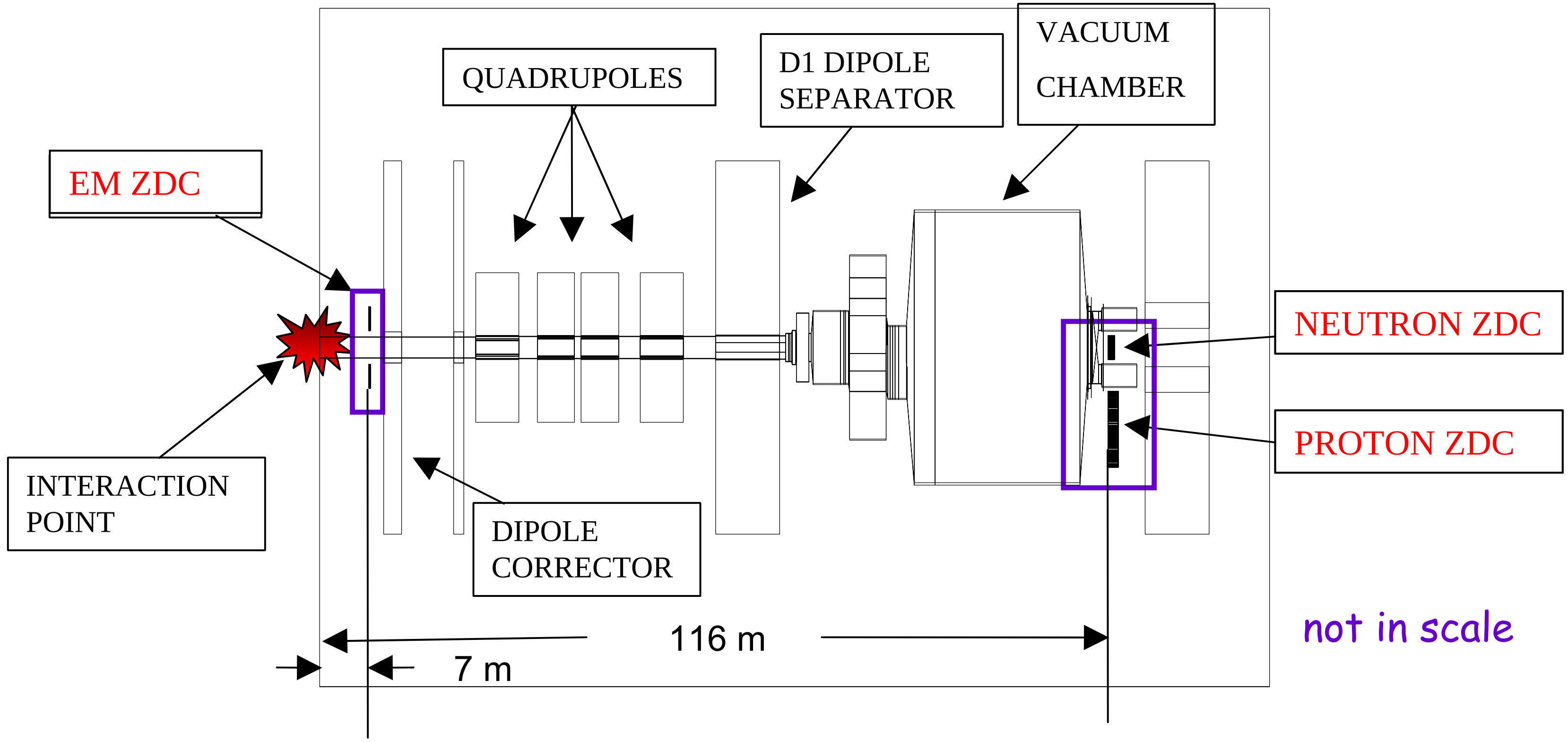
during pp runs:

- **diffractive events**
  - Relative luminosity ?

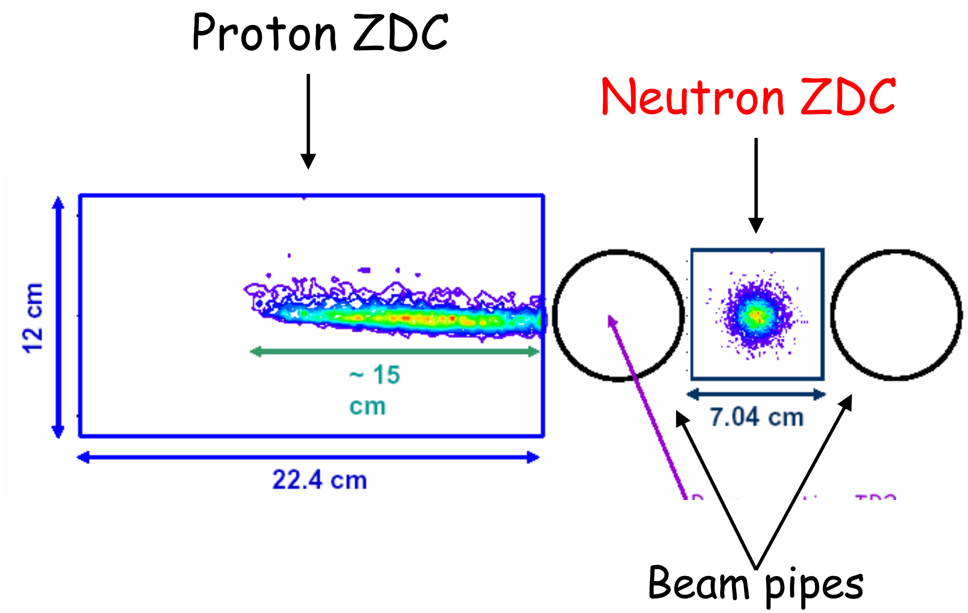
ZDC calorimeters

- The ZDC detector is made by two sets of calorimeters, located at opposite sides with respect to the IP2
- ~ 116 meters away from IP2, where the two LHC beams circulate in two different pipes.
- Each set of detectors consists of
- 2 hadronic “spaghetti” calorimeters
  - one for spectator neutrons (**ZN**), placed at 0° with respect to LHC axis
  - one for spectator protons (**ZP**), positioned externally to the outgoing beam pipe.
- two forward EM calorimeters (ZEM) , placed at ~7 m from IP2, on RB24 side, covering the pseudorapidity range $4.8 < \eta < 5.7$.

ZDC location



Spectator nucleons distribution



- In H.I. collisions ZN detects all the spectator neutrons, while ZP accepts ~70% of the spectator protons depending on the beam optics

ZN detector description

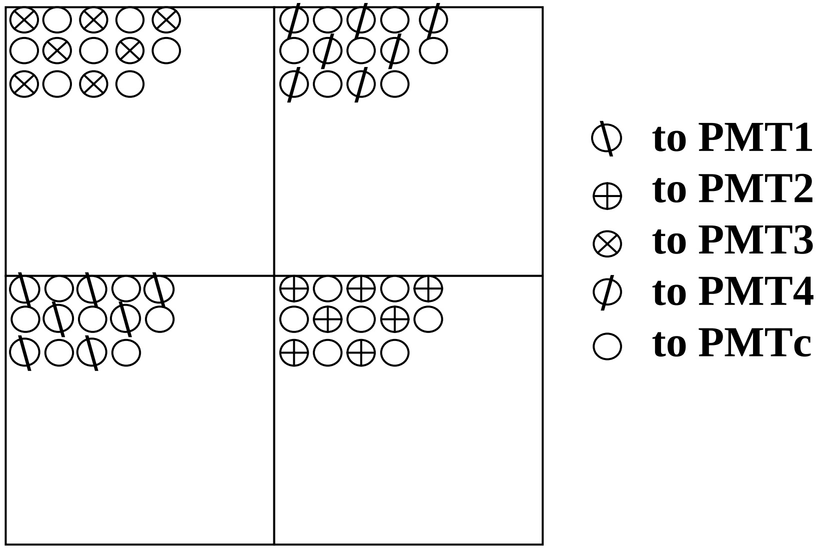
Passive material : W-alloy

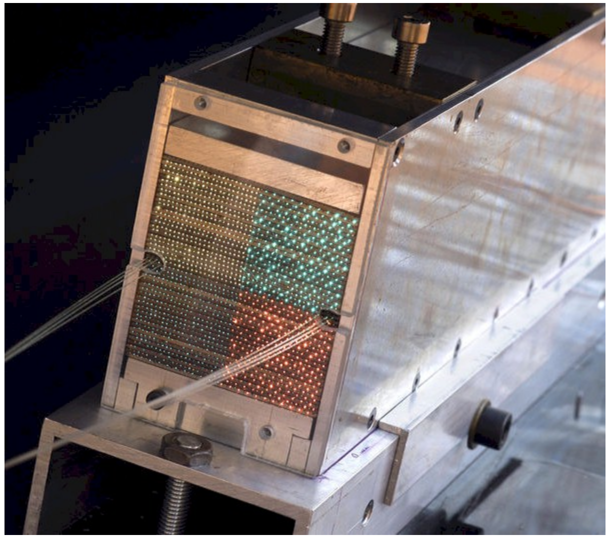
ρ = **17.6 g/cm3**

44 grooved slabs, each of them 1.6 mm thick, stacked to form a parallelepiped 7.2x7.2x100 cm^3.

Active material : quartz fibers

pure silica core, fluorinated silica cladding and a hard polymer coat with a diameter of 365, 400 and 430 μm respectively. The numerical aperture is 0.22.





- Fibres placed 0° with respect to LHC axis
- Distance between fibres = 1.6 mm
- Fibers out from the rear face of the calorimeter directly coupled to PMTs

- One out of two fiber sent to a photomultiplier (PMTc)
- The remaining fibers sent to four different photomultipliers (PMT1 to PMT4), forming four independent towers.
- The chosen PMT is the Hamamatsu R329-02

- *rough detection of the beam position*

ZP detector description

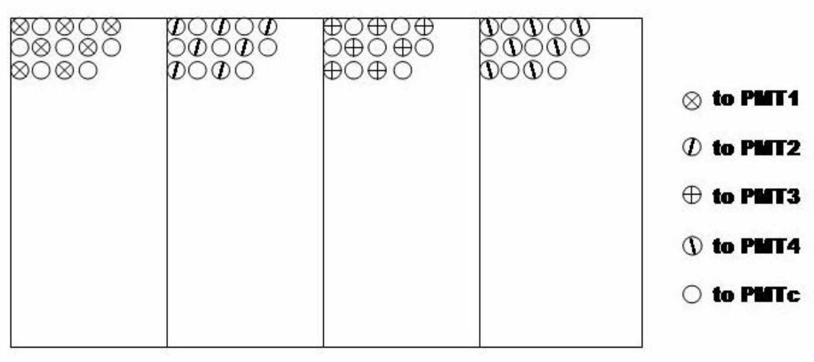
Passive material : brass

ρ = 9.0 g/cm3

30 grooved slabs, each of them 4 mm thick, stacked to form a parallelepiped 22.8x12x150 cm^3.

Active material : quartz fibers

pure silica core, fluorinated silica cladding and a hard polymer coat with a diameter of 550, 600, 630 μm respectively. The numerical aperture is 0.22



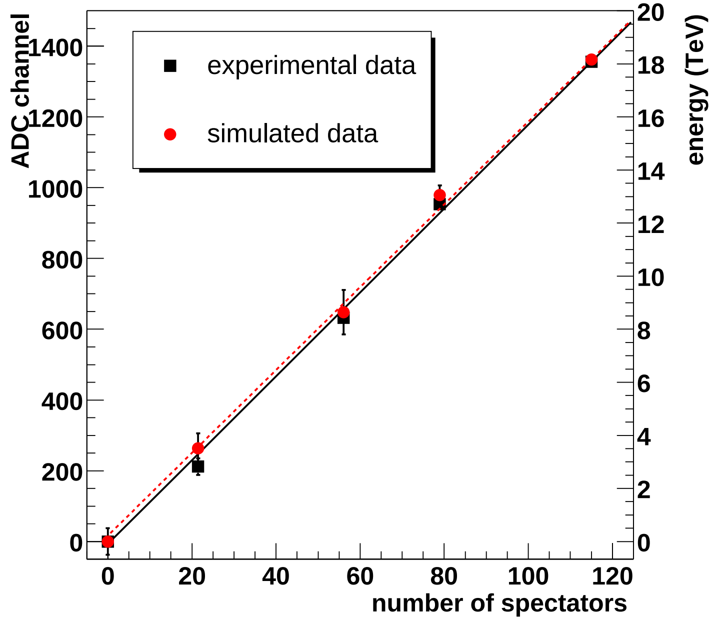
- Fibres placed 0° with respect to LHC axis
- Distance between fibres = 4 mm
- Fibers out from the rear face of the calorimeter directly coupled to PMTs
- One out of two fiber sent to a photomultiplier (PMTc)
- The remaining fibers sent to four different photomultipliers (PMT1 to PMT4), forming four independent towers.
- The chosen PMT is the Hamamatsu R329-02

- *rough detection of the beam position*

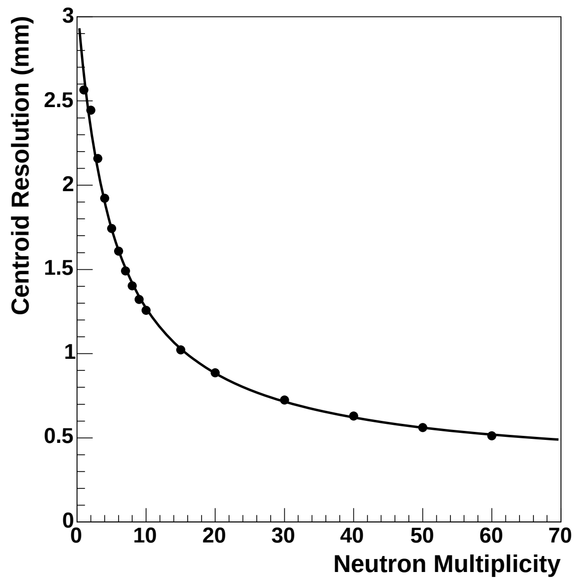
Physics performance

- Energy resolution : **~ 11% for one spectator neutron of 2.7 TeV**

- Linearity of the response as a function of the number of spectator nucleons
  → tested at SPS with the In beam

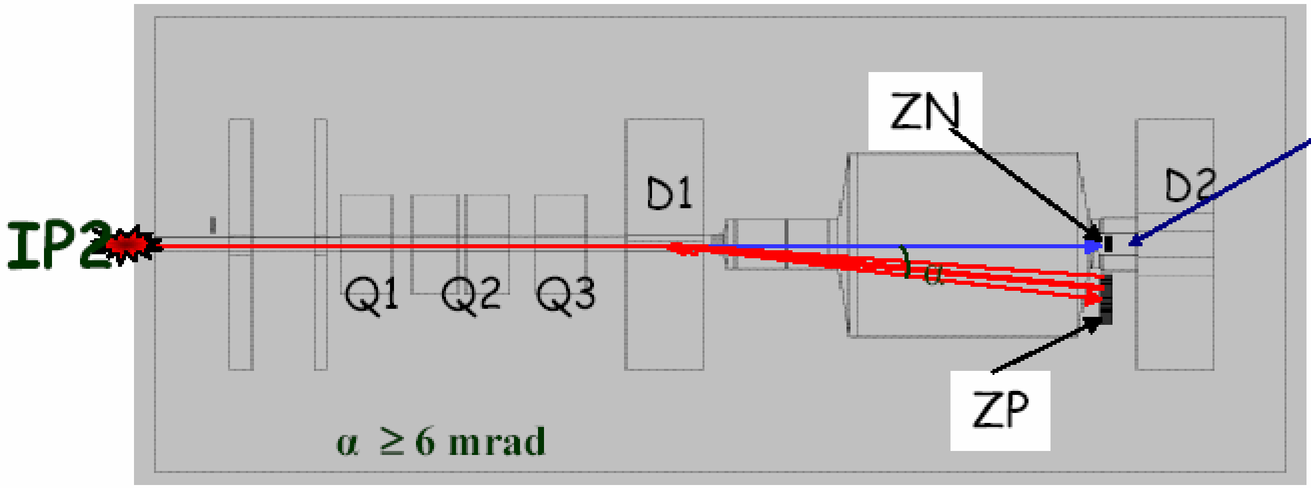


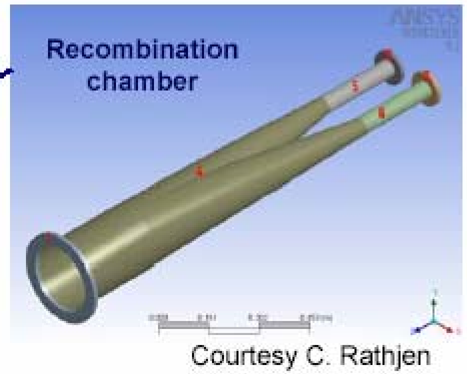
- Position reconstruction of the centroid of the spectator neutrons



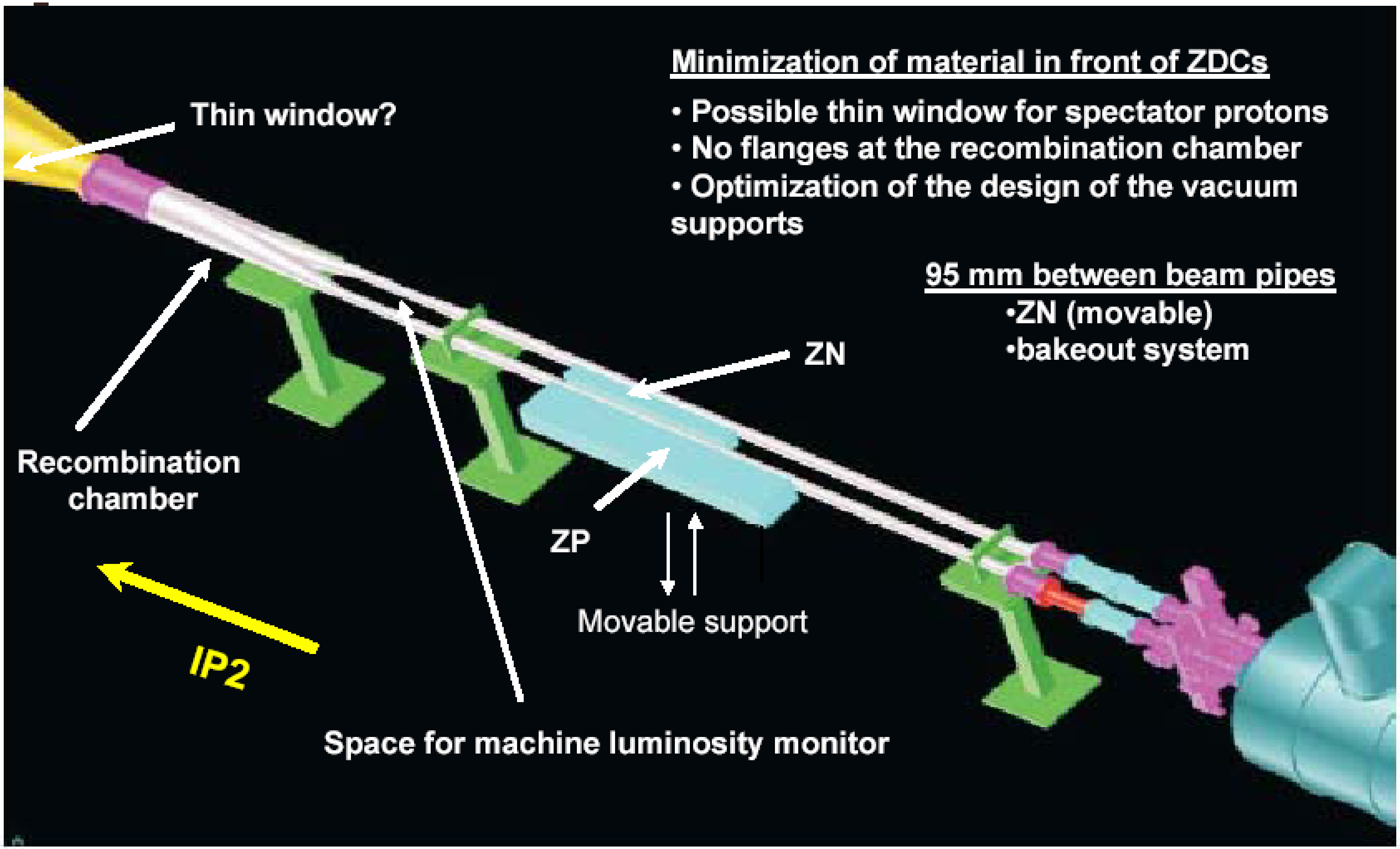
ZDC integration in the tunnel

- Aperture from D1 to ZP: maximize spectator protons acceptance in the ZP
- Minimize the amount of material in front of the ZDCs
- Enough space between the two beam pipes for the ZN

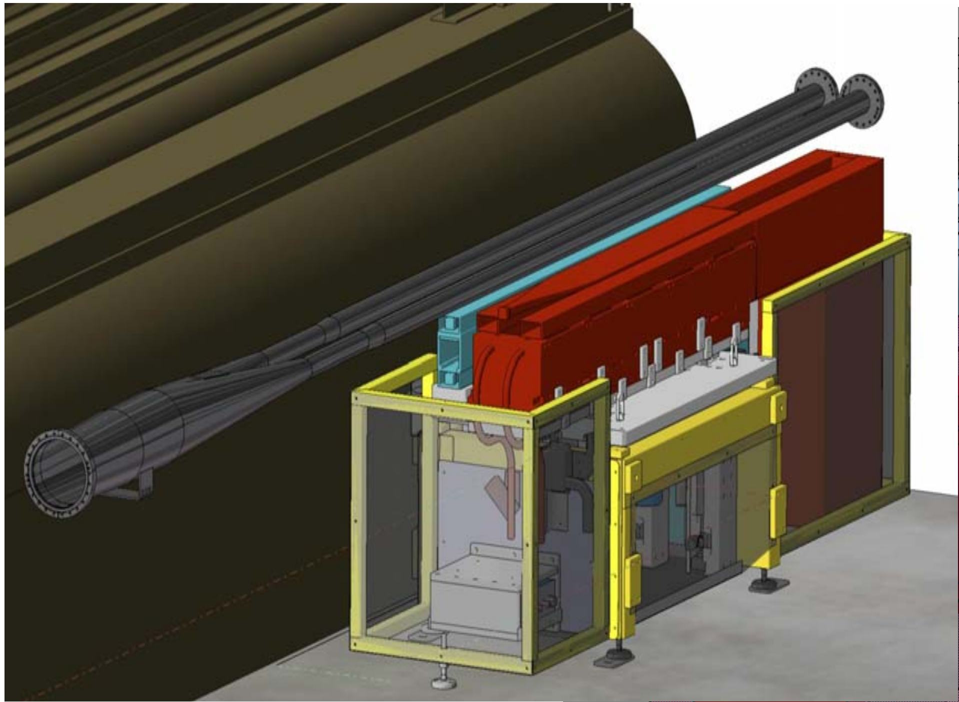


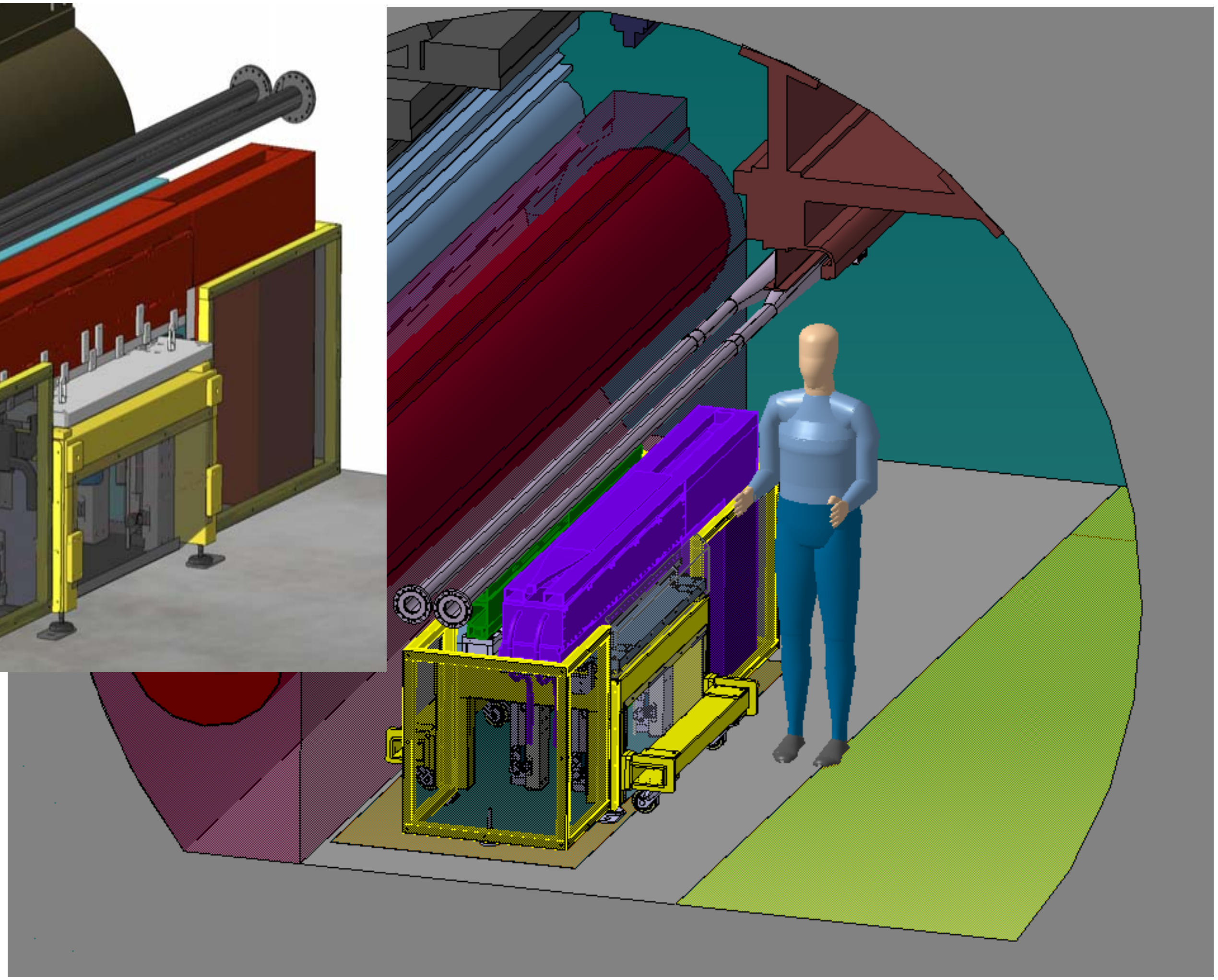


Beam pipe layout



ZDC support platform





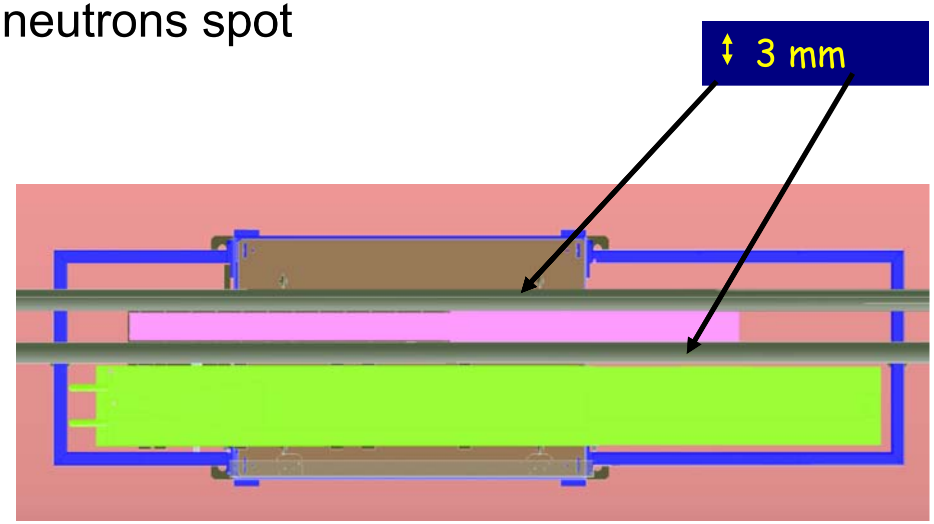
ZN and ZP at garage position

ZDC platform requirements

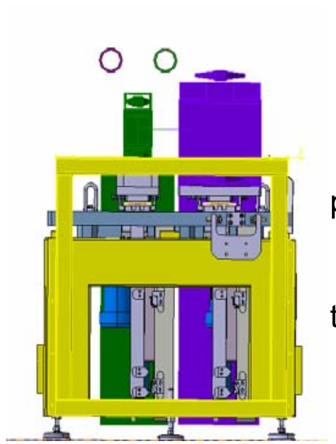
- ZP and ZN can be vertically moved **independently**
  - ZN normally at garage position (***20 cm** lower than beam plane*) during p-p runs
  - ZP may be used in p-p runs to select diffractive events

- The precision on the ZDC positioning is required to be **≤250 μm**
  - value comparable with the smallest error in the reconstruction of the centroid of the spectator neutrons spot

- Interference with the LHC vacuum chamber
  - 3 mm clearance between beam pipes and calorimeters
  - anti-collision switches will be used



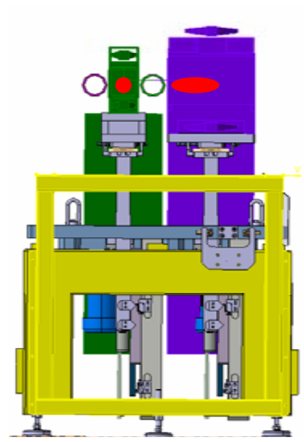
ZDC operation



Garage position
(20 cm below the beam level)

At injection: to protect the calorimeters from possible beam losses

Whenever data taking is not needed to minimise the absorbed dose



Data taking position
(at beam level)

Injection:

The ZDC are at garage position

When collisions are established or during the ADJUST mode:

The ZDC are positioned at the theoretical beam level

- Vertical fine adjustment to center the two calorimeters at the actual beam level

ZDC trigger

- e.m. dissociation trigger (L0)

  analog signal from ZN PMTc on RD26 side (2nd anode output) send to trigger rack C23 and discriminated to select at least one spectator neutron

  "Normally" NOT FEASIBLE (latency problems)

- Centrality trigger (L1) and e.m. dissociation trigger (L1)

  . 3 centrality triggers:

  - ZDC_Minimumbias
  - ZDC_SemiCentral
  - ZDC_Central

  . mutual e.m. dissociation

  - ZDC_Special: one spectator neutrons detected on both side of IP

ZDC status

- All the four hadronic calorimeters (ZN1, ZN2, ZP1, ZP2) assembled and **ready** to be mounted on the movable platforms
  - All tested with hadron beams (50 – 200 GeV)
- One of the two ZEM assembled
- The commercial electronic modules for trigger and readout procured; work in progress on the readout card
  - We use the same readout card of the dimuon trigger system with some modification in the FPGA programming
- Movable platforms already assembled at Point2
  - Motors and control systems being installed on the platforms
  - Commissioning of the servocontrols in progress

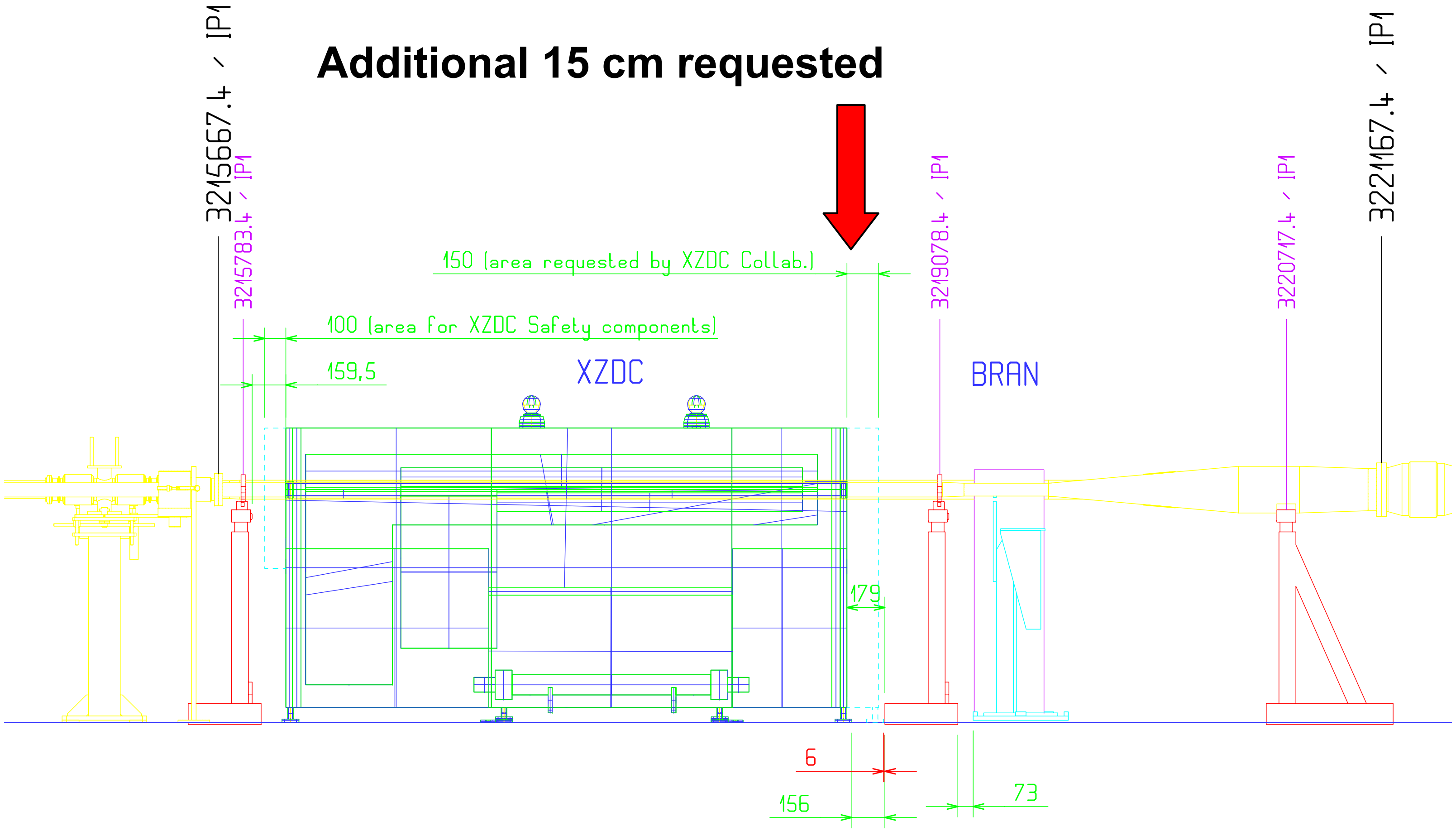
Integration issues

- More space needed (15 cm on the IP side) to allow the integration of the fibres transmitting the laser light to ZP for monitoring
  - Changes due to modifications with respect to the original project
  - On going discussions with the integration team

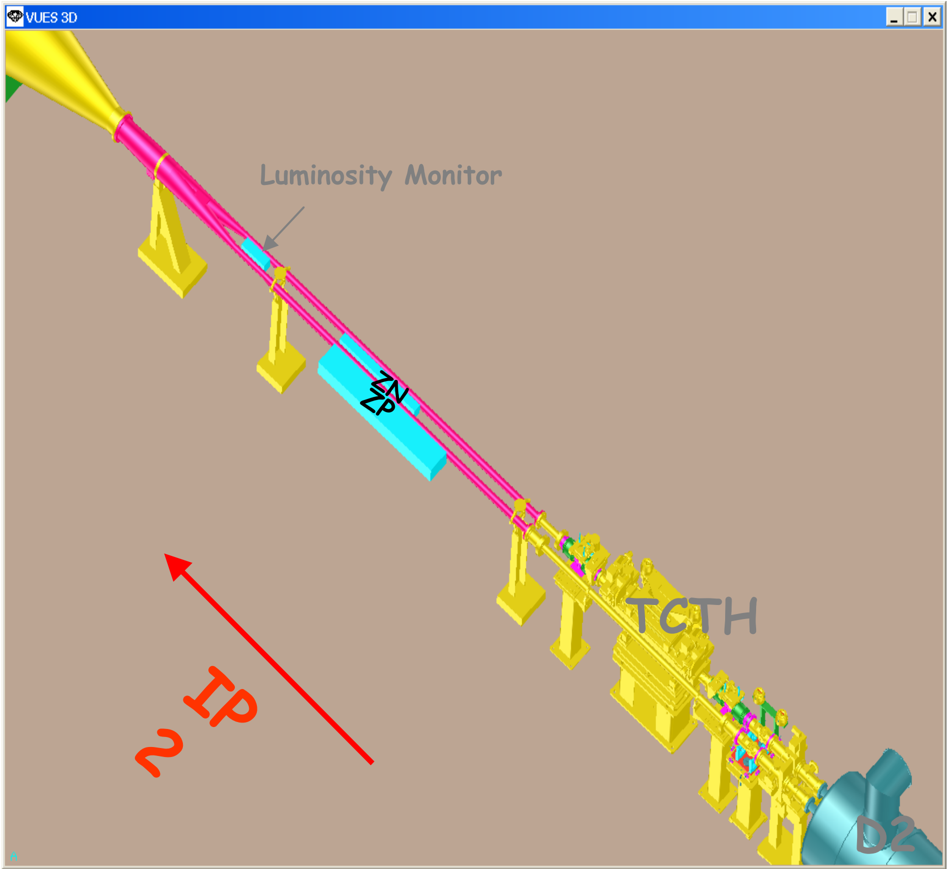
- Compatibility of ZN with the converter of the LHC luminometer (BRAN) during H.I. runs
  - energy resolution
  - precision on the reconstruction of the centroid

Integration layout

Additional 15 cm requested



Compatibility with BRAN (1)



- technology for LHC luminometer in IR2 chosen recently (CdTe detector)
- BRAN needs a Cu converter
- LHC luminometer is foreseen to work in p-p runs
- LHC luminometer may be used in H.I. runs if compatible with ZN

Compatibility with BRAN (2)

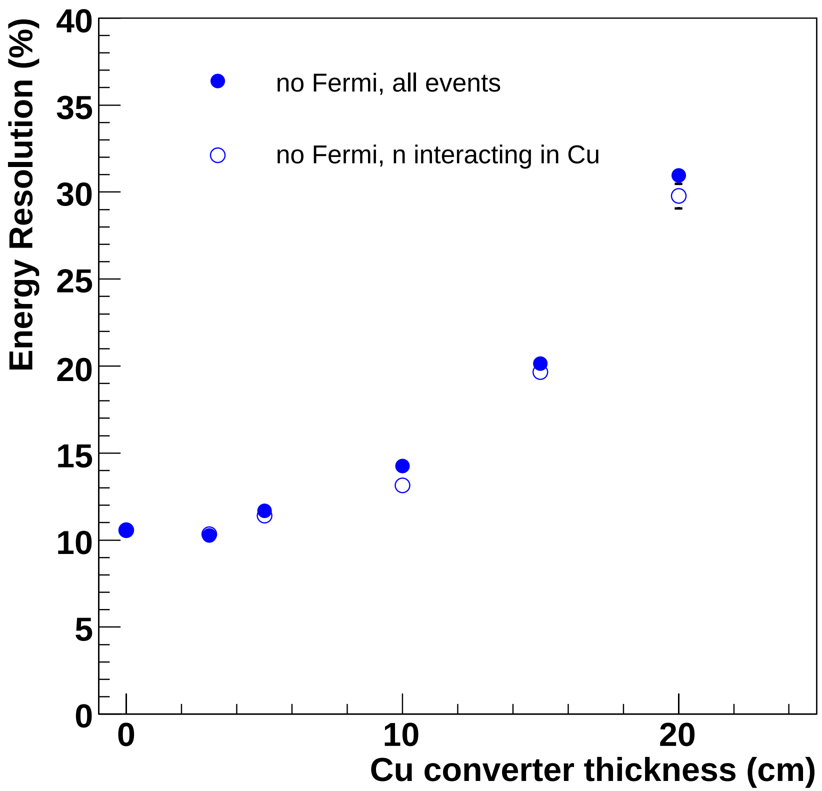
- The compatibility depends on the amount of converter necessary for the luminosity monitor

  - We simulated the BRAN as a Cu converter, positioned 1.1 m before the front face of ZN
  - Various thicknesses were considered

First results show that:

ZN energy resolution still acceptable for 3 cm converter

~11% for a single 2.7 TeV neutron

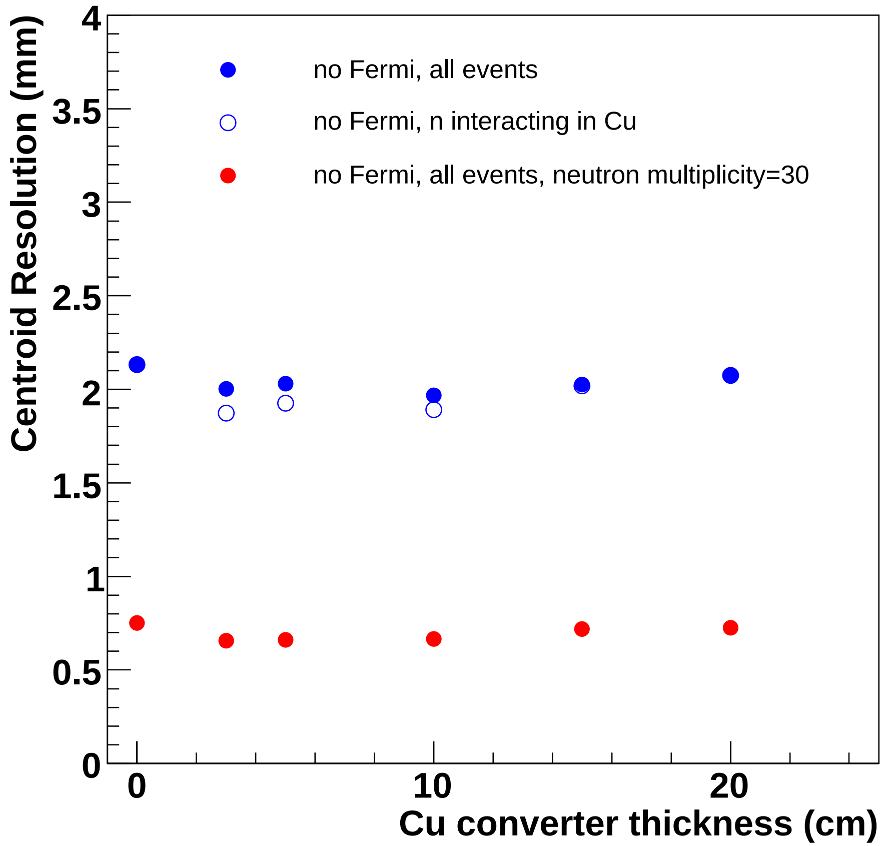


Compatibility with BRAN (3)

The insertion of the converter upstream of the ZN calorimeter does not affect the centroid resolution

In case of 1 spectator neutron centroid resolution → **~ 2 mm**

In case of 30 spectator neutrons (mean multiplicity in Pb-Pb minimum bias events) centroid resolution → **~0.7 mm**



Installation planning

- Cables to be pulled
  - in the tunnel (LHC campaign): March 2007
    - Signal cables (~215 m low-loss CK50) for ZN and ZP
    - HV cables (~ 30 m) for ZN and ZP
  - in the ALICE cavern: March/April 2007 (tbc)
    - Signals from ZEM, delay cables and trigger cables
- Platform assembled with the hadronic calorimeters to be installed into the tunnel
  - on the right side (LSS2R) : 9/4 – 13/4 2007
  - on the left side (LSS2L) : 7/5 – 11/5 2007

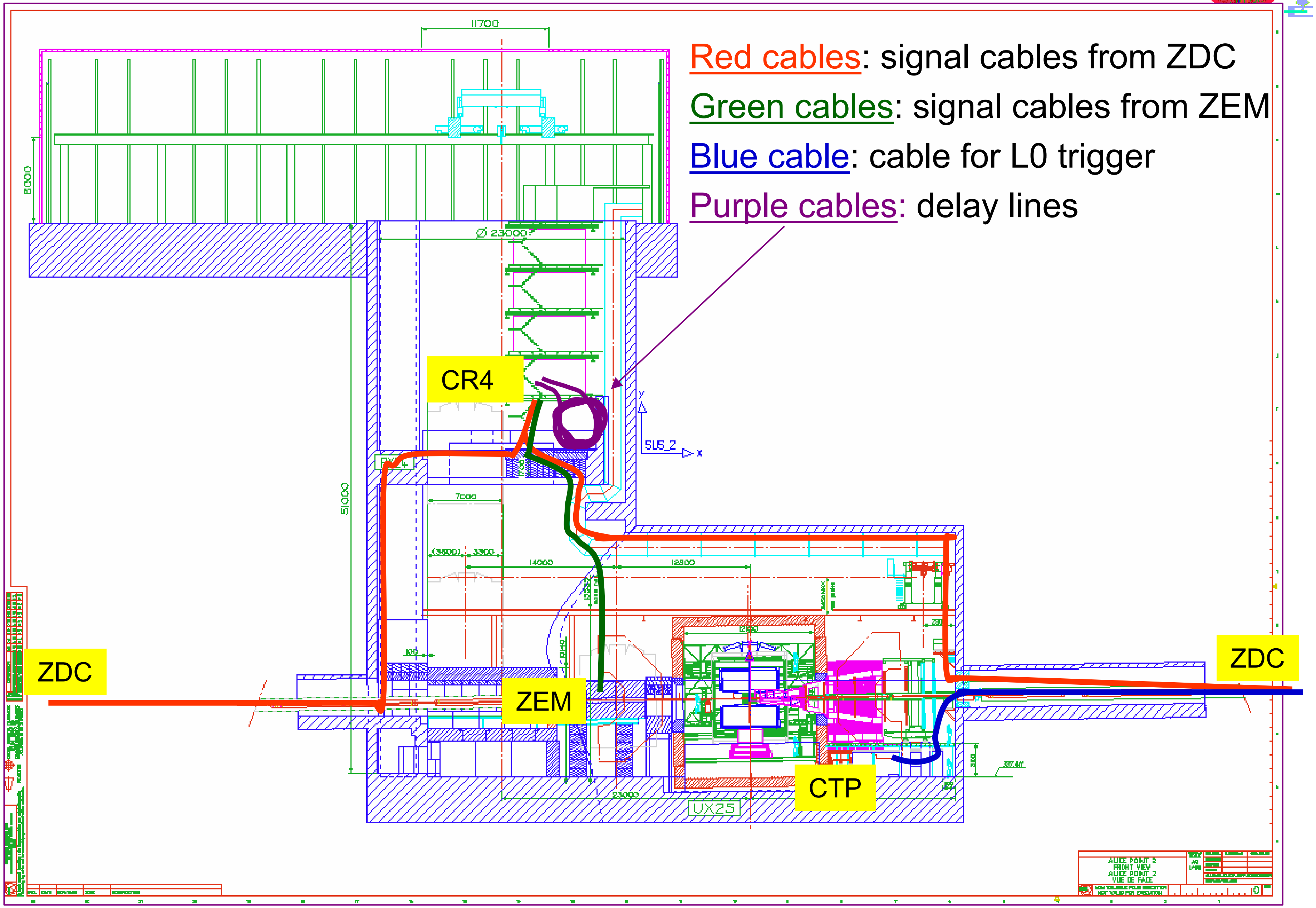
Cabling layout

Red cables: signal cables from ZDC

Green cables: signal cables from ZEM

Blue cable: cable for L0 trigger

Purple cables: delay lines



On surface commissioning

- Check of vertical movement of the platforms
  - Check of loads
- Check of integration of the PMT monitoring system
- Dummy beam pipes needed to precalibrate the anticollision switches

In “situ” commissioning

- Check connections
- Test calorimeter movement
- Final calibration of anticollision switches
  - when beam pipes available
- Test PMT HV
- Test PMT with laser light
- Measurement of the single photoelectron peak with cosmic rays

Backup slides

ZDC as a luminosity monitor (1)

- During H.I. runs ZDC can measure the rate dN/dt^{ED} of the mutual e.m. dissociation in the neutron channel σ^{ED}
  $dN/dt^{ED} = L\,\sigma^{ED}$

- Accuracy of the absolute luminosity measurement
  - 10% for (1n-1n) correlated emission cross-section
  - 2% for the sum of mutual 1n and 2n emission (LMN)
  (1n-1n) + (1n-2n) + (2n-1n) + (2n-2n)
  σ_{LMN} = 1378 mb RELDIS code (Pshenichnov et al.)
- Trigger can be counted but ZDC cannot be readout without a L0 trigger signal

ZDC as a luminosity monitor (2)

- Experimental considerations

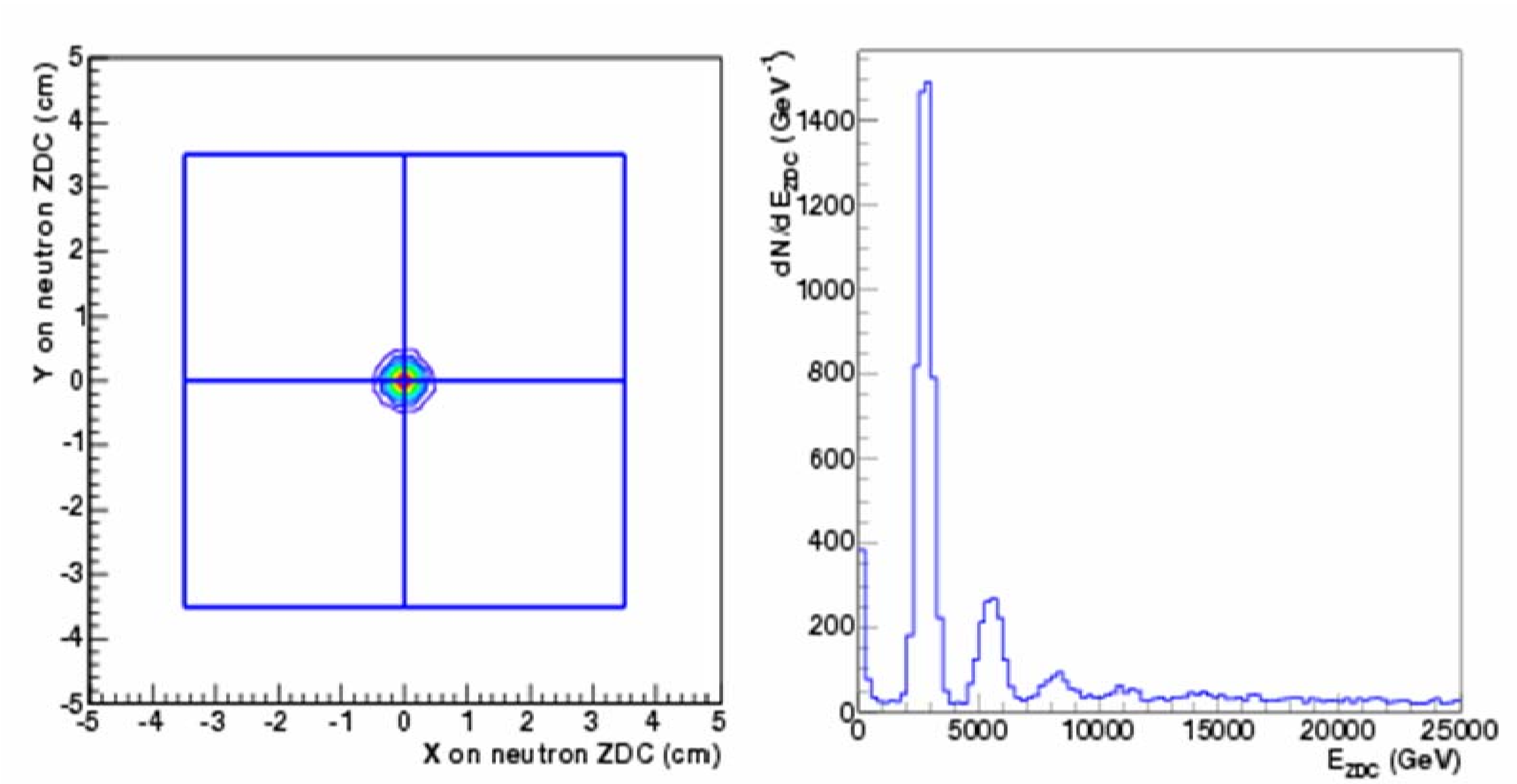
- All the emitted neutrons fall in the ZN acceptance
p_T of the neutrons produced in the decay of the GDR
$p_T < 250$ MeV/c

→ neutron spot very well contained

- Energy resolution (~11% for a single 2.7 TeV neutron)
allows clean separation of 1n-2n-3n contribution

- The e.m. dissociation is relatively background free ($\sigma^{ED} \sim Z^2$)

ZDC as a luminosity monitor (3)



ZDC as a luminosity monitor (4)

- During pp runs ZP can be used to tag leading protons produced in diffractive events
- ZP acceptance ≠ 0 for leading protons in the range ***$2<p_z<4.5$ TeV*** emitted at very small angles *(<150 μrad)*
- Careful simulation has to be done

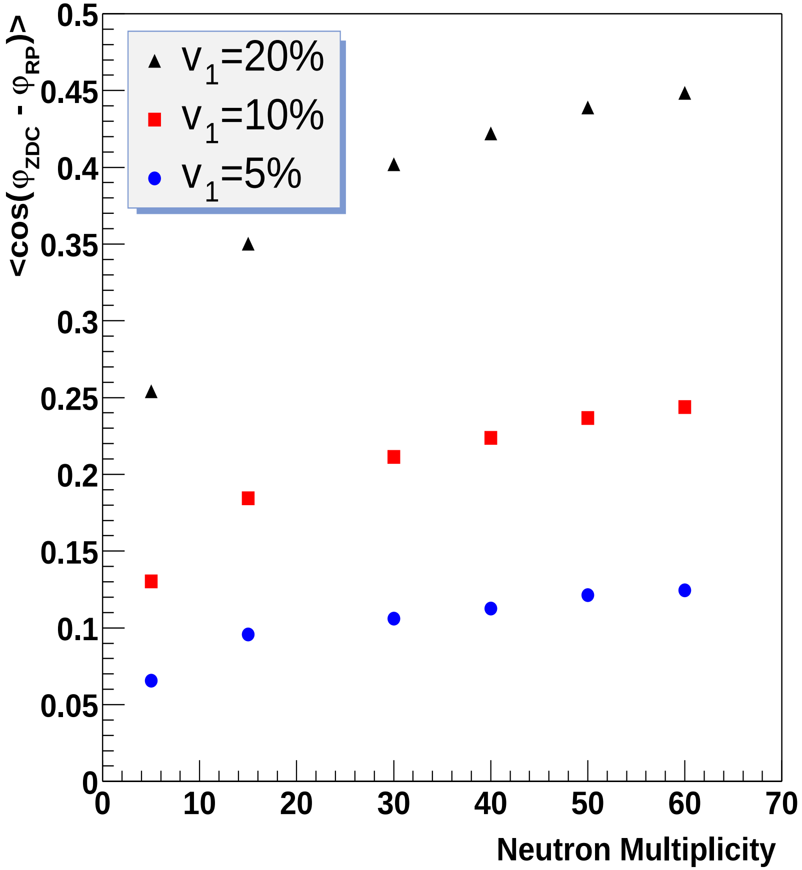
Reaction Plane Estimate

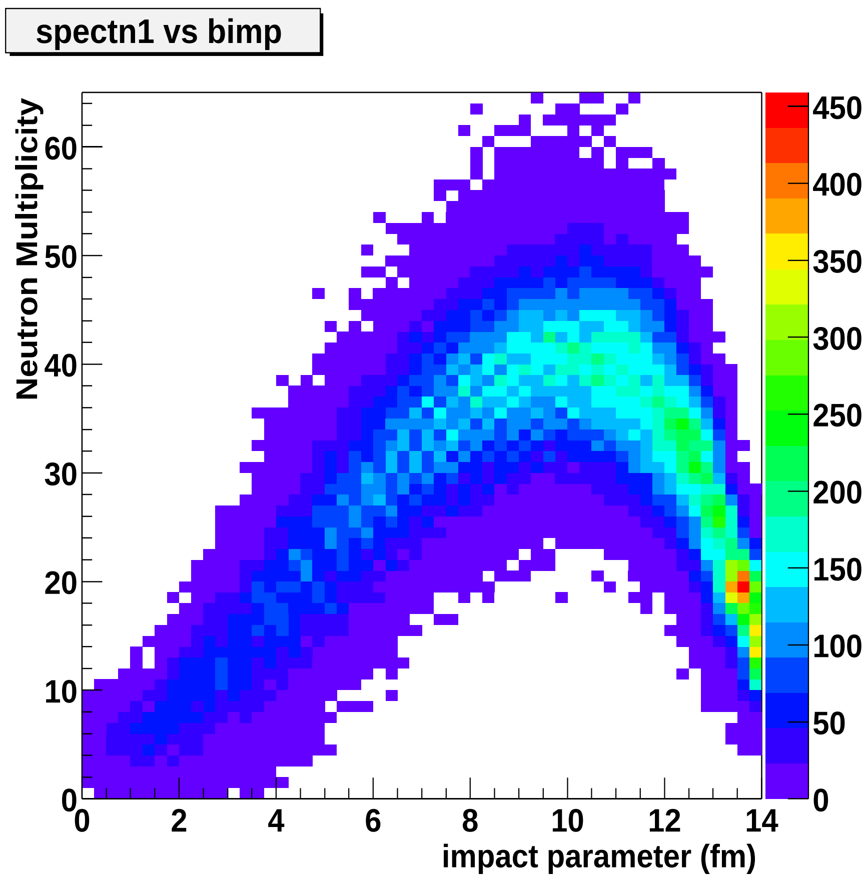
- Spectator neutrons (2.76 TeV) on one side of I.P. generated
  - Fermi momentum distribution taken into account Fermi
  - transverse Pb beam divergence (30 μrad)
  - beam transverse size at I.P.= 16 μm.
- Random reaction plane azimuth (***phiRP***) assigned to each event
- Directed flow of spectator neutrons v_1 introduced
  - Poskanzer and Voloshin, Phys. Rev. C58, 1998

- We use as an estimator of the event plane resolution the mean cosine of the angular difference
<cos(phiZDC – phiRP)>
where ***phiZDC*** is the event plane azimuth from spectator neutrons reconstructed centroid

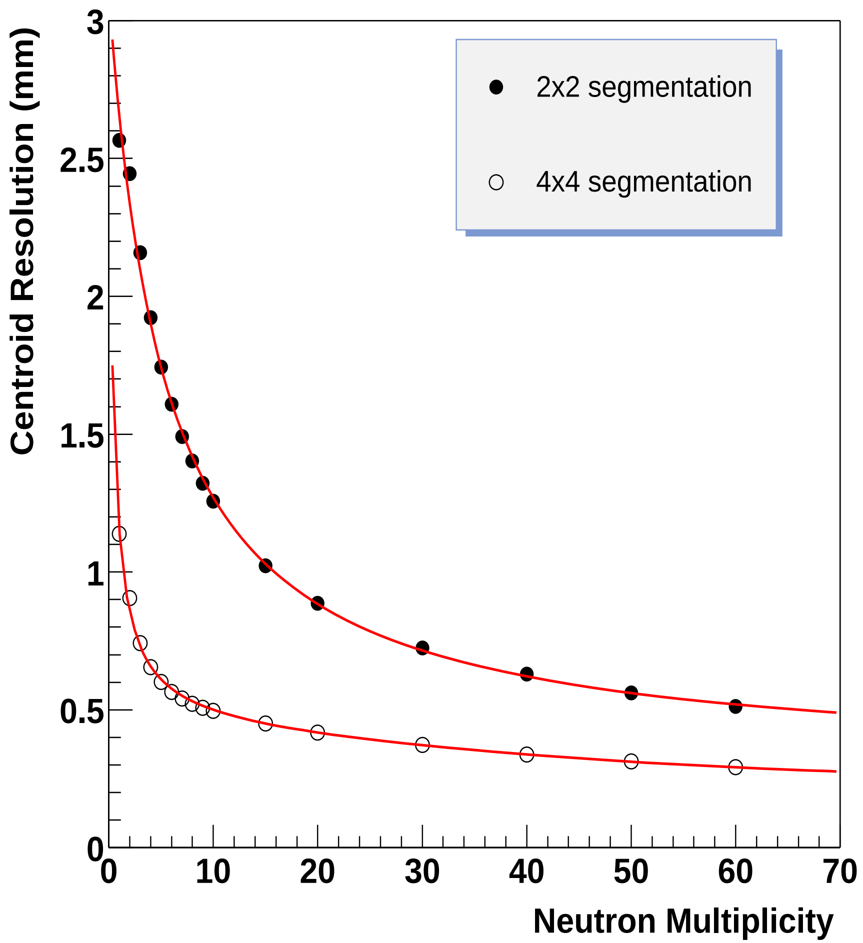
-> Study of Event Plane resolution vs Neutron Multiplicity for v_1 = 5%, 10%, 20%

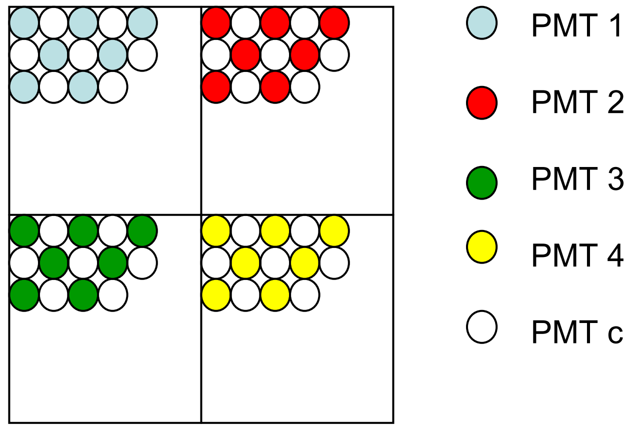
Event Plane Resolution

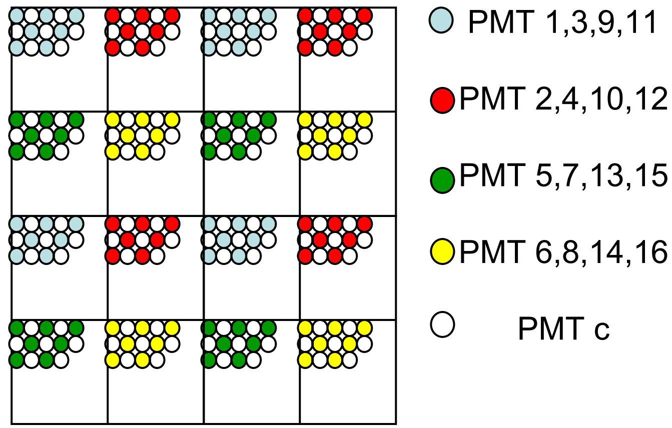




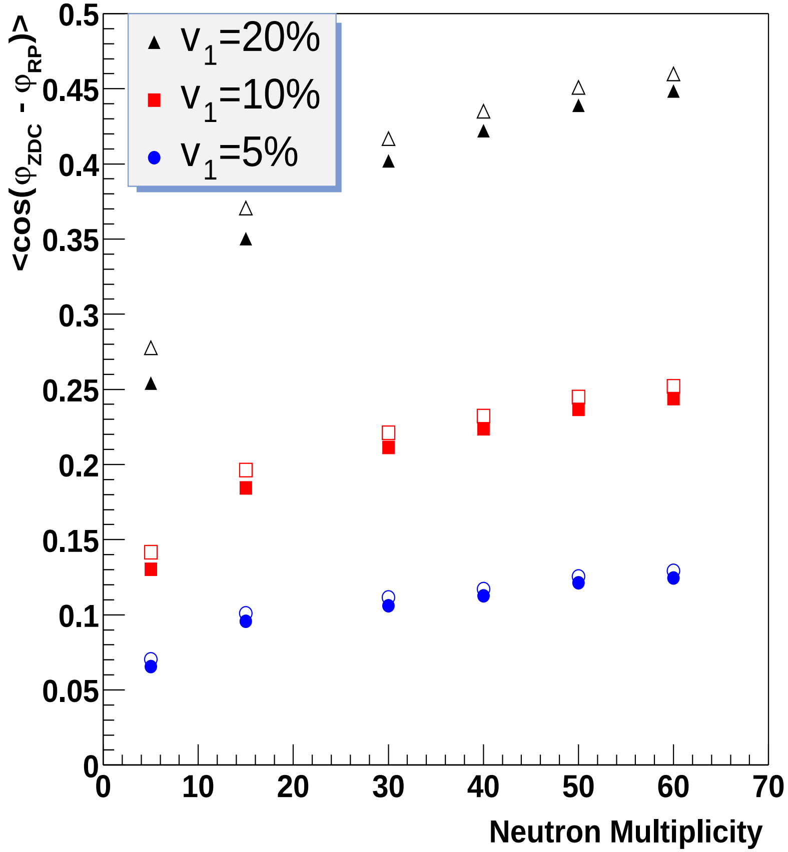
Comparison between 2x2 and 4x4 ZN segmentation - 1



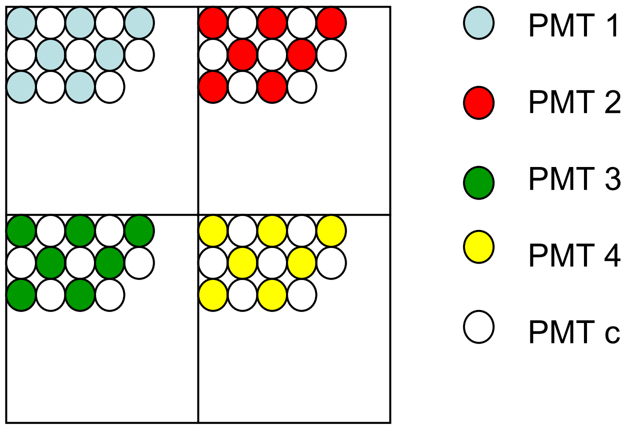




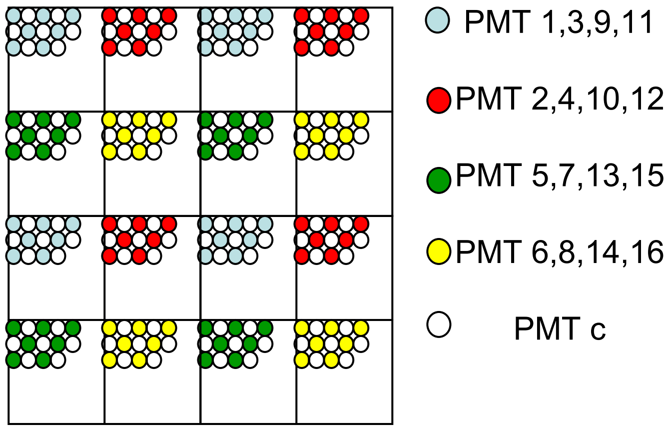
Comparison between 2x2 and 4x4 ZN segmentation - 2



2x2 segm
Full marker



4x4 segm
Open marker



-> Small difference, why ?

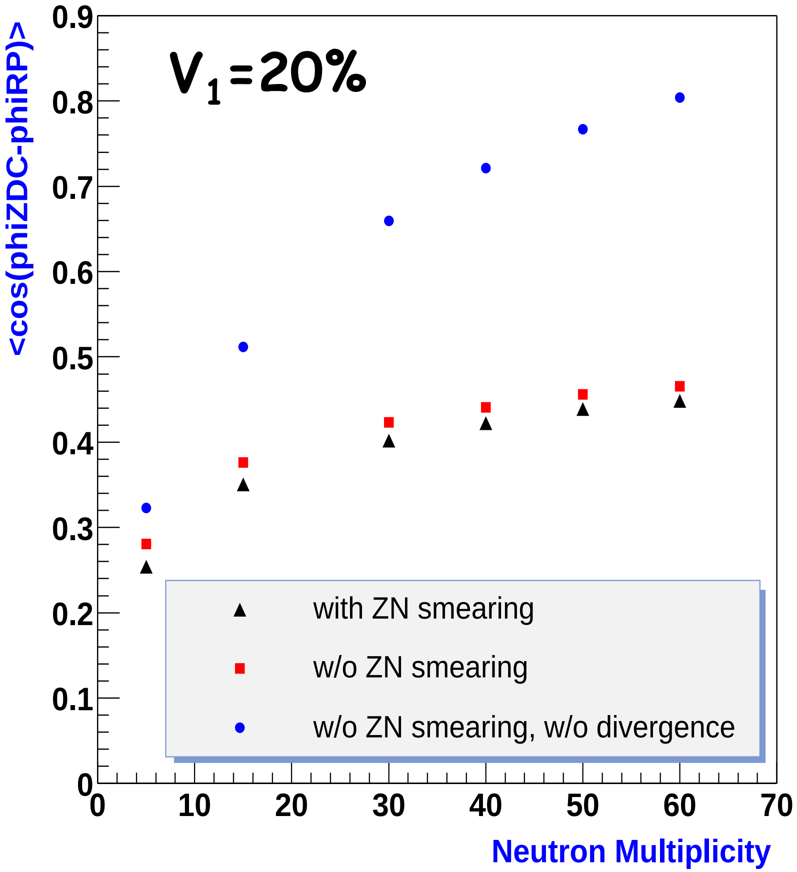
Beam parameters contribution to event plane resolution

Transverse Pb beam divergence at IP2: 30 μrad

This value depends on the LHC beam parameters:
- transverse normalised emittance ε_n
- twiss function β*
- relativistic gamma factor γ

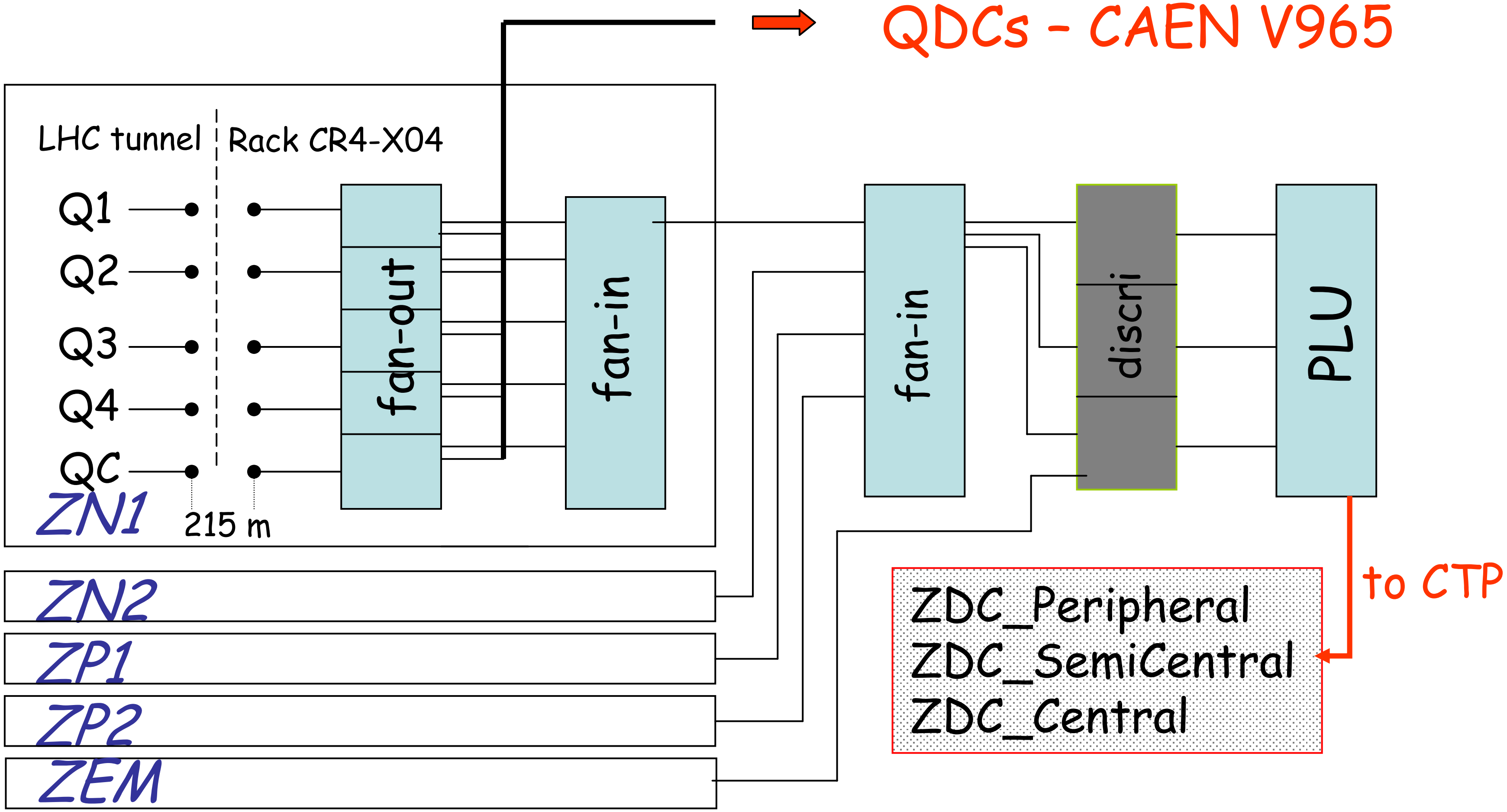
$$\vartheta_{RMS} = \sqrt{\frac{\varepsilon_n}{\beta^* \cdot \gamma}}$$

- ε_n = 1.5 μm rad
- β* at IP2 = 0.5 m
- γ = 2963.5



→ Event plane resolution is dominated by the bias due to beam divergence

ZDC centrality trigger (L1)



Long low-loss cables used to transmit the analogic signals from PMTs to counting rooms