Luminosity Determination in ALICE

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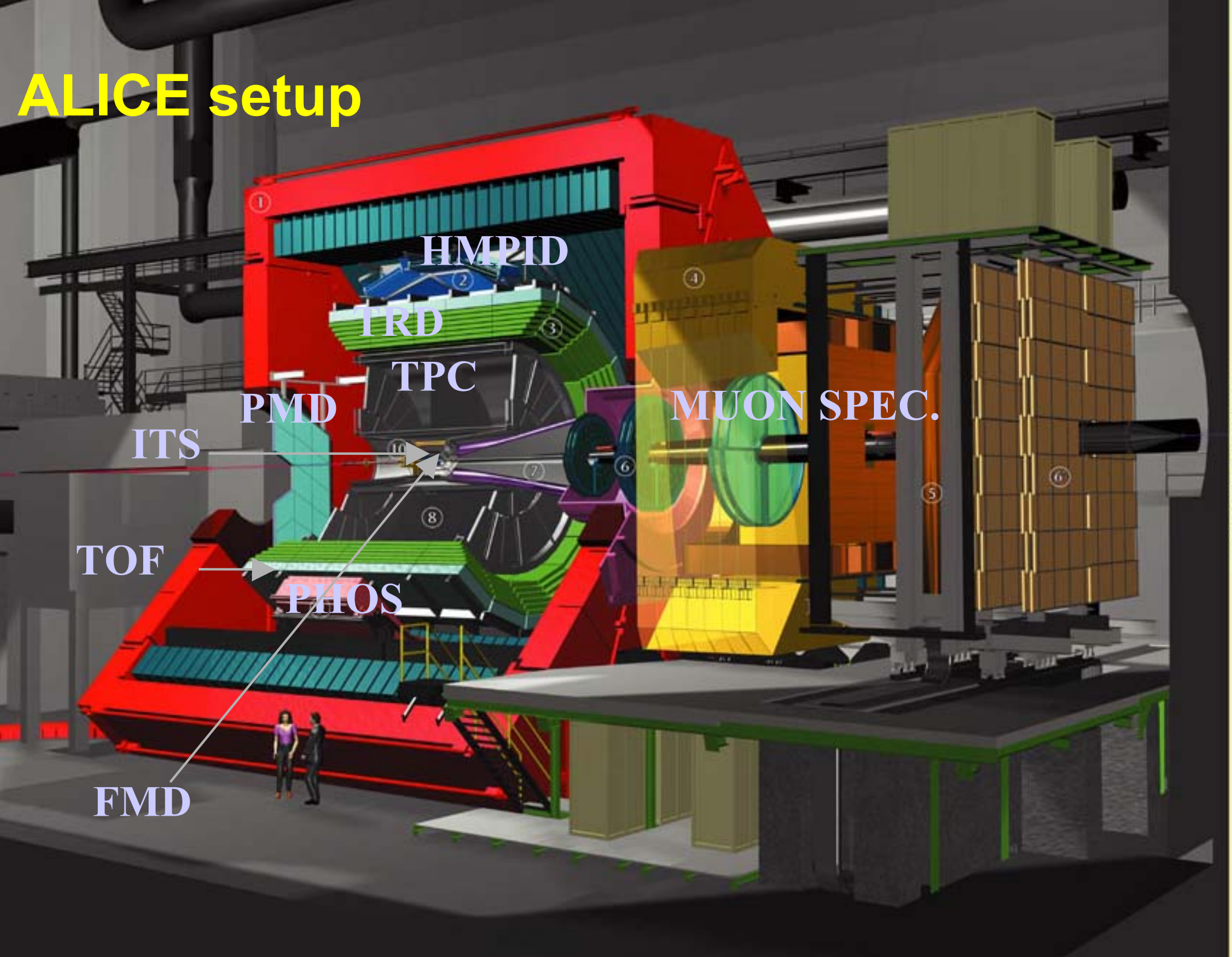
Overview

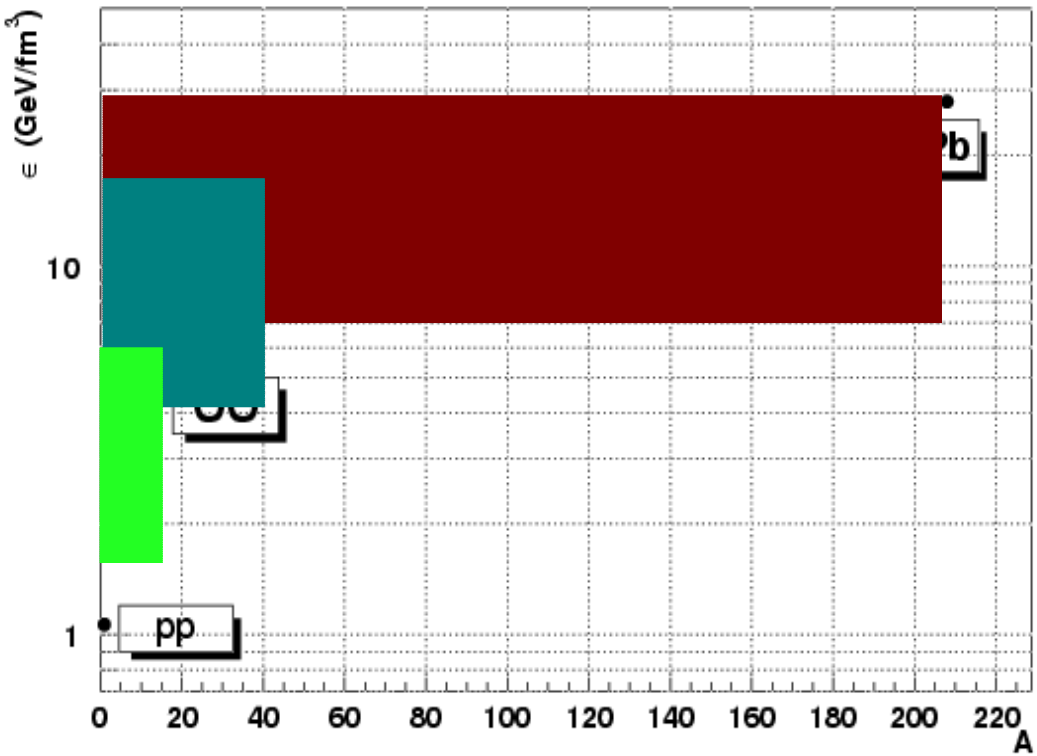
- LHC experimental conditions
  - ALICE running strategy
  - Luminosity requirements
  - Background conditions
- Luminosity determination
  - Heavy ion collisions
  - pp Collisions
- Beam instrumentation issues

ALICE setup



ALICE Running Strategy

- Regular pp runs at $\sqrt{s}$ = 14 TeV
- Initial heavy ion program
  - Pb-Pb physics pilot run
  - 1-2 years Pb-Pb
  - 1 year pPb like collisions (pPb. dPb or αPb)
  - 1-2 years Ar-Ar



ALICE Running Strategy

- Later options some of the depending on the outcome of the initial data analysis
  - Dedicated pp or pp-like (dd or $\alpha\alpha$) collisions at $\sqrt{s_{NN}}$ = 5.5 TeV
  - Possibly another intermediate mass A-A system (N-N, O-O, Kr-Kr or Sn-Sn)
  - Possibly another pA (dA, αA) system
  - Possible lower energy Pb-Pb runs
  - Further high energy Pb-Pb runs

Luminosity Requirements

- Heavy ions (limited by LHC)
  - Pb-Pb 1×10^{27} cm^{-2} s^{-1}
  - Ar-Ar 1×10^{29} cm^{-2} s^{-1}
  - O-O 2×10^{29} cm^{-2} s^{-1}
- pA (200 kHz rate limit)
  - pPb 1.1×10^{29} cm^{-2} s^{-1}
  - pAr 3.0×10^{29} cm^{-2} s^{-1}
- pp (200 kHz rate limit)
  - $(10^{29}$- $3 \times 10^{30})$ cm^{-2} s^{-1}

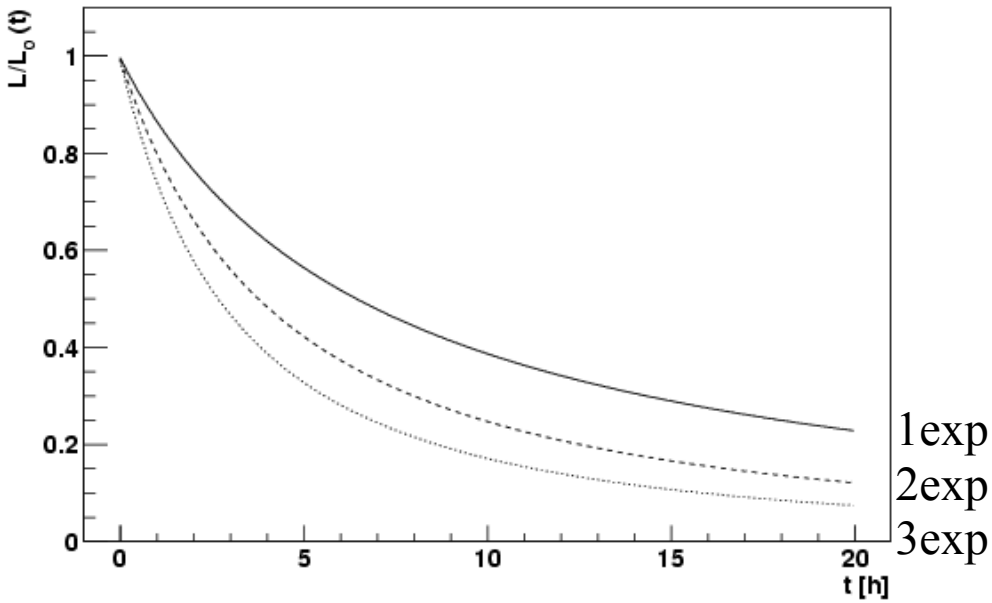
Running Conditions Critical for Luminosity Monitoring

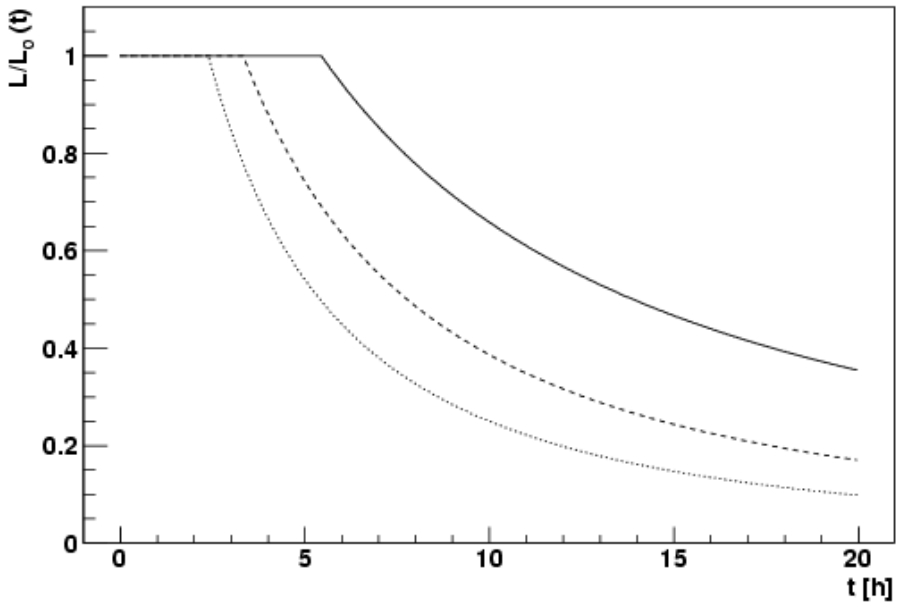
- Short luminosity half-life in Pb-Pb Collisions
- Background conditions in pp Runs

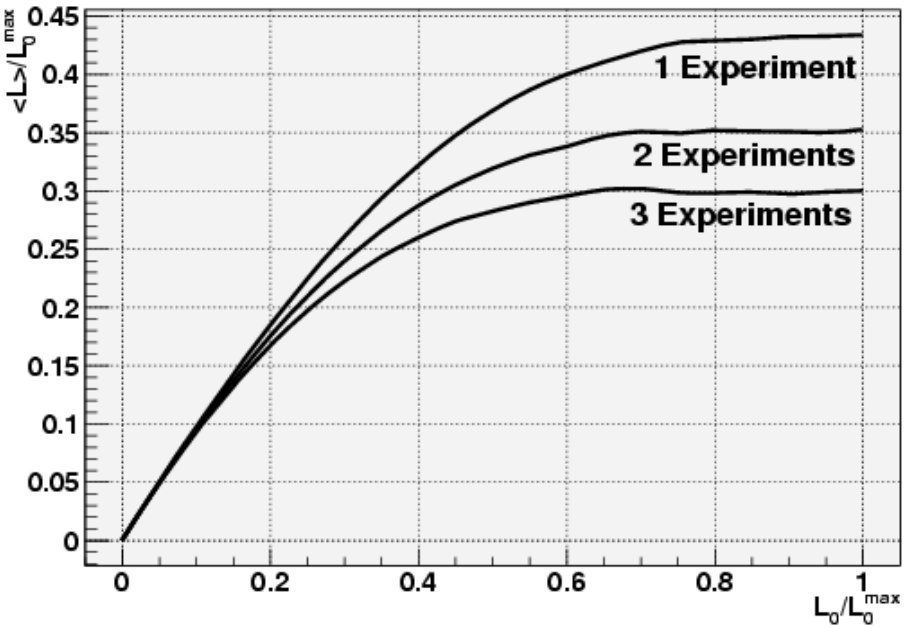
Luminosity Lifetime

- Lifetime in PbPb
  - Limited by electromagnetic processes (≈ 500 barn)
  - Half-life (mean luminosity)
    - 1 Experiment 6.7 h (0.44 L_0)
    - 2 Experiments 3.1 h (0.35 L_0)
    - 3 Experiments 2.7 h (0.29 L_0)

Luminosity Lifetime







ALICE prefers β* tuning

- Keep luminosity constant reducing β* during the run
- Also useful for $L_0 < 10^{27}$ $cm^{-2}s^{-1}$
  - Same average luminosity as for $L_0 = 10^{27}$ $cm^{-2}s^{-1}$
- Avoids quench problem
- ALICE INT-2002-32

Background Conditions in pp Runs

- Runs at reduced luminosity (/10^4) and full current
  - Hence, S/B by factor 10^4 worse
- Dynamic vacuum in interaction region factors 100-1000 higher than the static vacuum ?
- Beam gas interaction rate in IP±20 m ≈500 kHz to be compared to 200 kHz of planned collisions (L = 3×10^{30} $cm^{-2}s^{-1}$).
- Studies are ongoing.

IR2 Beam Parameters

	pp	PbPb
Energy per nucleon [TeV]	7	2.76
β at the IP (collisions) [m]	10-(100 ?)	0.5-(2)
r.m.s. beam radius at IP [μm]	71-(226 ?)	16-(64)
r.m.s. bunch length [cm]	7.5	7.5
r.m.s. vertex spread [cm]	5.3	5
Crossing half angle (vertical) [μrad]	100	75
Number of bunches	2808	592
Bunch spacing [ns]	25	100
Number of particles per bunch	1.10E+11	6.80E+07
Luminosity [cm^-2 s^-1]	< 3 E30	1.00E+27

ALICE Luminosity Meaurements

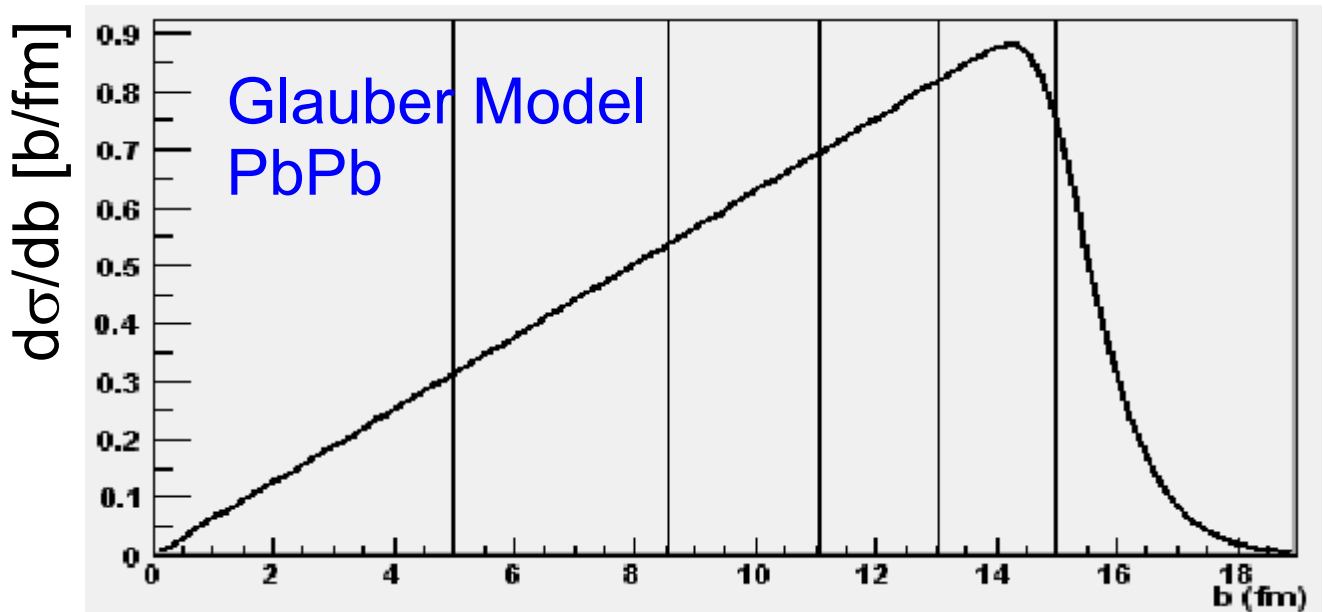
- Both absolute and relative measurements needed
  - Absolute: For example for unique charm cross section measurement in pp down to p_T=0.
  - Relative: Some signals are expressed as double ratios.
    - Example $(R_\psi/R_{cont})_{PbPb}/(R_\psi/R_{cont})_{pp}$

Luminosity Determination

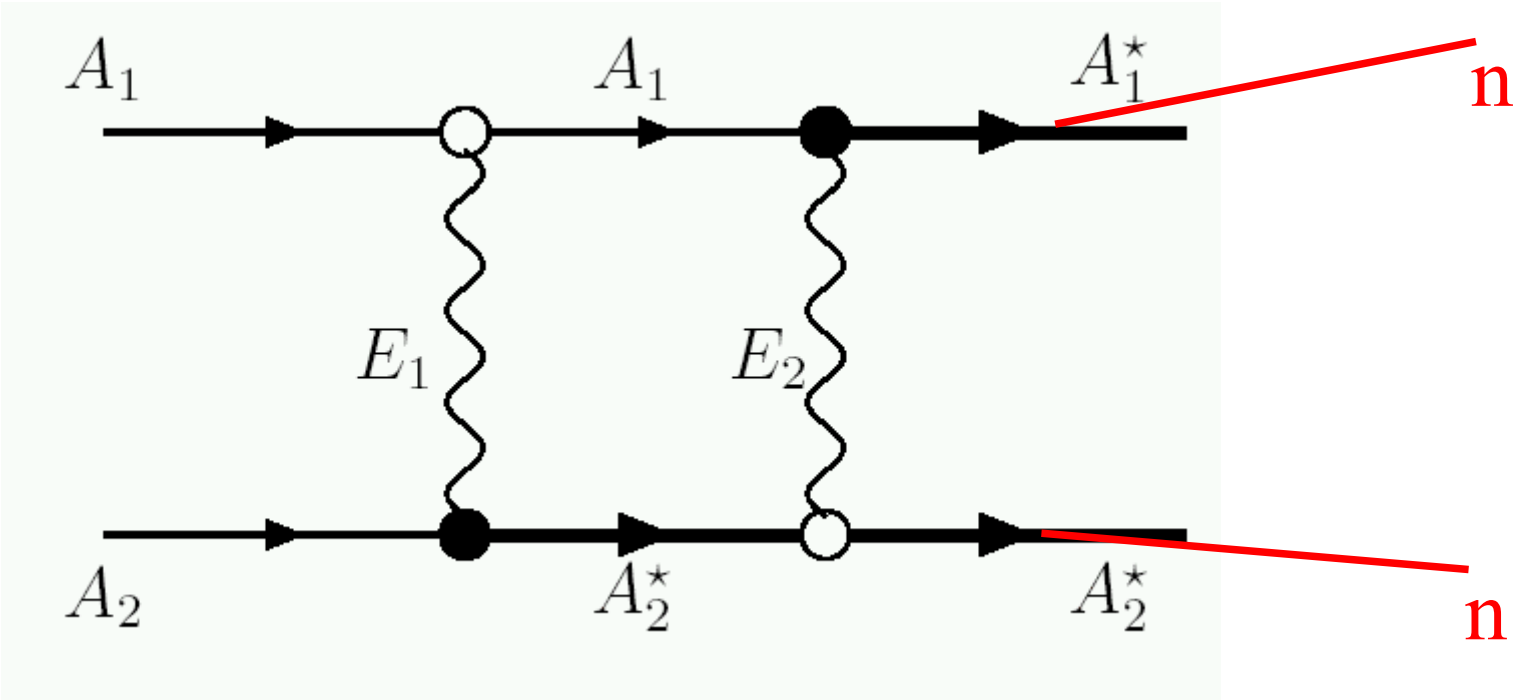
- Heavy Ion Collisions
  - Total inelastic (hadronic) cross-section
  - Mutual electromagnetic dissociation
- pp
  - Rate of inelastic interactions

Total inelastic cross-section

- Heavy ion cross section mainly given by geometry of Pb nucleus
  - Small dependence on nucleon-nucleon cross-section
  - 5% error from geometry parameter uncertainty
    - See talk by S. White, BNL



Mutual Electromagnetic Dissociation



Signal:
Correlated very Forward/Backward neutron production.

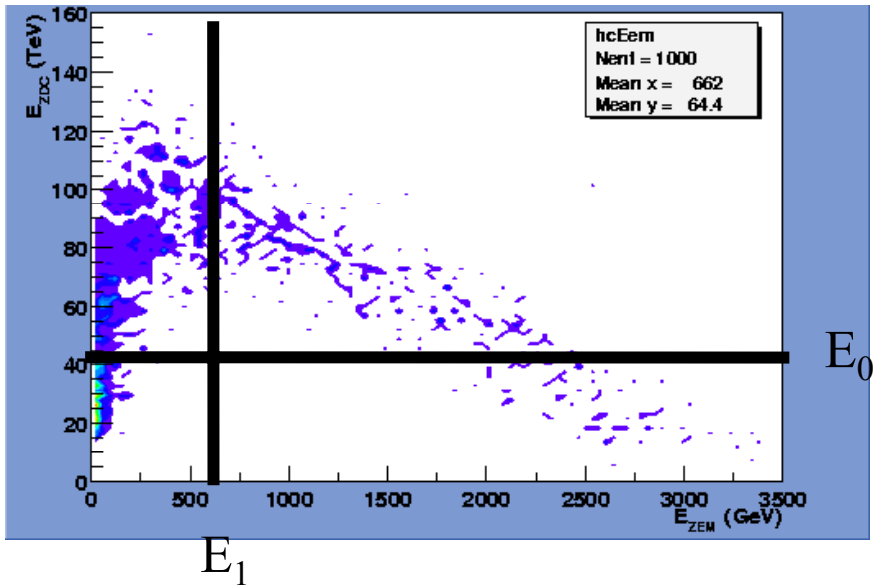
Event Geometry: ALICE ZDC Calorimeters

Aim: determination of the impact parameter of the collision by measuring the energy carried by the spectator nucleons

Where: hadronic calorimeters at ~ 116 m from IP
e.m. calorimeter at ~ 8 m from IP

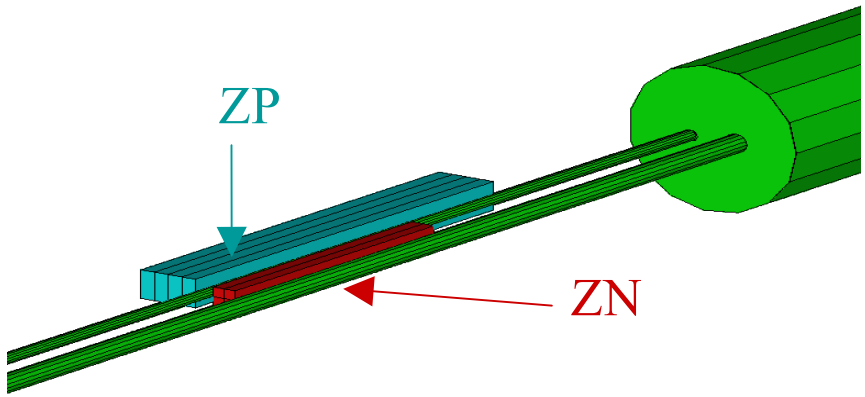
Central events selected with ***both***:
-Energy in hadronic calorimeters $< E_0$
-Energy in e.m. calorimeter $> E_1$

E_{had} vs $E_{e.m.}$



E_0

E_1

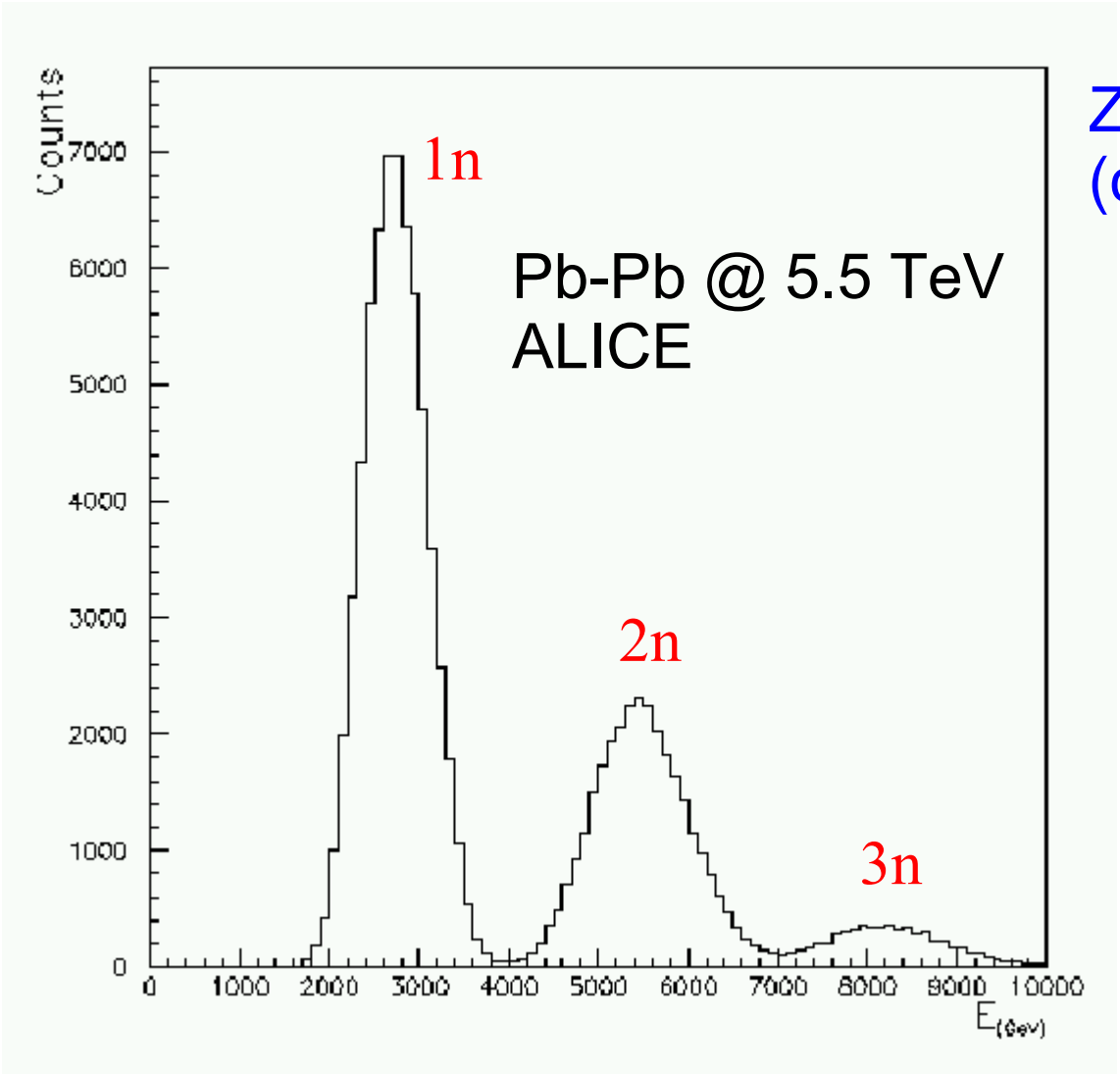


	Proton ZDC (ZP)	Neutron ZDC (ZN)	EM ZDC
Dimensions (cm^3)	12x21x150	7x7x100	7x7x21
Absorber	brass	W-alloy	lead
Fibre angle wrt LHC axis	0º	0º	45º
Fibre ∅ (μm)	550	365	550

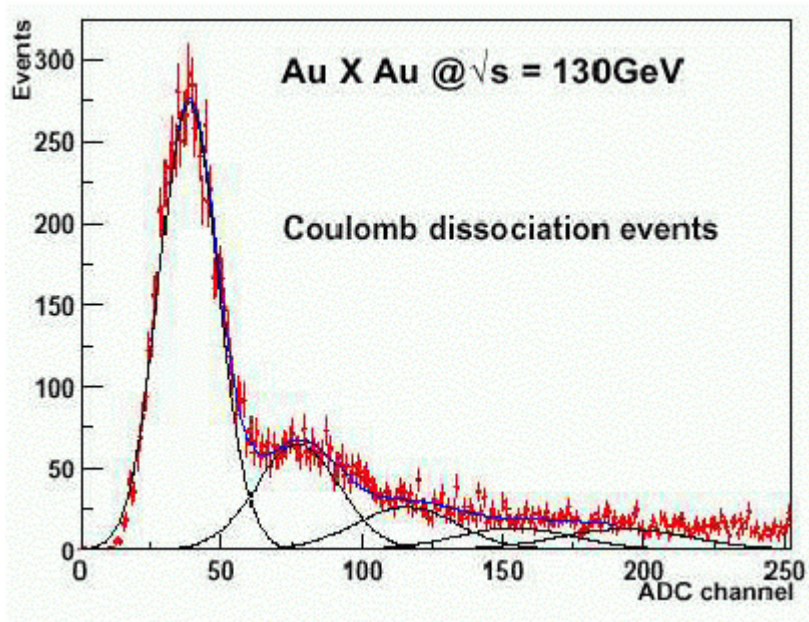
ZDC as a luminosity monitor

- Experimental considerations
  - Transverse momentum of n < 250 MeV
    - Emission angle < 0.1 mrad corresponding to 1 cm radius spot on ZDC front surface
  - Energy range 2.1 – 3.4 TeV
    - Clear separation between single and multi-neutron de-excitation
  - Both single and multi-neutron signals can be measured
    - Good background rejection (beam-gas)

Expected energy distribution of neutrons from e.m. excitation



ZDC resolution (10%) included
(compare RHIC: 20%)



ZDC as a luminosity monitor

- Theoretical considerations

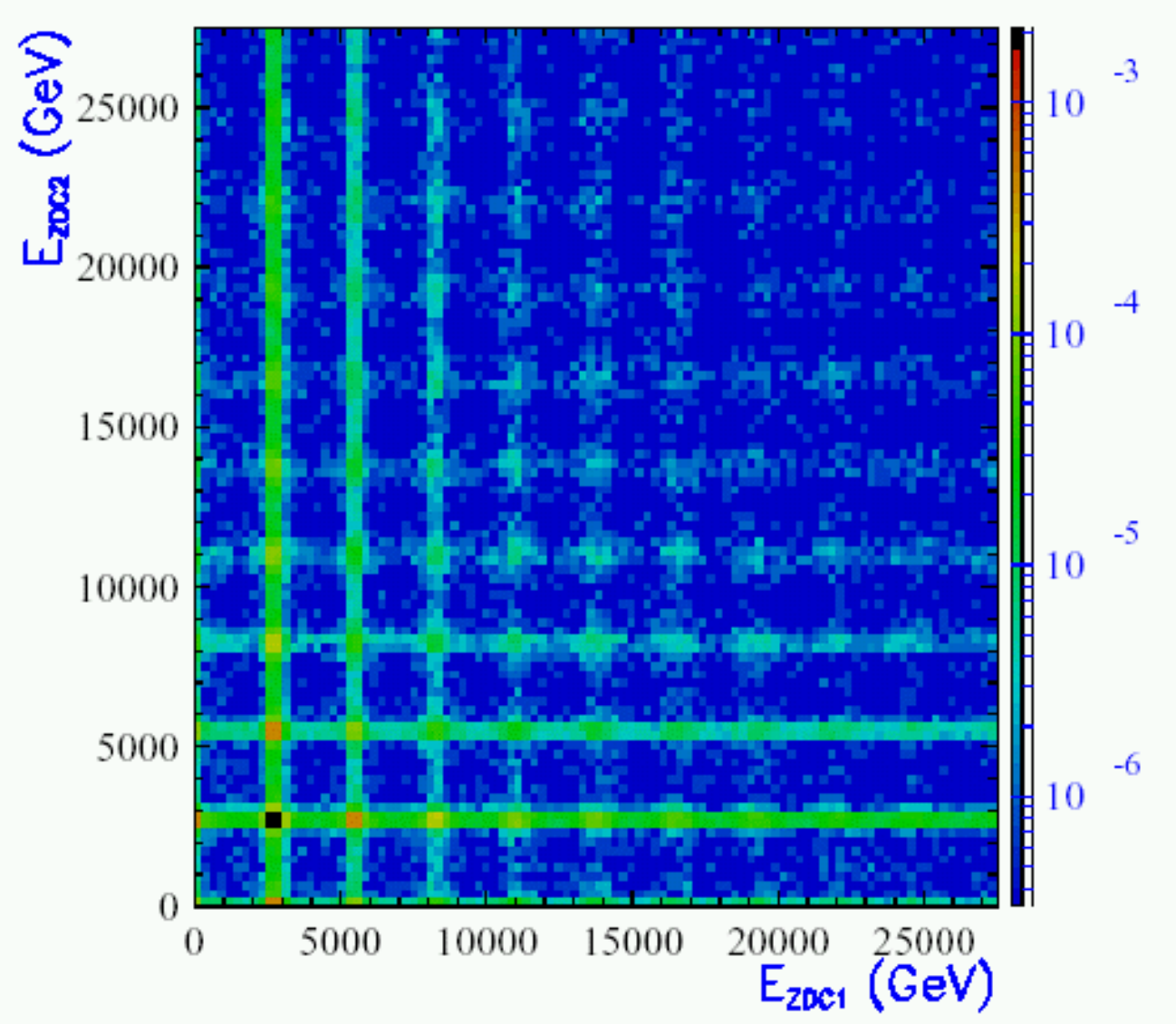
  (I.A. Pshenichnov et. al.)

  - Mutual electromagnetic dissociation cross-sections can be calculated with good accuracy
  - Model (parameter) variation of cross-sections
    - 10% for the 1n-1n correlated emission cross-section
    - 2% for the sum of one and two neutron emission channels “LMN” (1n-1n)+(1n-2n)+(2n-1n)+(2n-2n)
    - Expected cross-section: 1.38 barn
  - LMN proposed for luminosity measurement

Model (parameter) dependence of mutual electromagnetic dissociation cross-section

Cross section (mb)	$E_\gamma \leq 24$ MeV LO	$E_\gamma \leq 140$ MeV LO		Full range of E_γ LO+NLO	
	RELDIS $P_n^{dir} = 0$	GNASH	RELDIS $P_n^{dir} = 0$	RELDIS $P_n^{dir} = 0$	RELDIS $P_n^{dir} = 0.26$
$\sigma_m^{ED}(1nX \mid 1nY)$	519 533 [18]	488	544	727	**805**
$\sigma_m^{ED}(1nX \mid 2nY)+$ $\sigma_m^{ED}(2nX \mid 1nY)$	154	220	217	525	**496**
$\sigma_m^{ED}(2nX \mid 2nY)$	11	24	22	96	**77**
$\sigma_m^{ED}(LMN)$	684	732	783	1348	**1378**

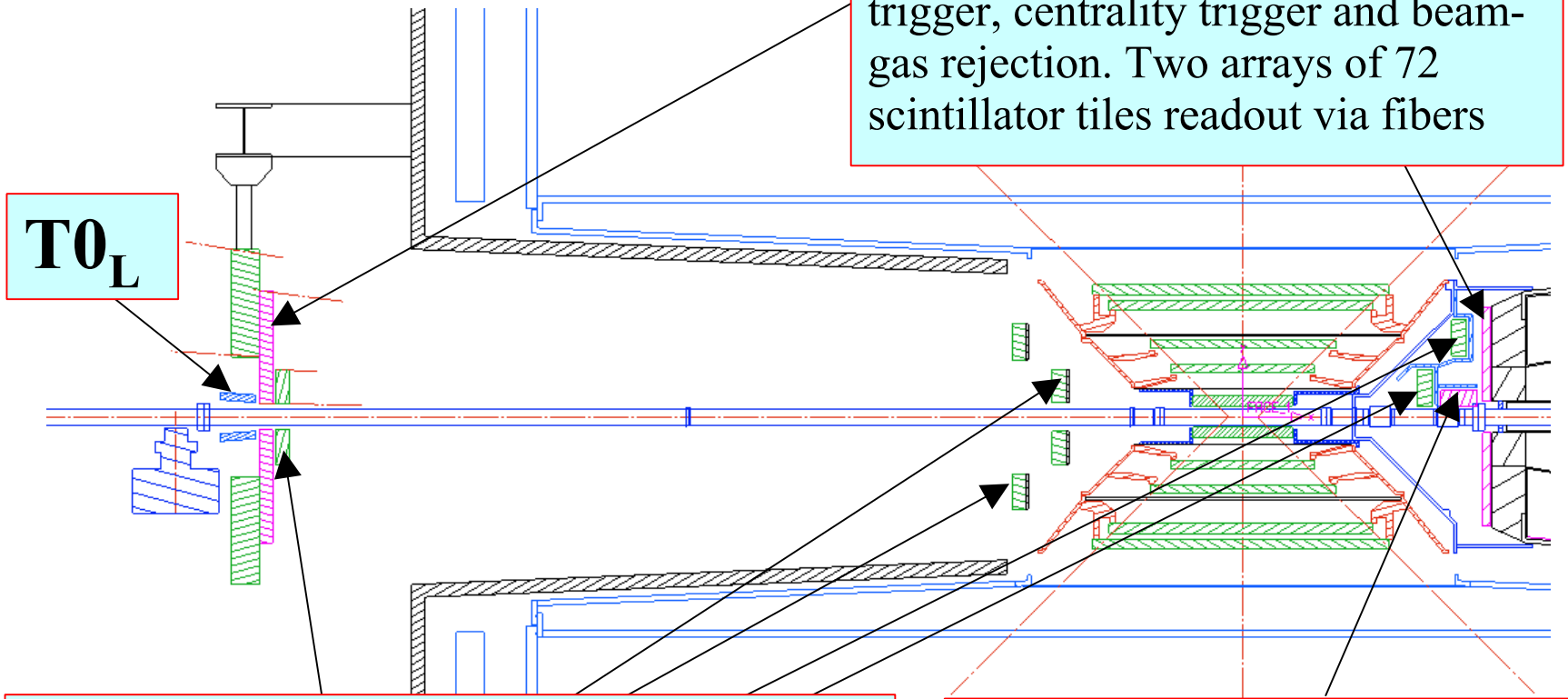
Distribution of the total forward-backward energy of neutrons emitted in mutual electromagnetic dissociation in PbPb collisions at the LHC



Luminosity determination in pp collisions

- TOTEM experiment measures total cross-section σ_{tot}.
  - ALICE will measure a fraction Acc x R_{tot} of the rate of inelastic interactions
  - Using V0 we can trigger on 86% of the total inelastic cross-section
    - 95% of the non-diffractive interactions
    - 45% of diffractive interactions
  - Experience from Tevatron shows
    - Error on acceptance can be reduced to few percent
    - Error dominated by uncertainty on total cross-section (5%)

Forward detectors



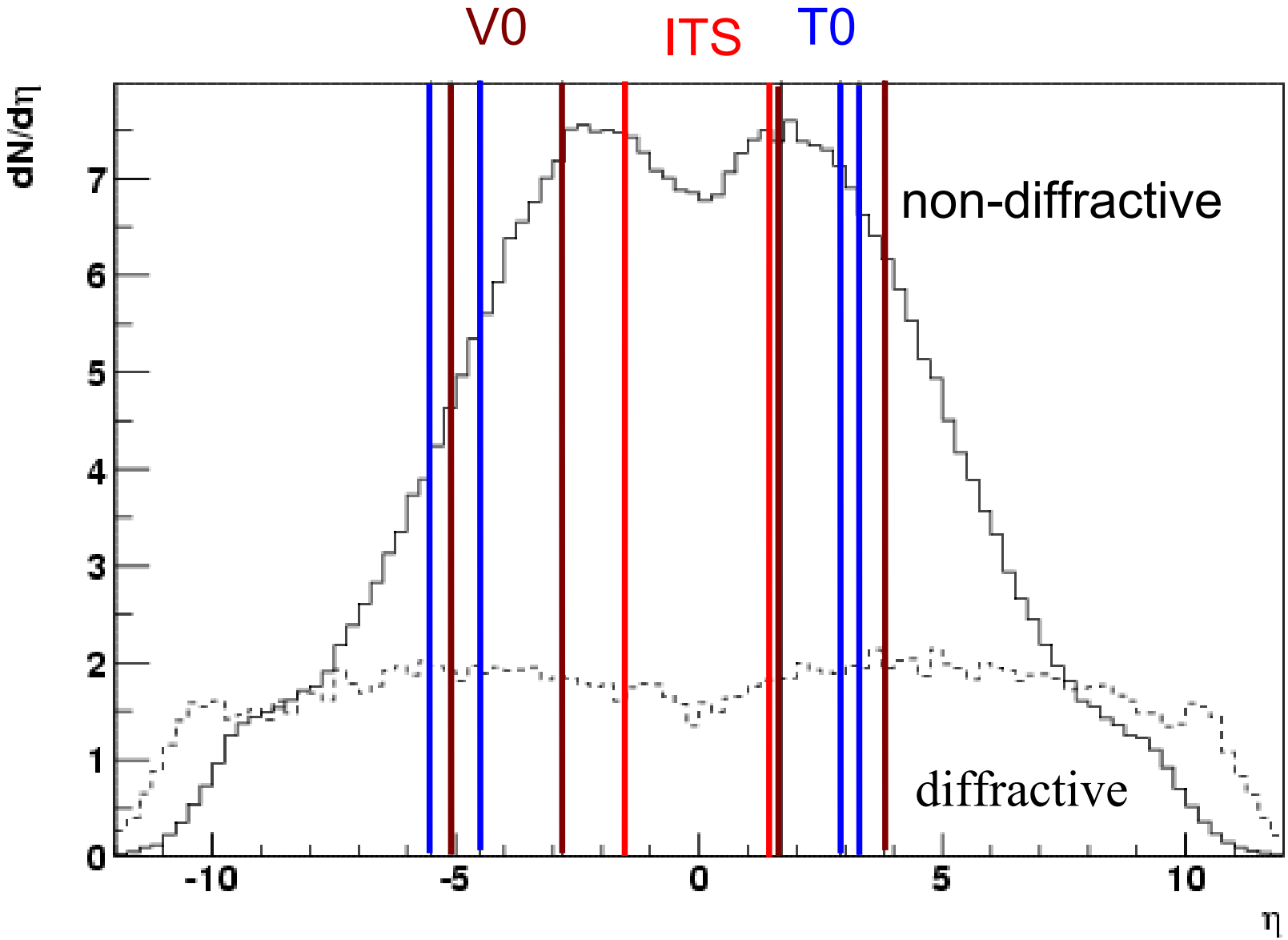
V0 $1.6 < |\eta| < 3.9$ Interaction trigger, centrality trigger and beam-gas rejection. Two arrays of 72 scintillator tiles readout via fibers

$T0_L$

FMD Measure Multiplicity and η dist. over $1.6 < \eta < 3$, $-5.4 < \eta < -1.6$
Silicon pad detector disks (slow readout) with 12k analog channels (occ.>1)

$T0_R$ $2.6 < |\eta| < 3.3$
T_0 for the TOF (~ 50 ps time res.) Two arrays of 12 quartz counters. Also backup to V0

Acceptance and Multiplicity



Beam Instrumentation Issues

- Instrumentation Group intents to put luminometer in front of ZDC
- First results show that ZDC energy resolution is not affected
  - Luminometer has been modeled by 3 cm thick Cu -box.
- Mechanical integration to be studied.
- Can ZDC and Luminometer be combined ?

Conclusions

- Both absolute and relative measurements needed
  - Absolute: For example for unique charm cross section measurement in pp down to p_T=0.
  - Relative: Some signals are expressed as double ratios.
- ALICE can measure absolute Pb-Pb cross-section with good precission (5%)
  - Total inelastic (geometric) cross-section
  - Correlated neutrons from electromagnetic dissociation
- Importance of PbPb luminosity measurement for pp-luminosity from machine (see talk by S. White) ?
- Relative measurement for pp, for absolute cross-section we need
  - Luminosity from machine or
  - Total cross-section from TOTEM