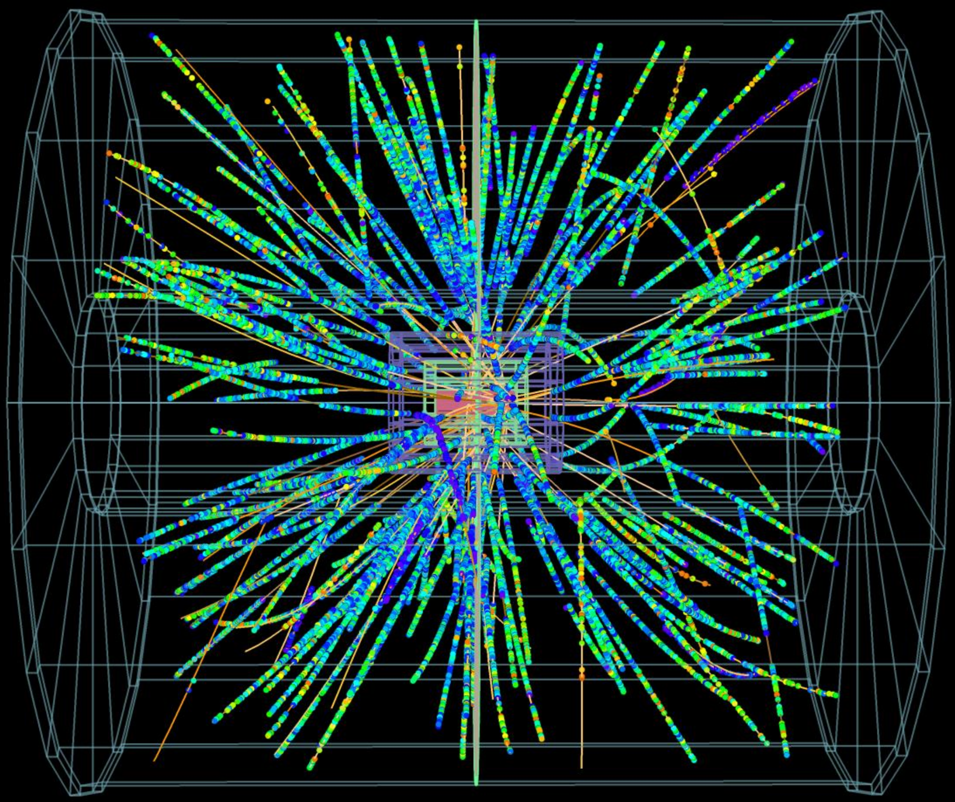
ALICE: diffraction studies, status and plans



p-Pb 2013

Introduction

Summary of measurements on Diffractive Physics

Central Diffractive studies

Plans to improve performance of ALICE in diffractive physics

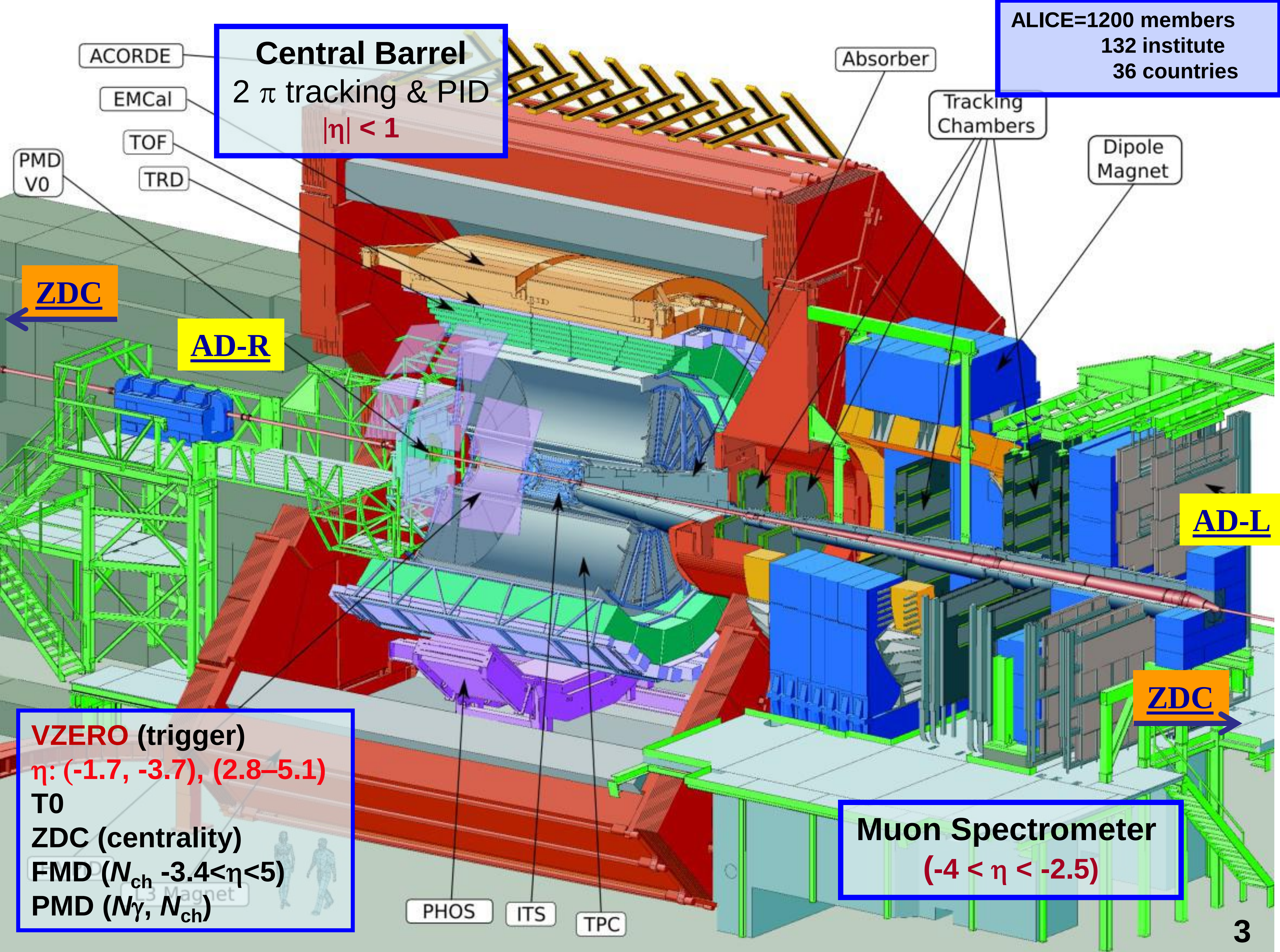
Plans for Diffractive studies in p-Pb

Conclusion

Results and prospects of forward physics at the LHC: Implications for the study of diffraction, cosmic ray interactions and more. CERN, feb. 11-12, 2013

Gerardo Herrera Corral

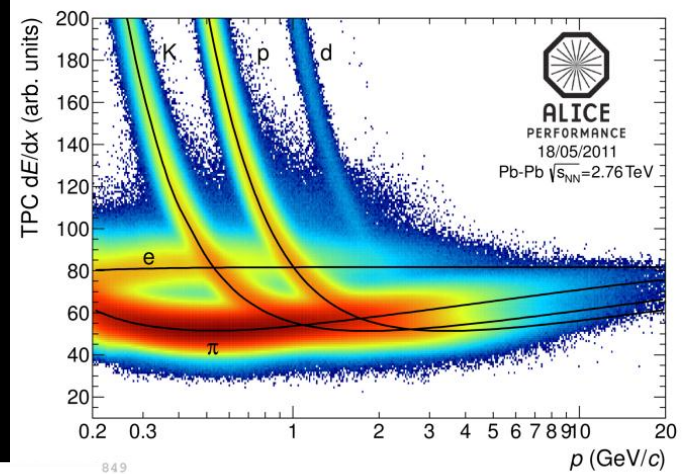
Introduction

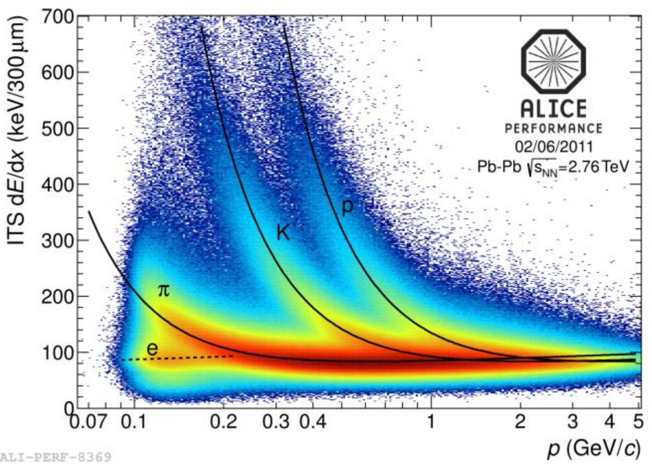

ALICE=1200 members
132 institute
36 countries
Central Barrel
2 π tracking & PID
|η| < 1
ACORDE
EMCal
TOF
TRD
PMD
V0
ZDC
AD-R
Absorber
Tracking Chambers
Dipole Magnet
AD-L
ZDC
VZERO (trigger)
η: (-1.7, -3.7), (2.8–5.1)
T0
ZDC (centrality)
FMD (N_ch -3.4<η<5)
PMD (Nγ, N_ch)
PHOS
ITS
TPC
Muon Spectrometer
(-4 < η < -2.5)

all known techniques for particle identification:

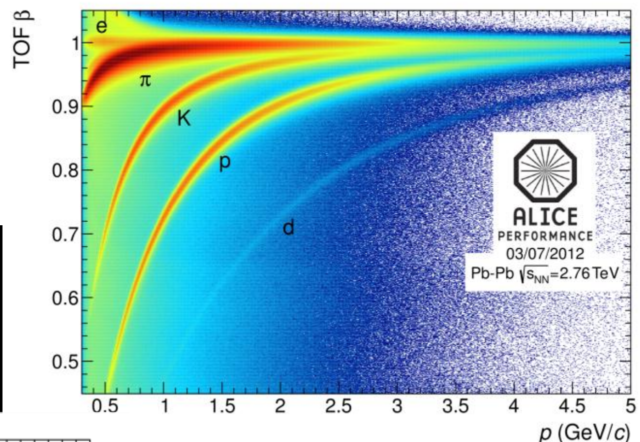
inclusive and exclusive particle production in centrally produced systems, in various channels …

in progress





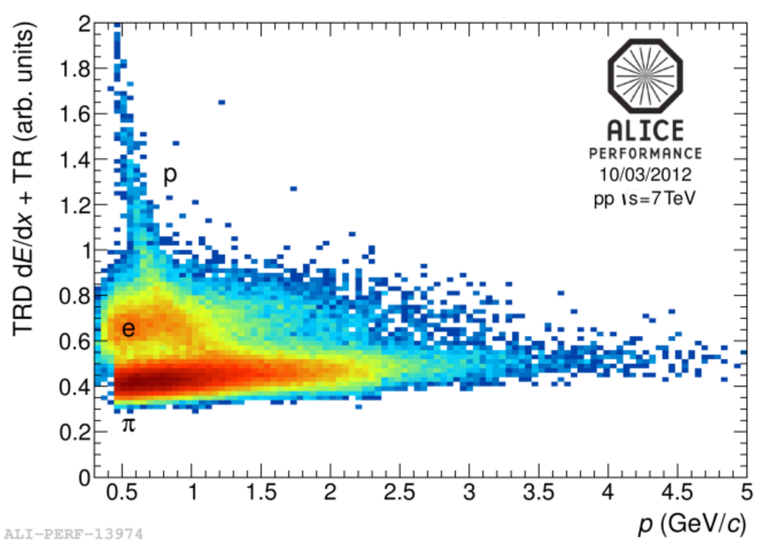
ITS



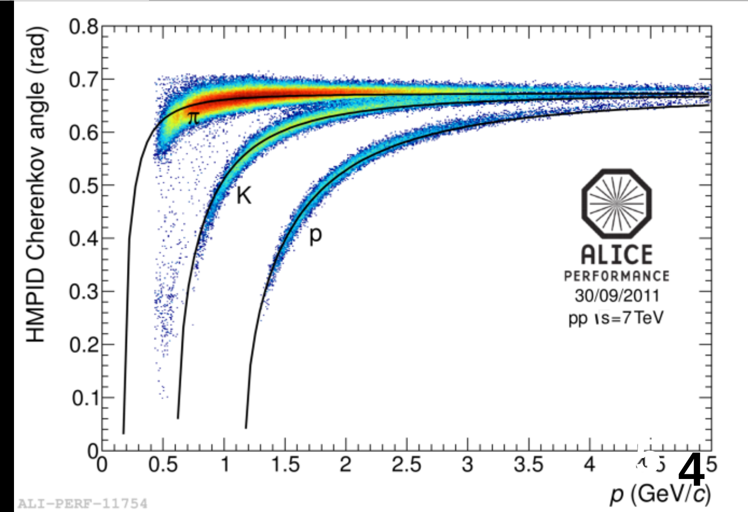
TPC

TOF

HMPID



TRD



LHC heavy ion runs

- **Two heavy-ion runs at the LHC so far:**
  - 2010 – commissioning and first data taking
  - 2011 – above nominal instant luminosity

- **p–Pb & Pb–p - 2013**
  - Goal ~ 30 nb^{-1}

  pilot run September 13th 2012 → **4 papers submitted**

- **Long Shutdown in 2013-2014**

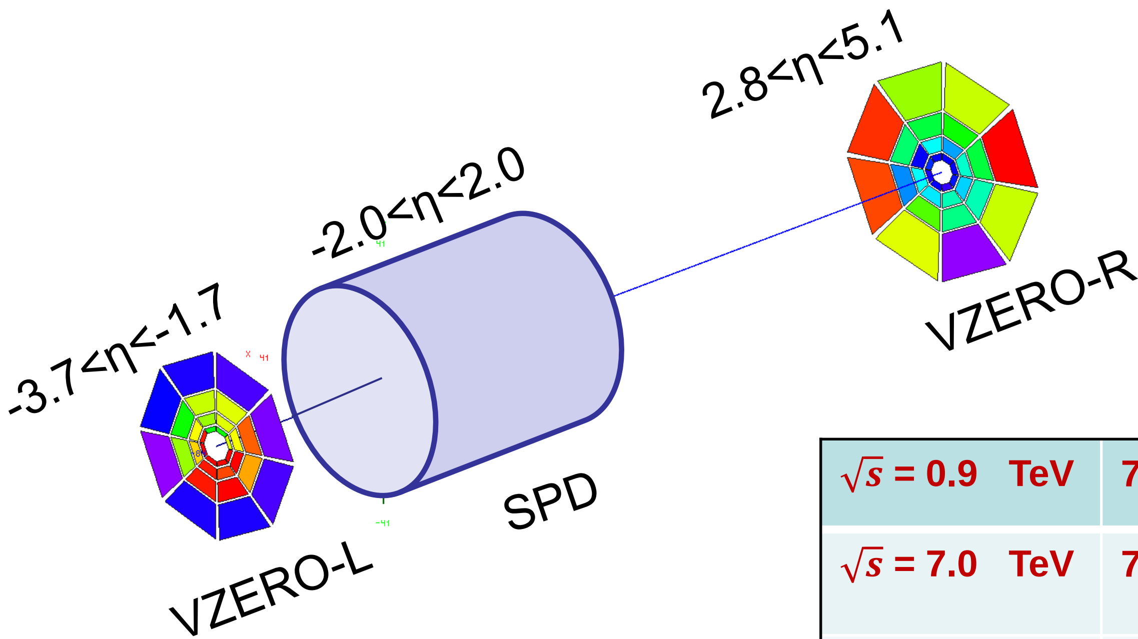
year	system	Energy $\sqrt{s_{NN}}$ (TeV)	integrated luminosity
2010	**Pb – Pb**	**2.76**	**~ 10 μb^{-1}**
2011	**Pb – Pb**	**2.76**	**~ 0.1 nb^{-1}**
2013	**p – Pb**	**5.02**	**~ 30 nb^{-1}**

Summary of measurements on Diffractive Physics

Measurements of Diffractive and Inelastic Cross Section

Event samples

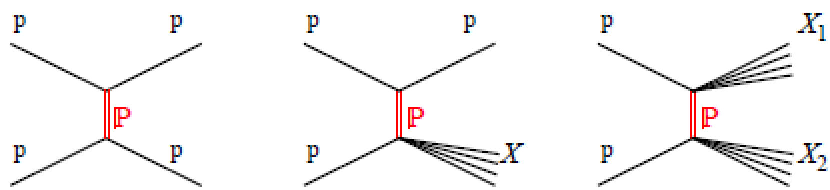
- Data at three energies : $\sqrt{s}$ = 0.9 2.76 7 TeV
- Low luminosity, low pile-up:
  average number of collisions per bunch crossing = 0.1
- Trigger used: Minimum Bias – OR i.e.
  at least one hit in SPD or VZERO
- VZERO signal should be in time with particles produced in the collisions



DATA

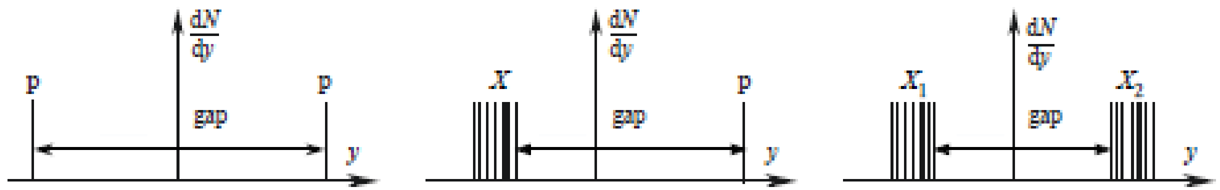
$\sqrt{s}$ = 0.9 TeV	7 $\times 10^6$ events
$\sqrt{s}$ = 7.0 TeV	75 $\times 10^6$ events
$\sqrt{s}$ = 2.76 TeV	23 $\times 10^6$ events

- Filled and empty bunch buckets used to measure beam induced background, accidentals due to electronics noise and cosmic showers



theory

elastic - single - double - diffractive proton-proton scattering



experiment

Silicon Pixel Detector
$|\eta|<2$

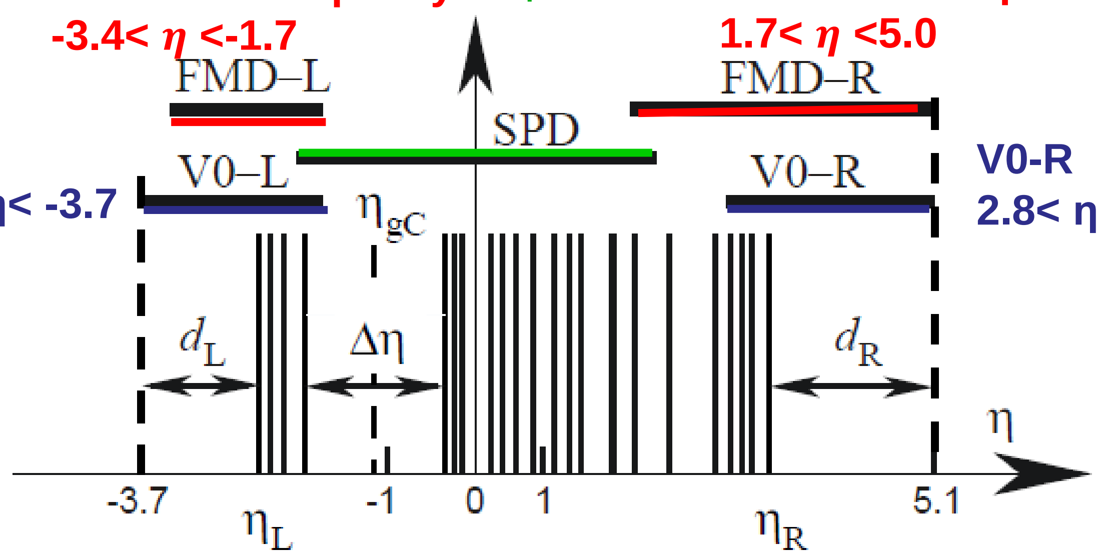
Forward Multiplicity
$-3.4< \eta <-1.7$

Forward Multiplicity
$1.7< \eta <5.0$

ALICE

V0-L
$-1.7< \eta< -3.7$

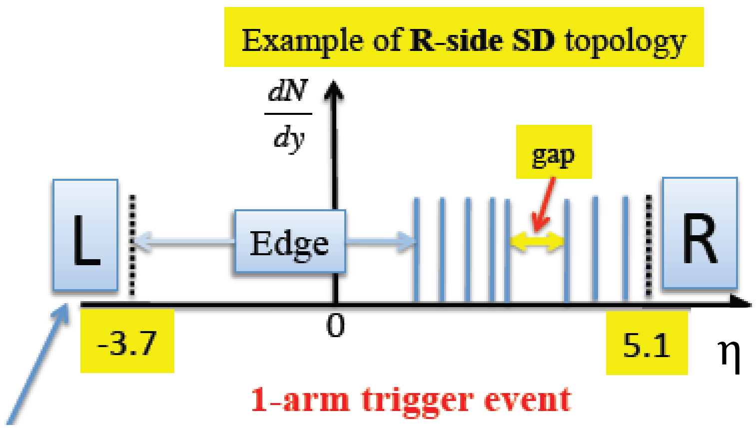
V0-R
$2.8< \eta< 5.1$

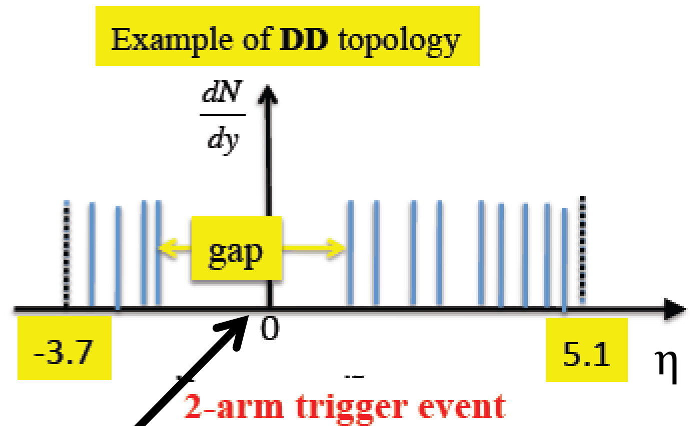


$$\eta_c = \frac{1}{2}(\eta_L + \eta_R)$$

η_L **lowest-** η_R **highest - pseudorapidity**

offline event clasification: “1 arm-L” “1 arm-R” “2 arm”





muon spectrometer

$$\eta_c = \frac{1}{2}(\eta_L + \eta_R)$$

$\eta_C < 0$	1-arm-L
$\eta_C > 0$	1-arm-R

if largest	$\Delta\eta > d_L$ and d_R	2-arm
if both	$-1 \leq \eta_L$ and $\eta_R \leq 1$	2-arm

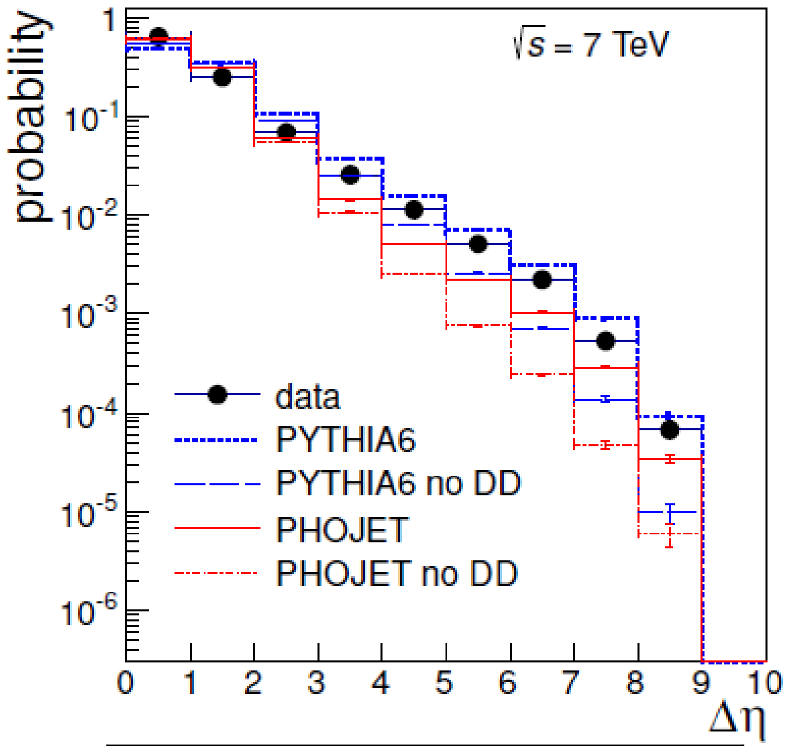
If	$\eta_R < 1$	1-arm-L
If	$\eta_L > -1$	1-arm-R

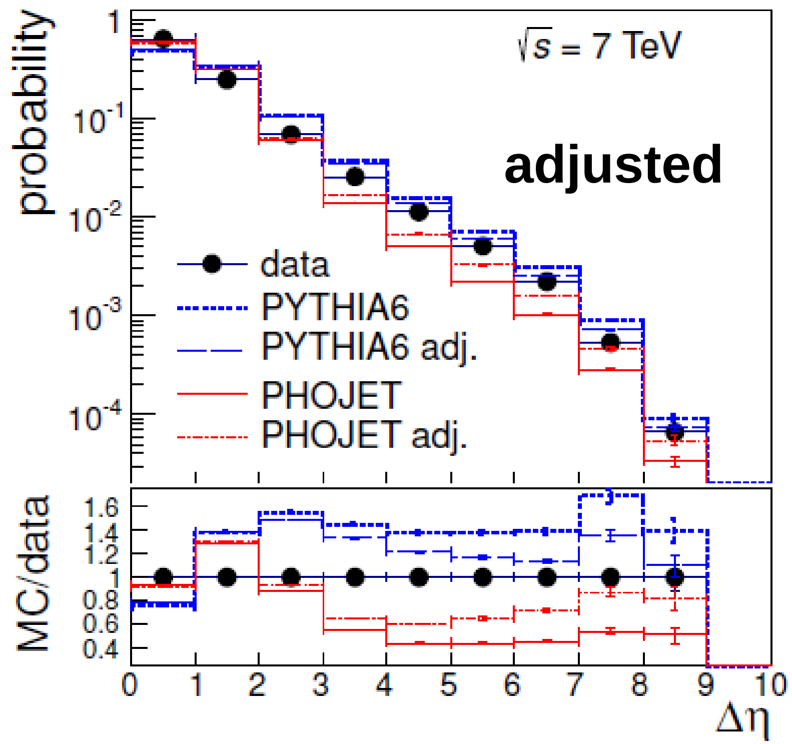
2-arm events

largest $\Delta\eta$

tuning PYTHIA and PHOJET double diffraction to experimental width distribution of two arm events

arXiv:1208.4968 [hep-ex]





$\sqrt{s}$ TeV	PYTHIA	PHOJET
0.9	0.12	0.06
7.0	0.13	0.05

$\sqrt{s}$ TeV	PHYTIA tuned	PHOJET tuned
0.9	0.10	0.11
7.0	0.09	0.07

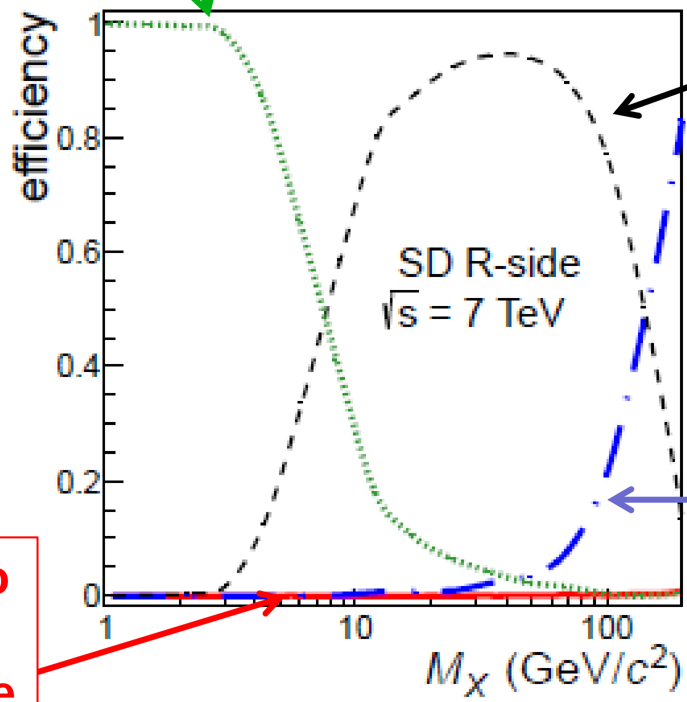
- **Once DD is chosen the ratios 1-arm-L and 1-arm-R to 2-arm can be used to compute SD fractions.**

- efficiency/in-efficiency versus diffractive mass for SD :

probability of not detecting

efficiency for a SD to be classified as 1-armL(R)

PYTHIA 6



efficiency to be classified as 2-arm

efficiency to be taken as the opposite

efficiencies used: mean between PYTHIA and PHOJET

efficiency of SD & NSD to be classified as 1-arm L(R), 2-arm at high energy the ratio remains constant

$\sqrt{s}$ (TeV)	ratio definition	ratio	side	$\sigma_{SD}/\sigma_{INEL}$ per side	total
0.9	1-arm-L/2-arm	0.0576 ± 0.0002	L-side	0.10 ± 0.02	0.21 ± 0.03
	1-arm-R/2-arm	0.0906 ± 0.0003	R-side	0.11 ± 0.02	
2.76	1-arm-L/2-arm	0.0543 ± 0.0004	L-side	0.09 ± 0.03	$0.20^{+0.07}_{-0.08}$
	1-arm-R/2-arm	0.0791 ± 0.0004	R-side	$0.11^{+0.04}_{-0.05}$	
7	1-arm-L/2-arm	0.0458 ± 0.0001	L-side	$0.10^{+0.02}_{-0.04}$	$0.20^{+0.04}_{-0.07}$
	1-arm-R/2-arm	0.0680 ± 0.0001	R-side	$0.10^{+0.02}_{-0.03}$	

consistent with UA5 $p\,\bar{p}$

results symmetric despite different acceptance from ALICE

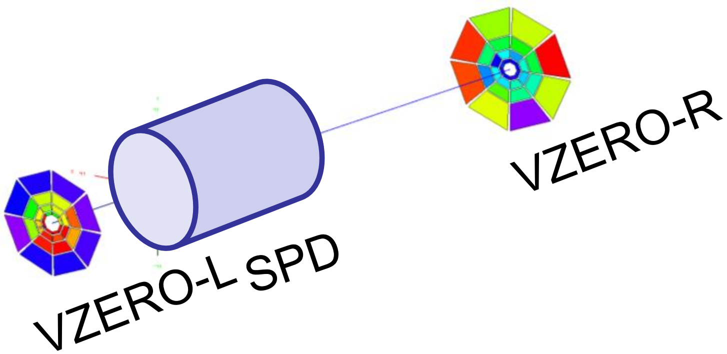
corrected for acceptance, efficiency, beam background, electronic noise and collision pileup

DD events defined as NSD with large gap

$\sqrt{s}$ (TeV)	$\sigma_{DD}/\sigma_{INEL}$
0.9	0.11 ± 0.03
2.76	0.12 ± 0.05
7	$0.12^{+0.05}_{-0.04}$

with $\Delta\eta > 3$

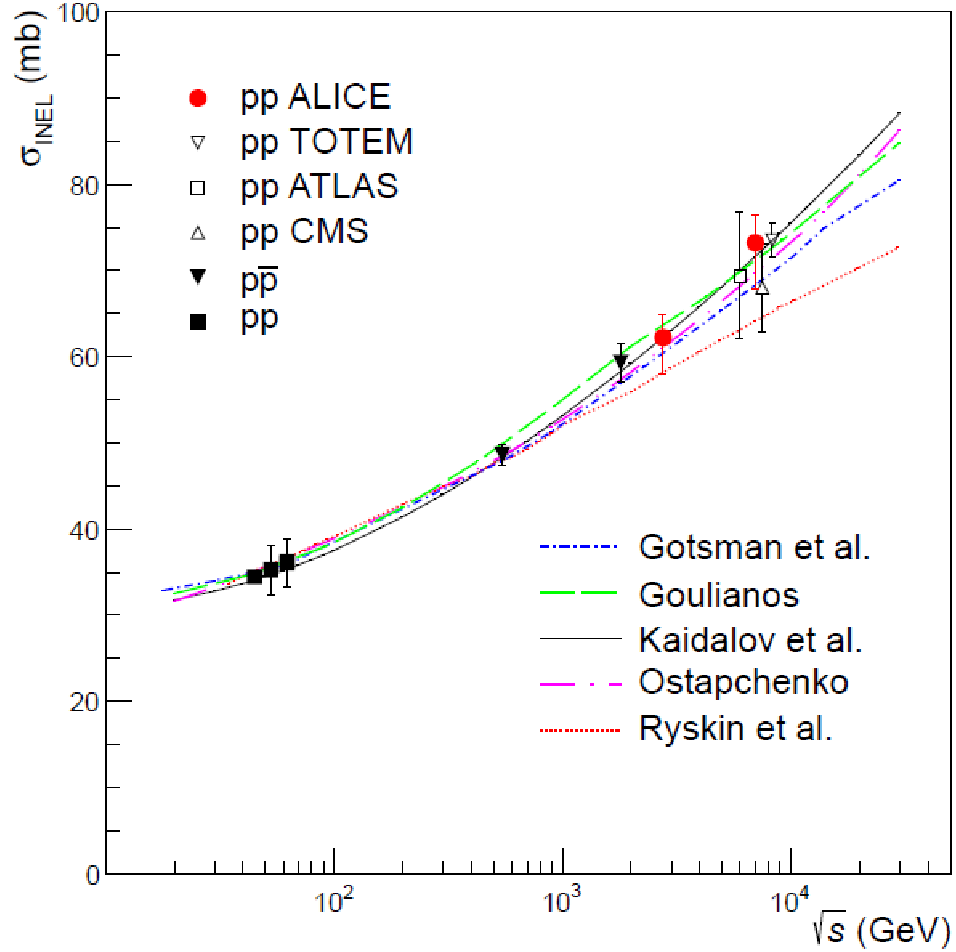
Measurement of Inelastic Cross Section



MB-and : coincidence of VZERO-L and –R in a van der Meer scan

$$\frac{dN(MBand)}{dt} = A \times \sigma_{inel} \times L$$

acc. and eff. determined with adjusted simulation



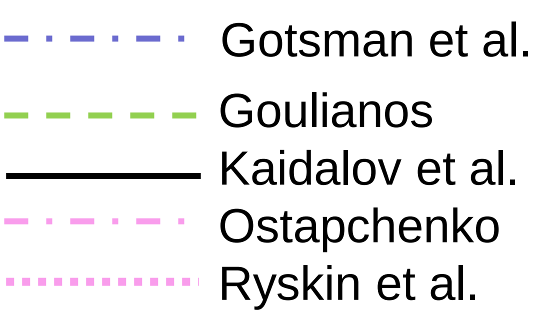
Experiment	σ_{INEL} (mb)
ALICE	$73.2^{+2.0}_{-4.6}(model) \pm 2.6(lumi)$
ATLAS [19]	$69.4 \pm 6.9(model) \pm 2.4(exp)$
CMS [20]	$68.0 \pm 4.0(model) \pm 2.0(syst) \pm 2.4(lumi)$
TOTEM [21]	$73.5^{+1.8}_{-1.3}(syst) \pm 0.6(stat)$

Measurements of Diffractive Cross Section

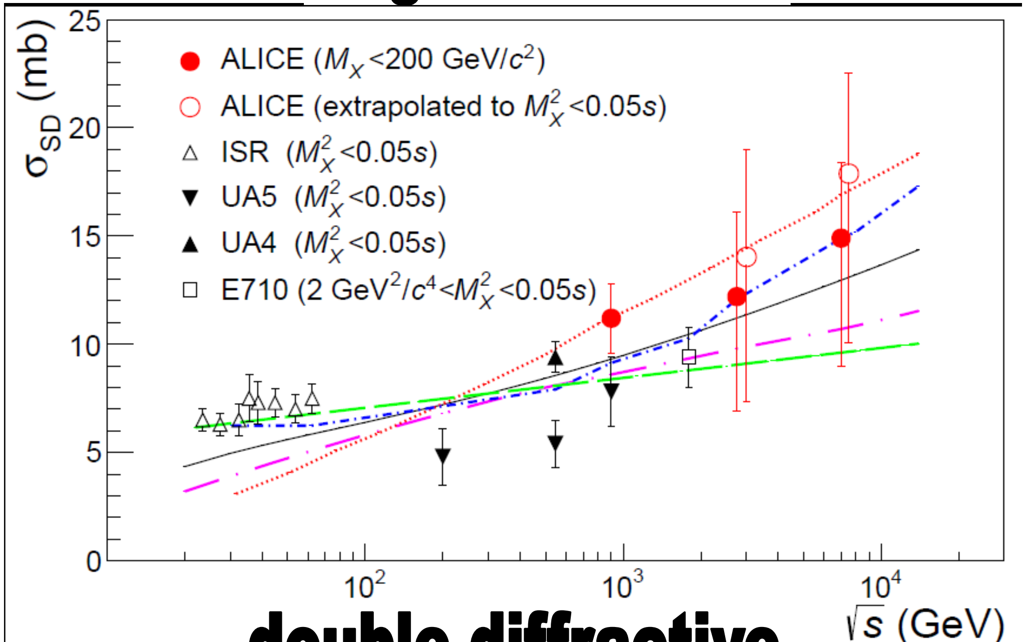
with inelastic cross section and relative rates we obtain SD and DD cross sections

for $\sqrt{s} = 0.9\ TeV$ we do not have vdM scan and σ_{inel} from UA5 was used

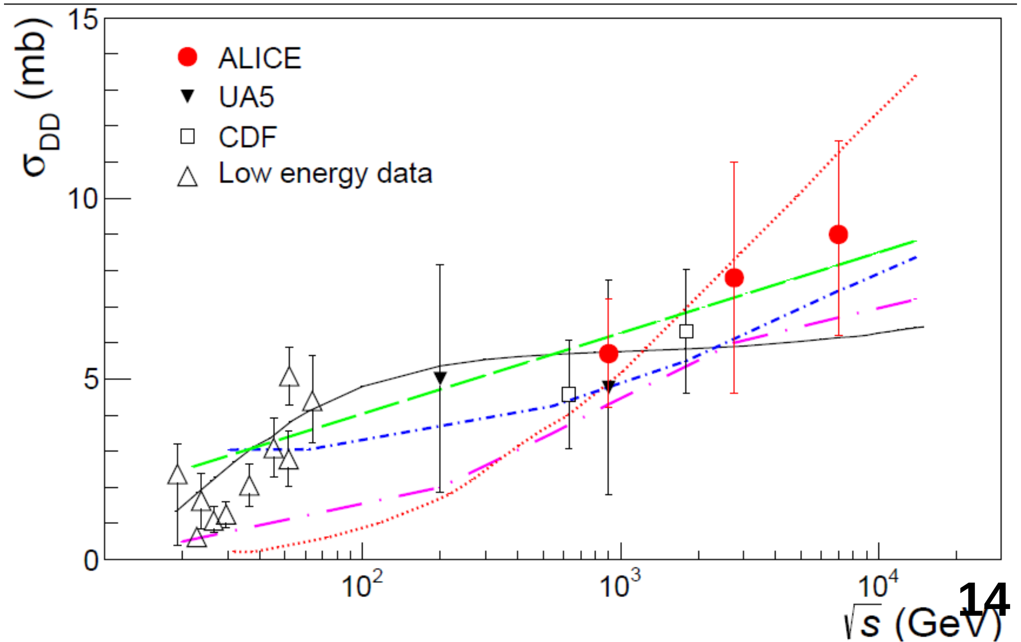
$$\sigma_{INEL} = 52.5^{+2}_{-3.3}\ mb$$



single diffractive



double diffractive

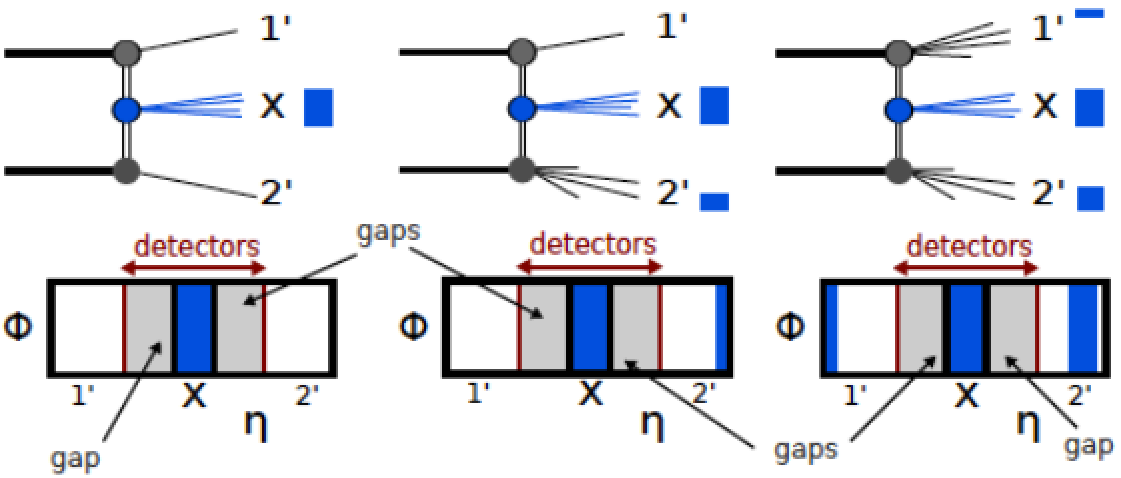


Central Diffractive Physics

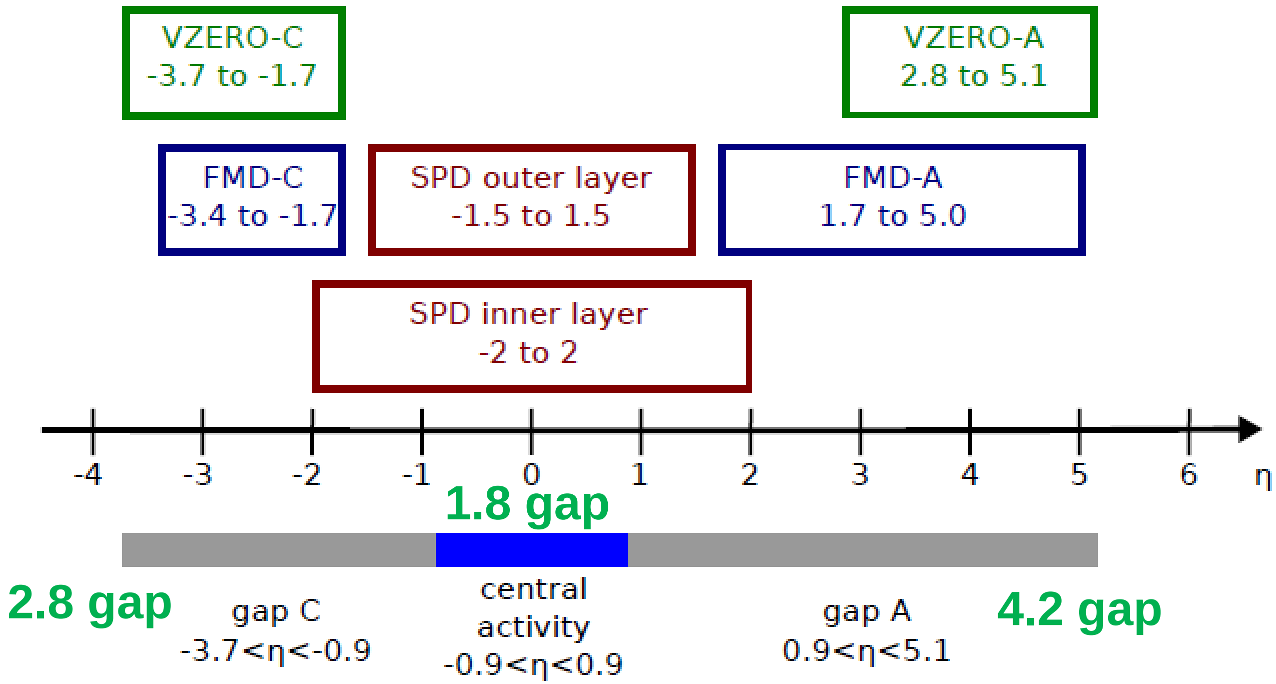
Central diffraction in proton proton collisions at $\sqrt{s}$ = 7 TeV

Double Gap topology as a filter for Central Diffraction

Central Diffraction | **CD with single Diffractive dissociation** | **CD with double Diffractive dissociation**



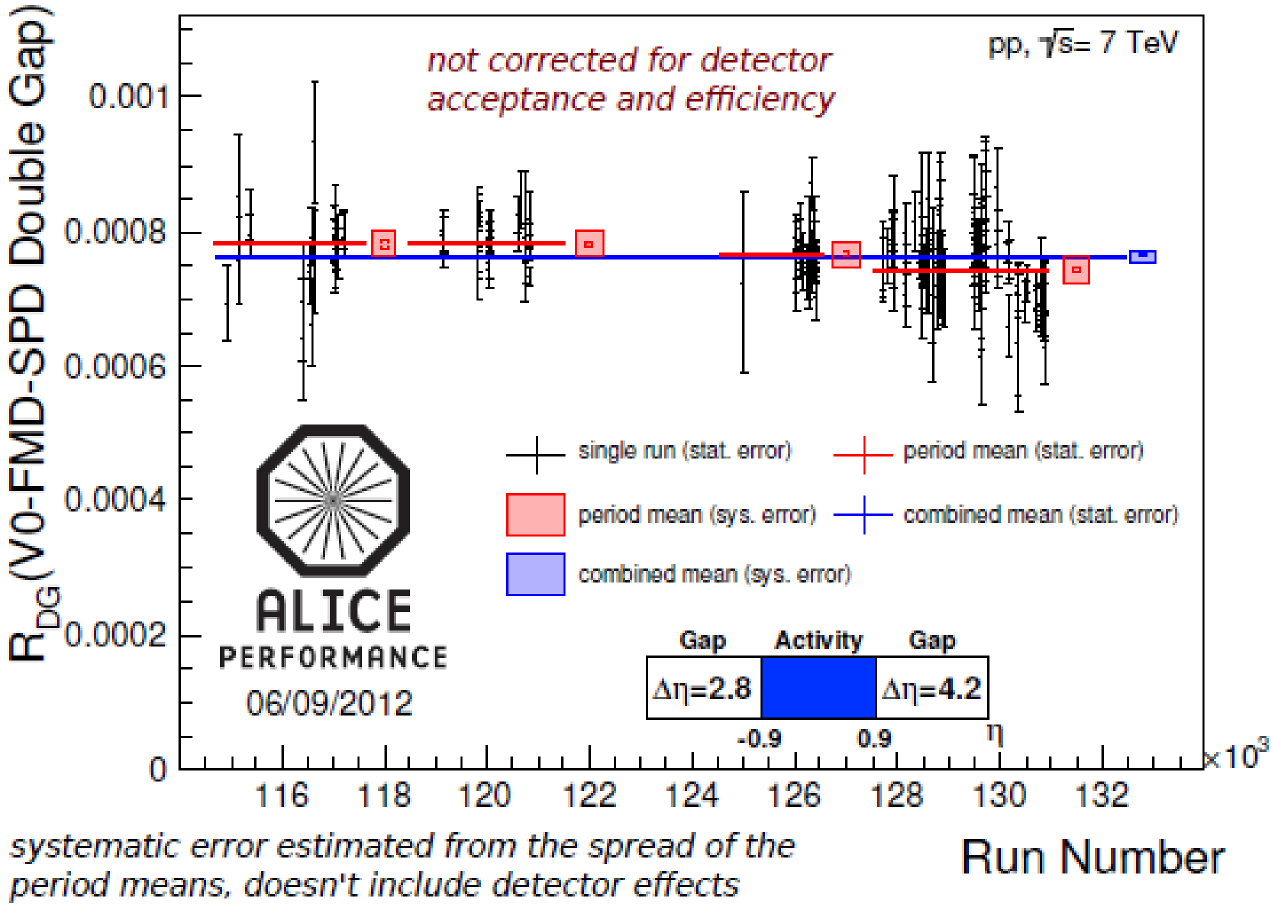
Double Gap topology



$$N_{DG} = \frac{\text{Number of Double Gap events}}{\text{Number of VZERO-L –R coincidence}}$$

Potential measure of the amount of Central Diffractive events in Minimum Bias data

Double Gap fraction in proton proton $\sqrt{s} = 7\ TeV$



- **fraction uniform over several data taking periods**

Next:

turn it into a cross section

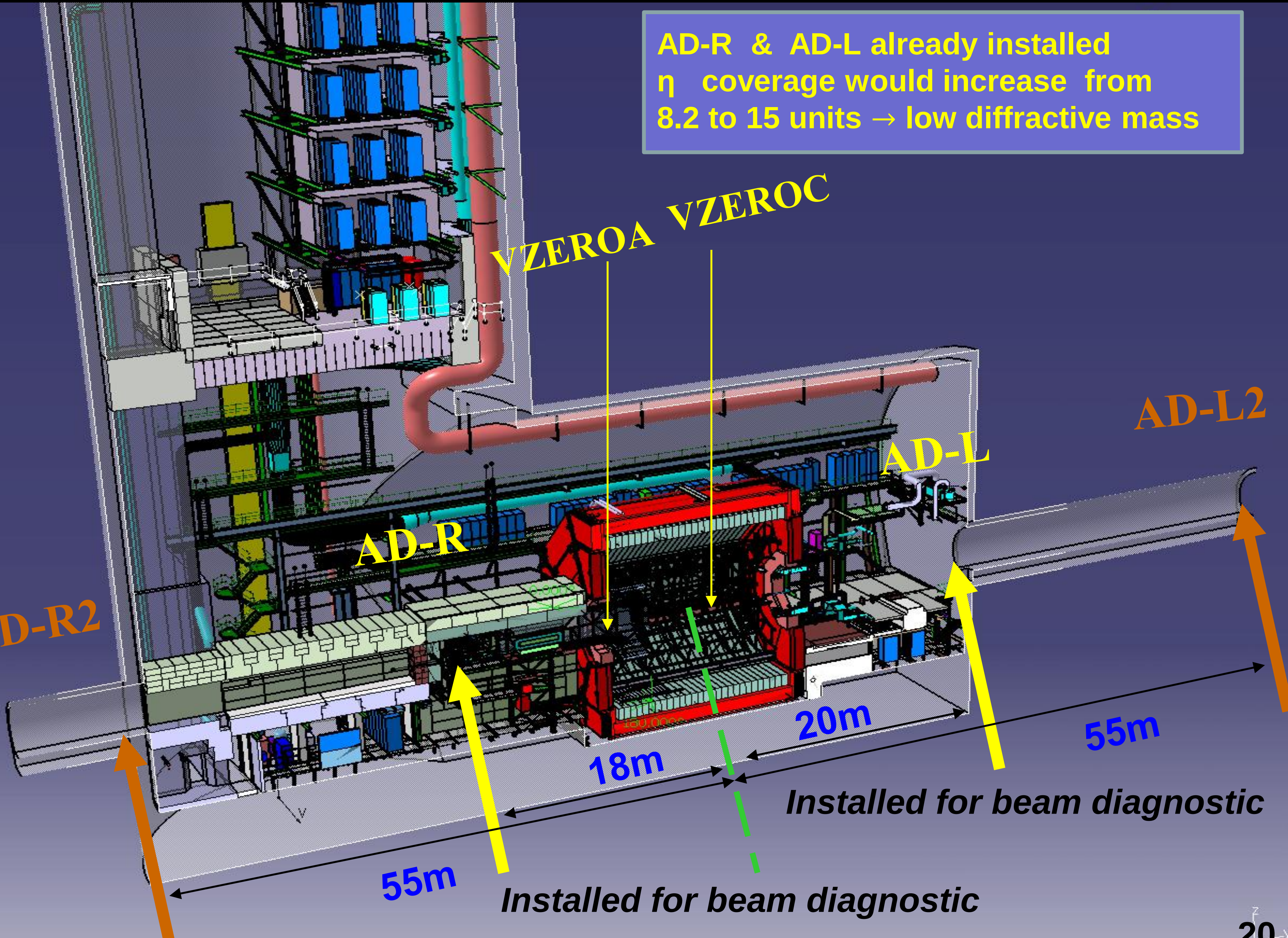
$$\frac{N_{DG}}{N_{\mathrm{MBand}}} = (7.63 \pm 0.02(stat.) \pm 0.95(syst.)) \cdot 10^{-4}$$

we are exploring the invariant mass distribution

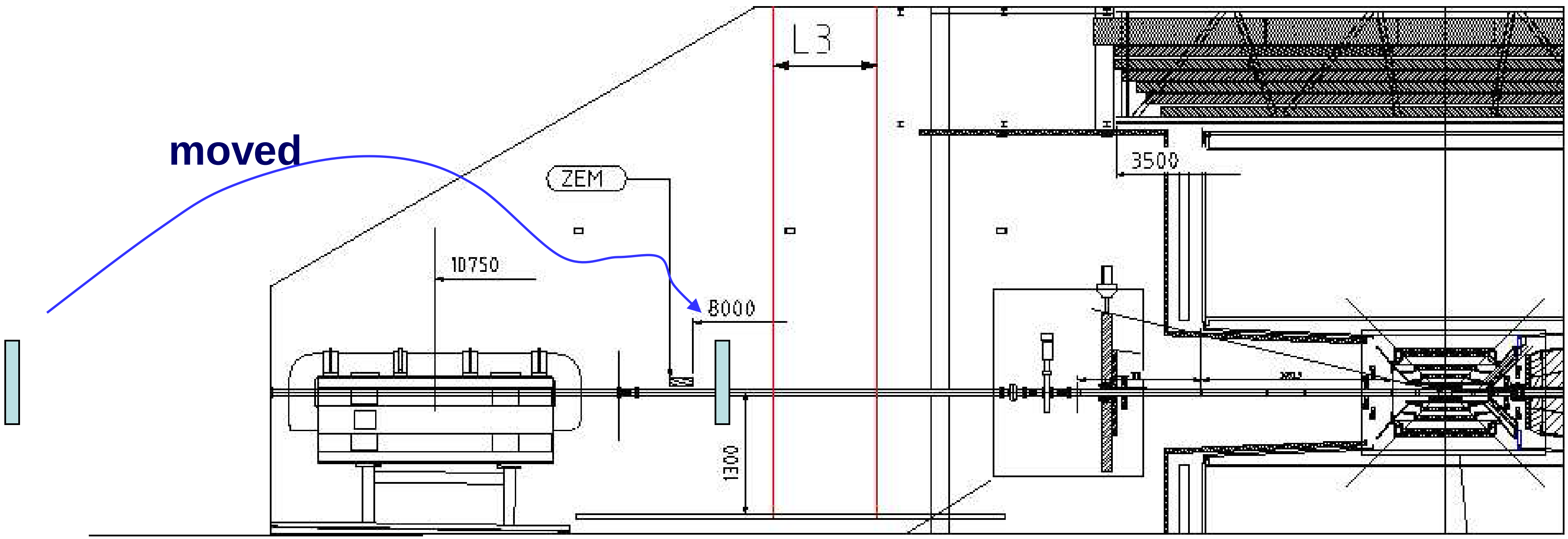
plans to improve ALICE performance on photon induced and diffractive physics

stations of scintillation detectors - Proposed -

AD-R & AD-L already installed
η coverage would increase from
8.2 to 15 units → low diffractive mass



AD-R installed and operating as beam loss monitor

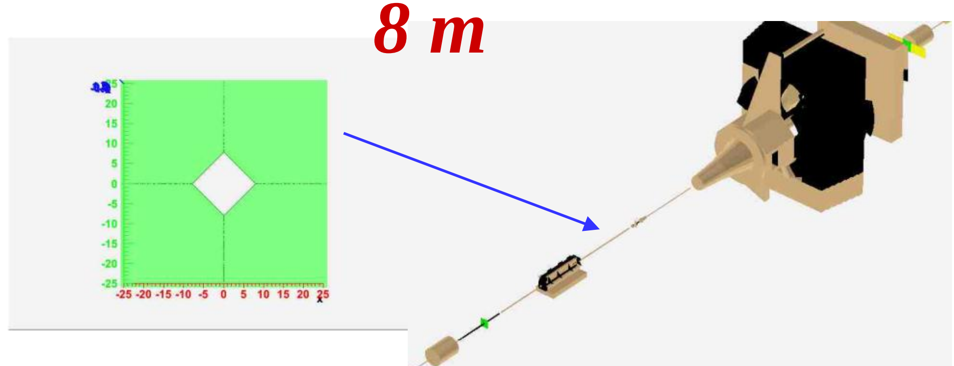


IP

17 m

8 m

AD-R



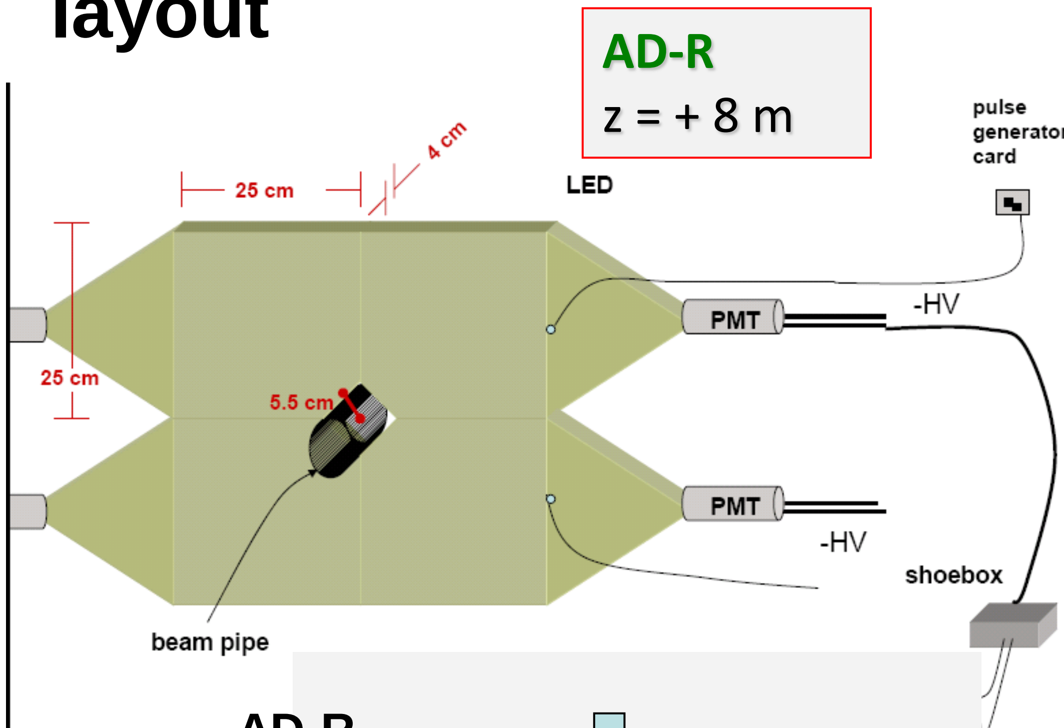
Diffractive Physics- Beam Loss Scintillator layout

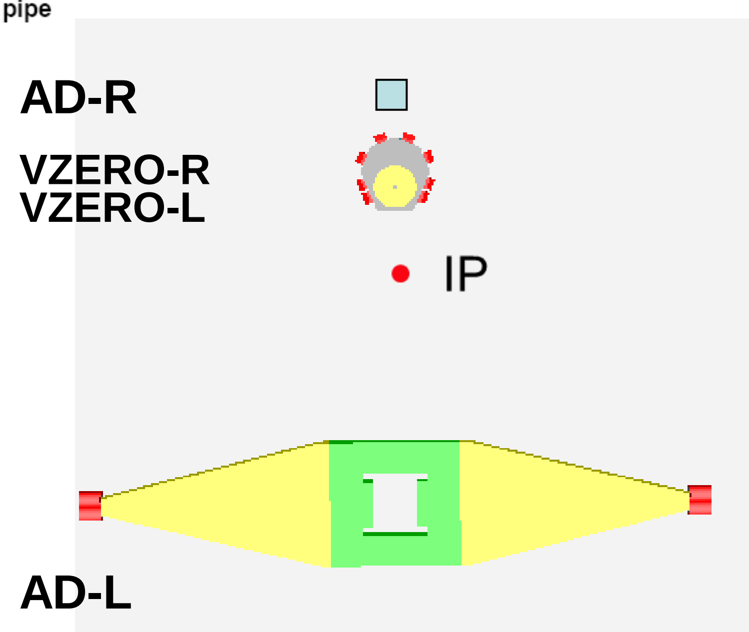
- Two arrays of 4 scintillators 25x25x4 cm surrounding the beam pipe both sides of the interaction point, mounted on EMI9814B PMTs (gain 3×10^{7})

- Conceived for diffractive physics

- Readout board: Beam Phase Intensity Monitor

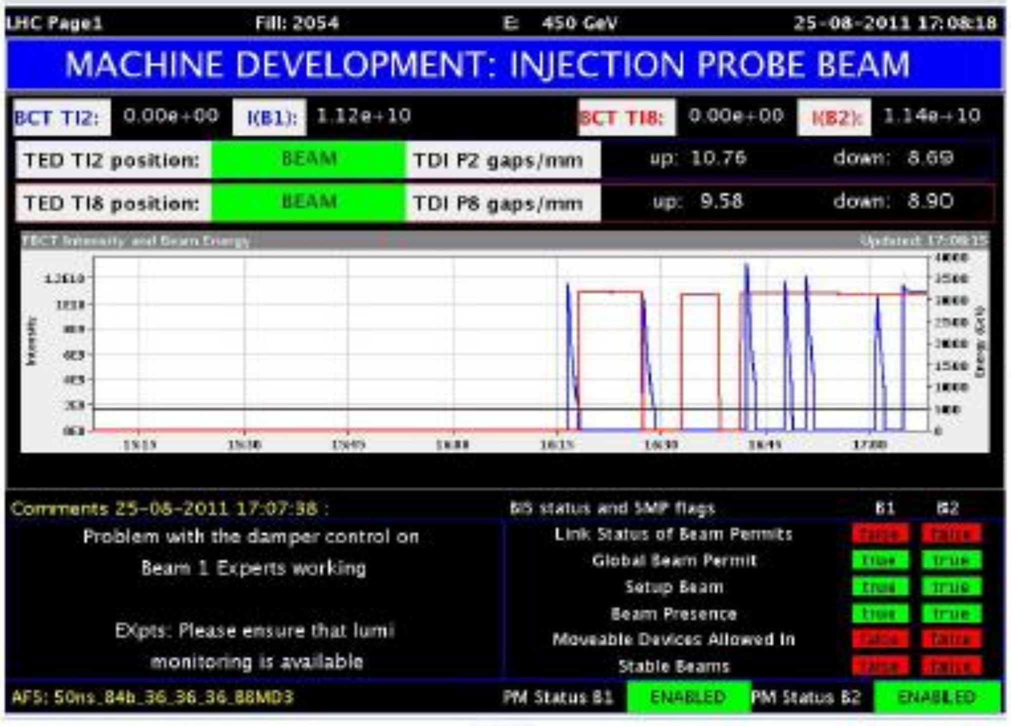
- Bunch by bunch rates, collision and background.

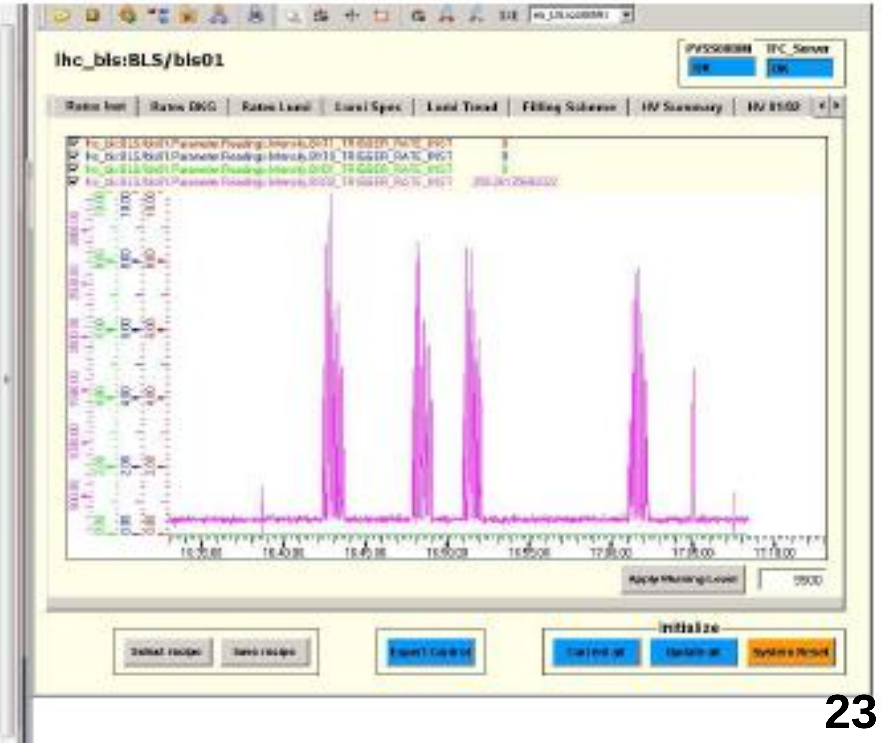




- **The only Beam radiation monitoring system capable of detecting minimum ionizing particles**

- **Measures relative rates of background particles and collision products entering ALICE**





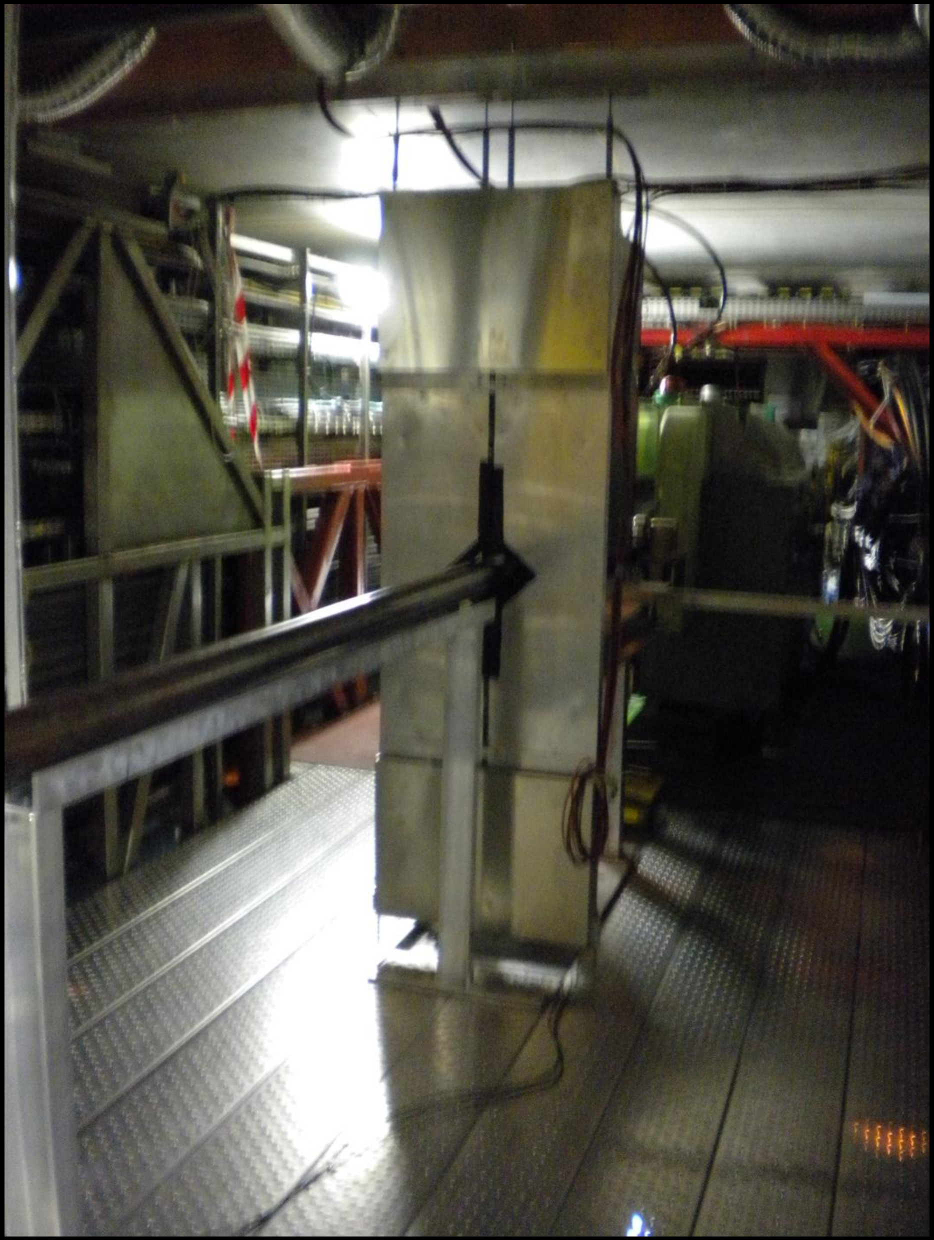
AD-R

Present:

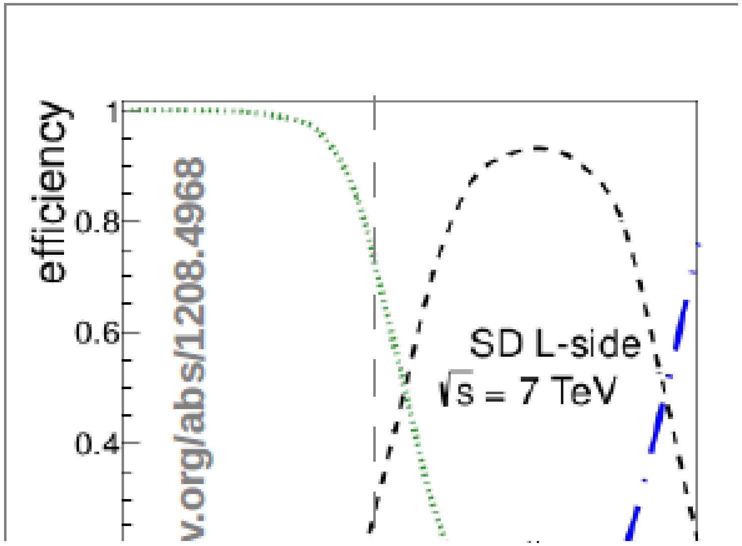
- **beam monitor with asynchronous read-out of charge deposited in the detectors → working**

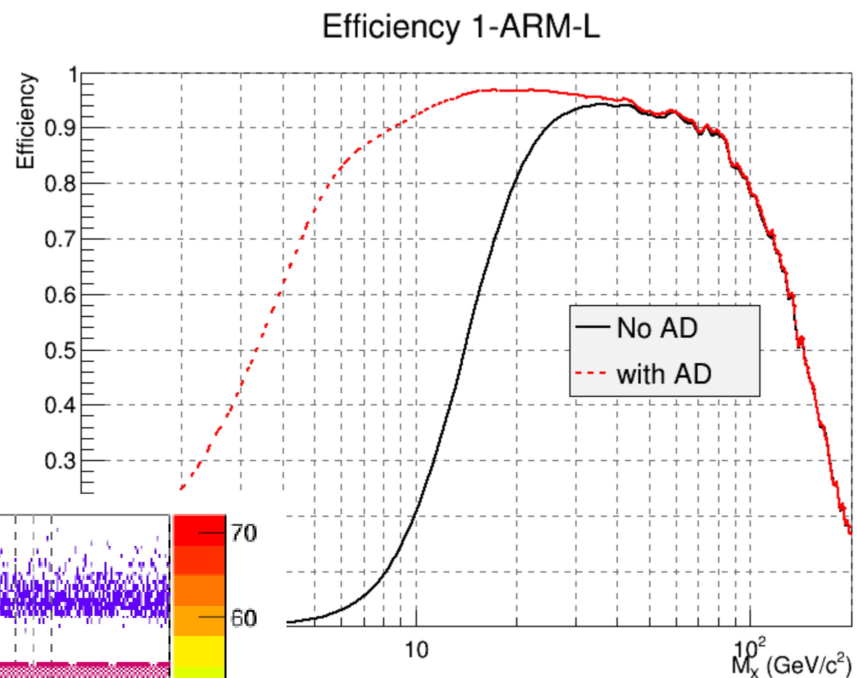
Future:

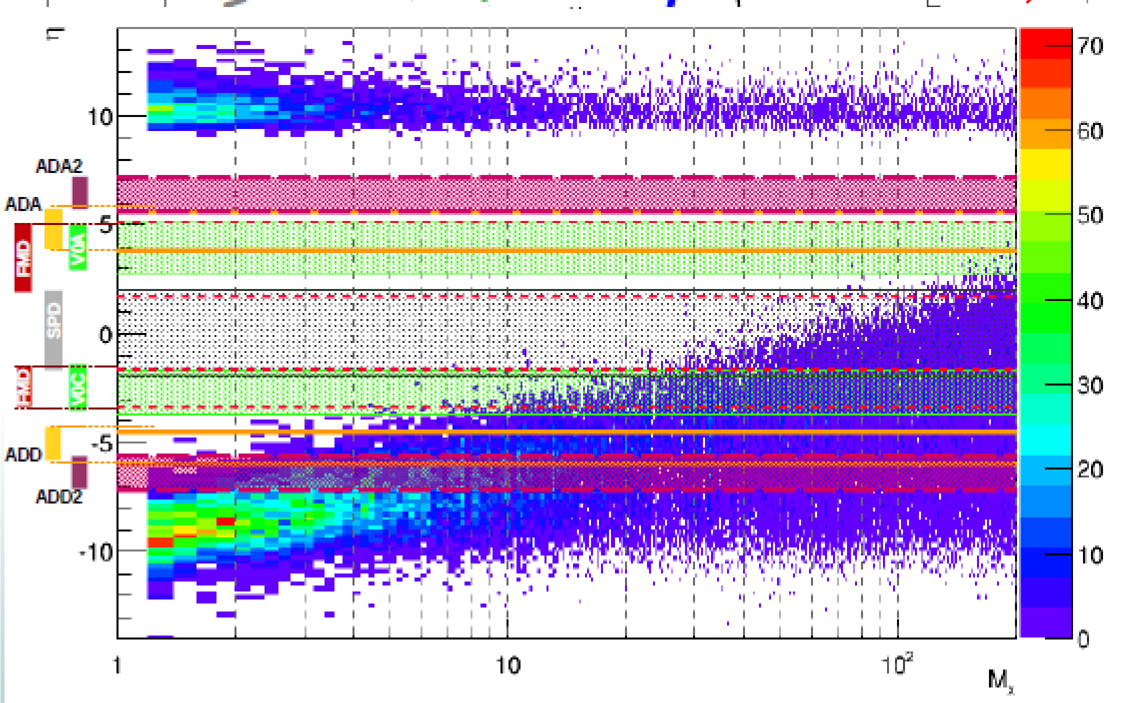
- **interesting diffractive physics using the particle identification of ALICE … could be offline trigger**

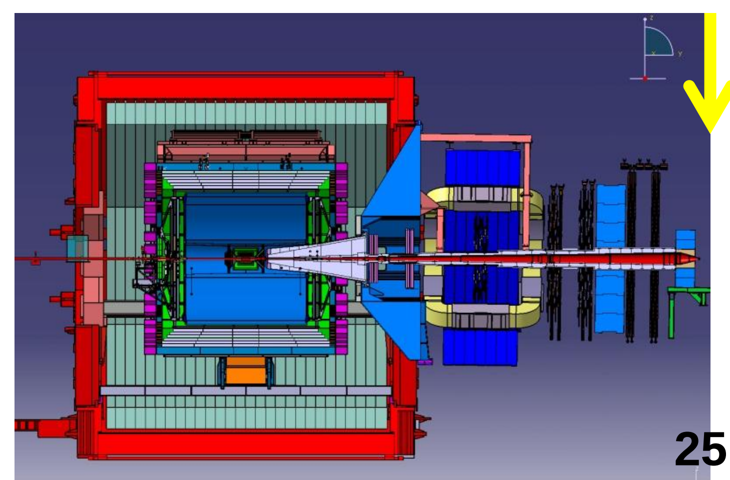


Integration of AD-L and AD-R in ALICE would enhance considerably the efficiency at low diffractive mass.







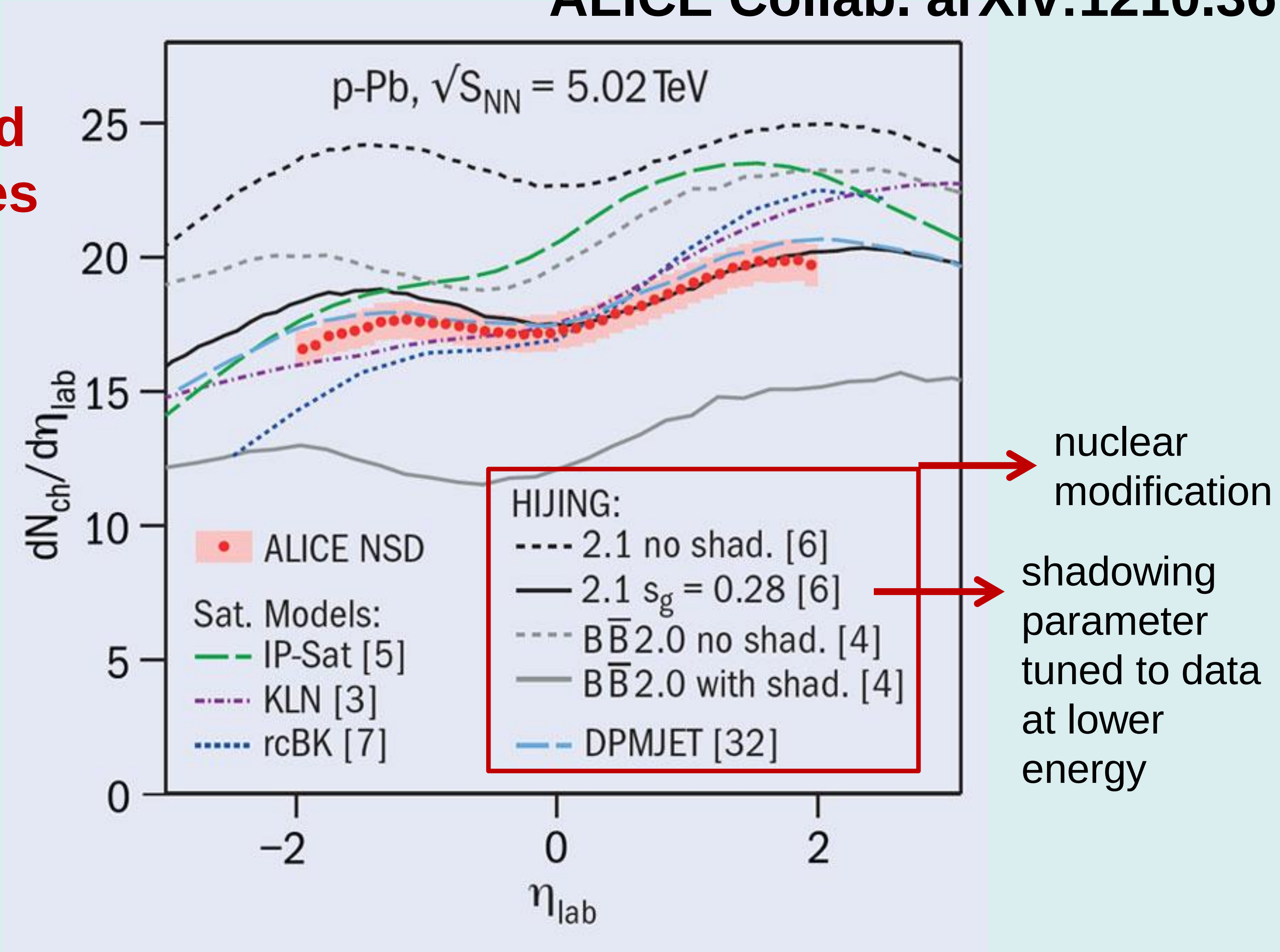


Plans for Diffractive Physics studies in p-Pb

Pseudo-rapidity density of charged particles

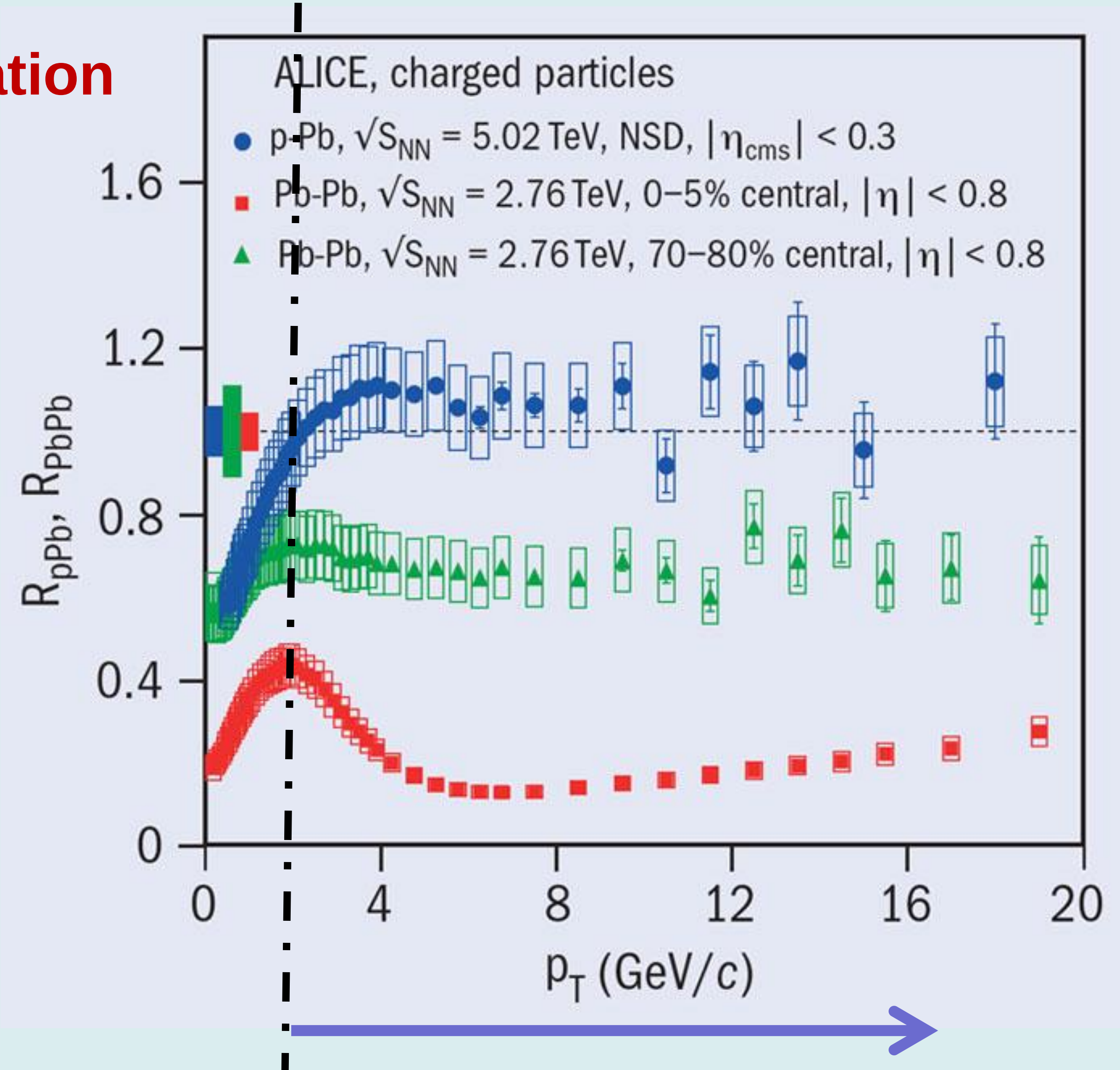
proton - Pb, 2 million events collected in september 2012

ALICE Collab. arXiv:1210.3615



Nuclear Modification Factor

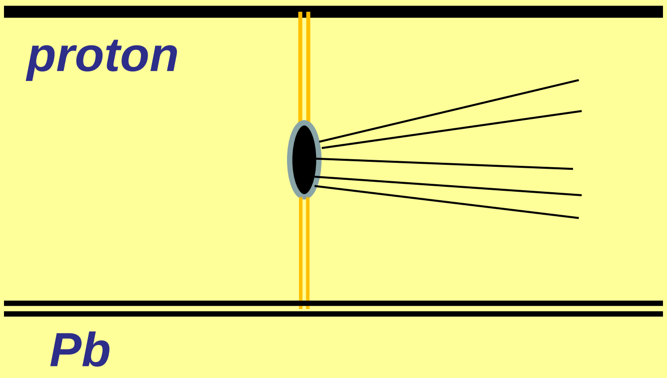
ALICE Collab. arXiv:1210.4520



the suppresion observed in PbPb is not the result of cold nuclear matter

Diffractive physics in proton - Pb

- diffractive physics in p A is almost completely unknown
- One could analyze central diffraction processes searching several final states : ρ^0 J/ψ f_0 f_2 ….
- Compare *pp* and *pA*
- Trigger implemented, goal: 20000 good events in pion channels



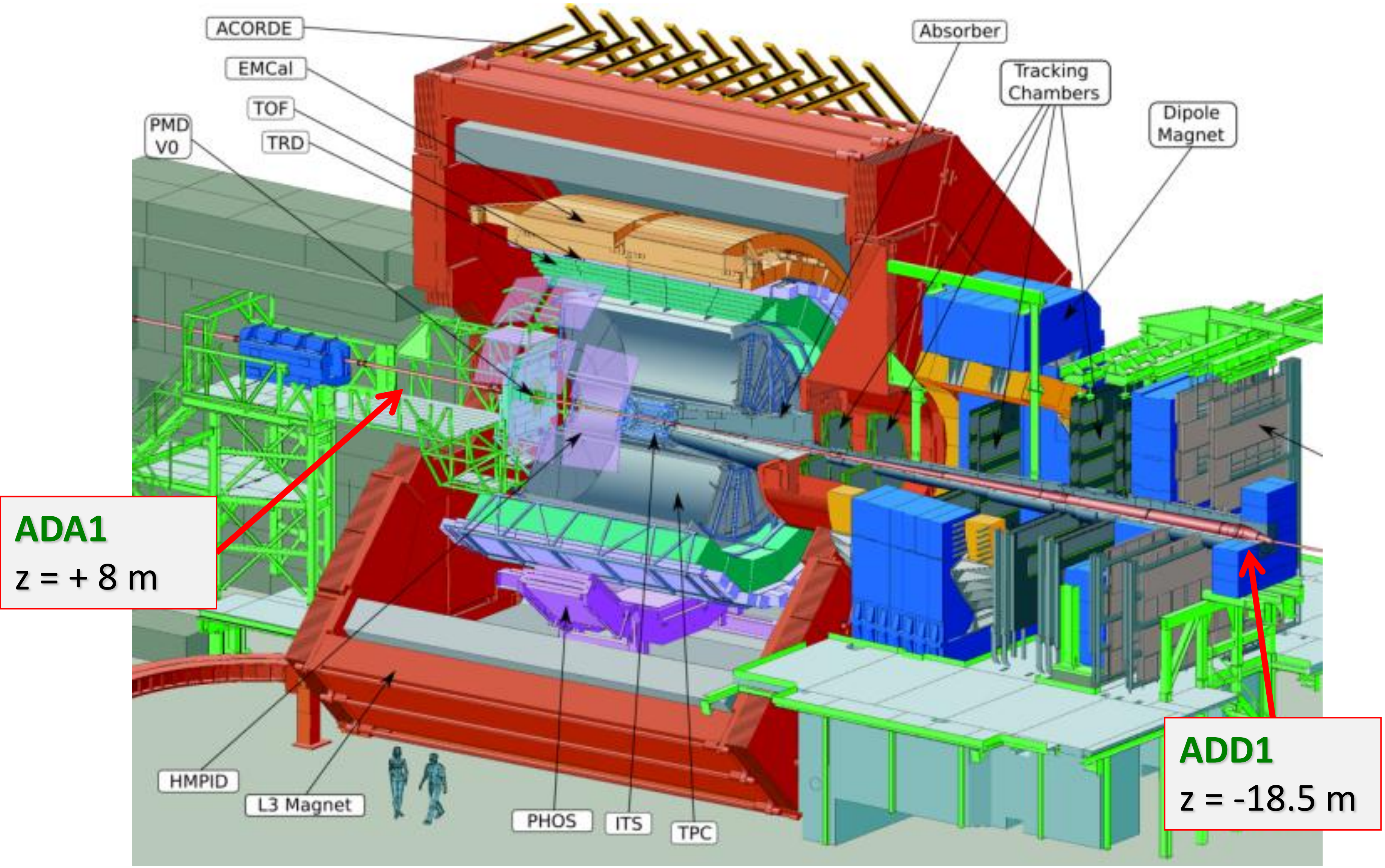
- Preliminar results may be ready for summer

Conclusions

- A rich program on Pb–Pb, proton-Pb and proton proton in the years to come
- Low p_T , photon induced and diffractive physics have started to produce results and will continue to do so
- In the long shutdown, the efficiency for Diffractive proton-proton could be enhanced by integrating to ALICE DAQ the information from new detectors, → AD forward detectors
- Forward calorimetry (talk by Thomas Peitzmann coming)
- Ultra Peripheral Collisions Studies (talk by Evgeny Kryshen)

back up

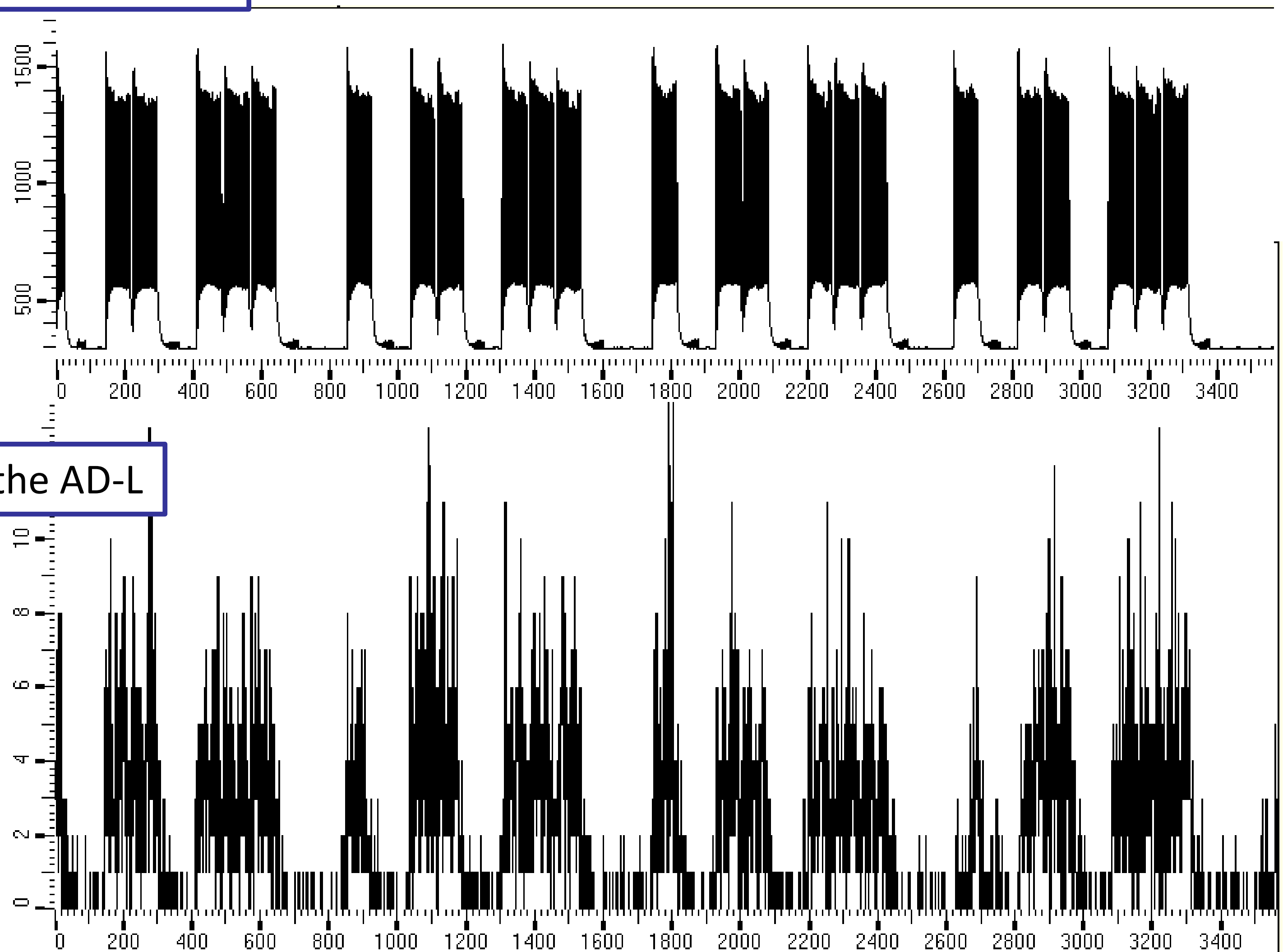
Detector location



performance on April 12 2012

Bunches seen in the BPIM

Beam **P**hase and **I**ntensity **M**onitor

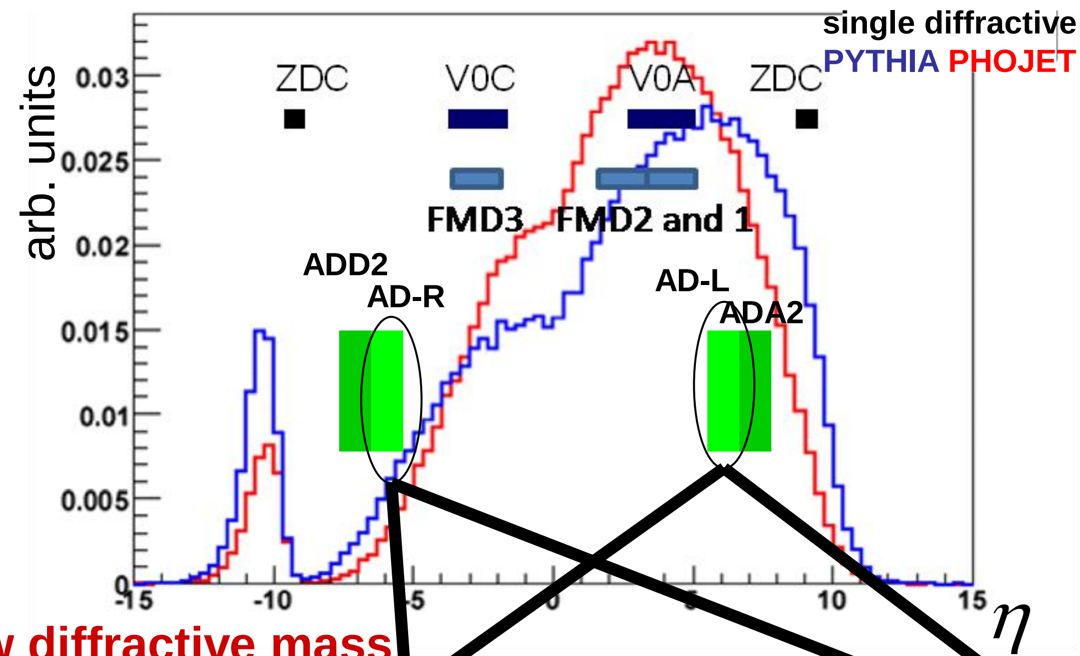


Losses seen in the AD-L

Time →

offline triggger

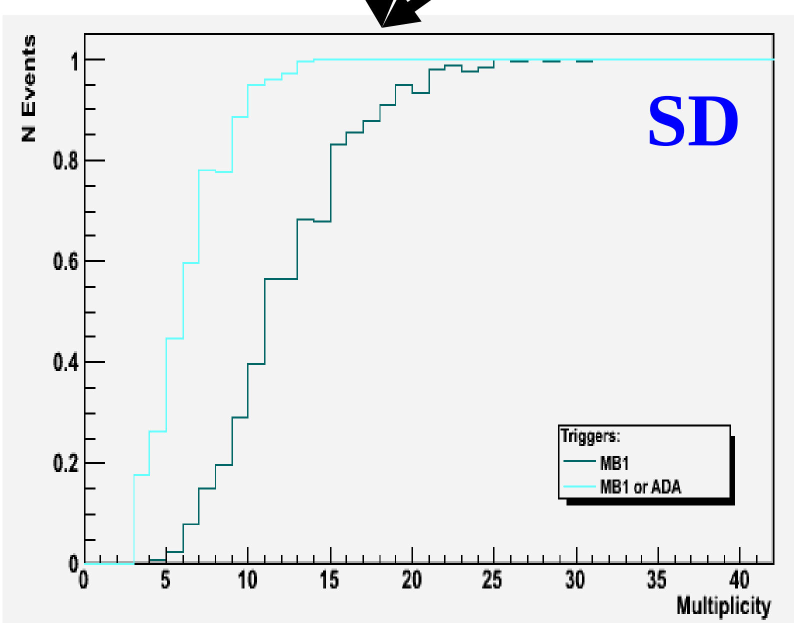
Gap tagger in a sensitive region of pseudorapidity to separate SD and DD events.

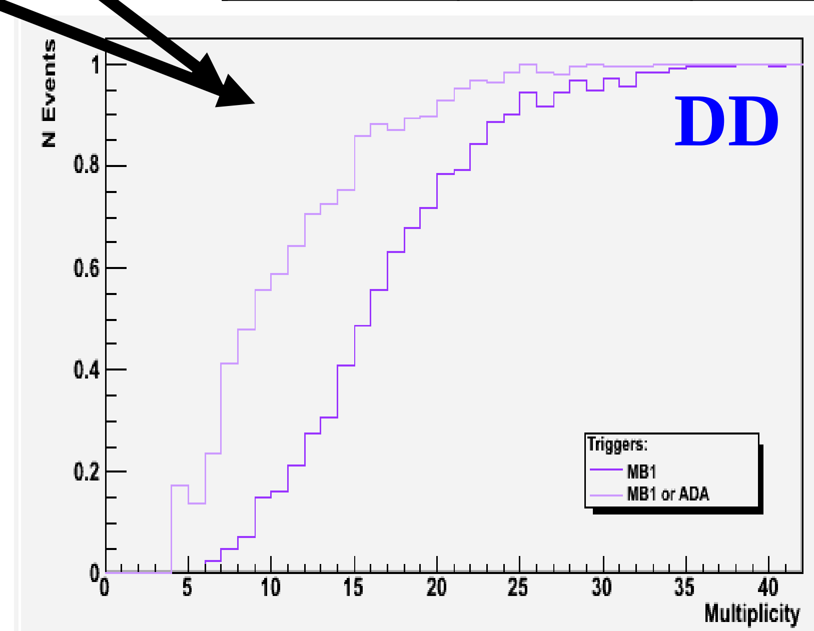


low diffractive mass

PHOJET PYTHIA

PHOJET	Default fractions	PYTHIA
0.134	SD	0.187
0.063	DD	0.127





ALICE upgrade

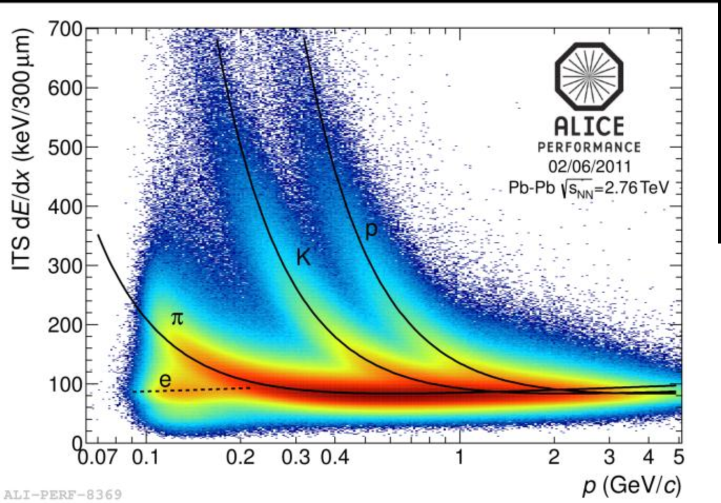
- luminosity upgrade – 50 kHz target minimum-bias rate for Pb–Pb
- run ALICE at this high rate

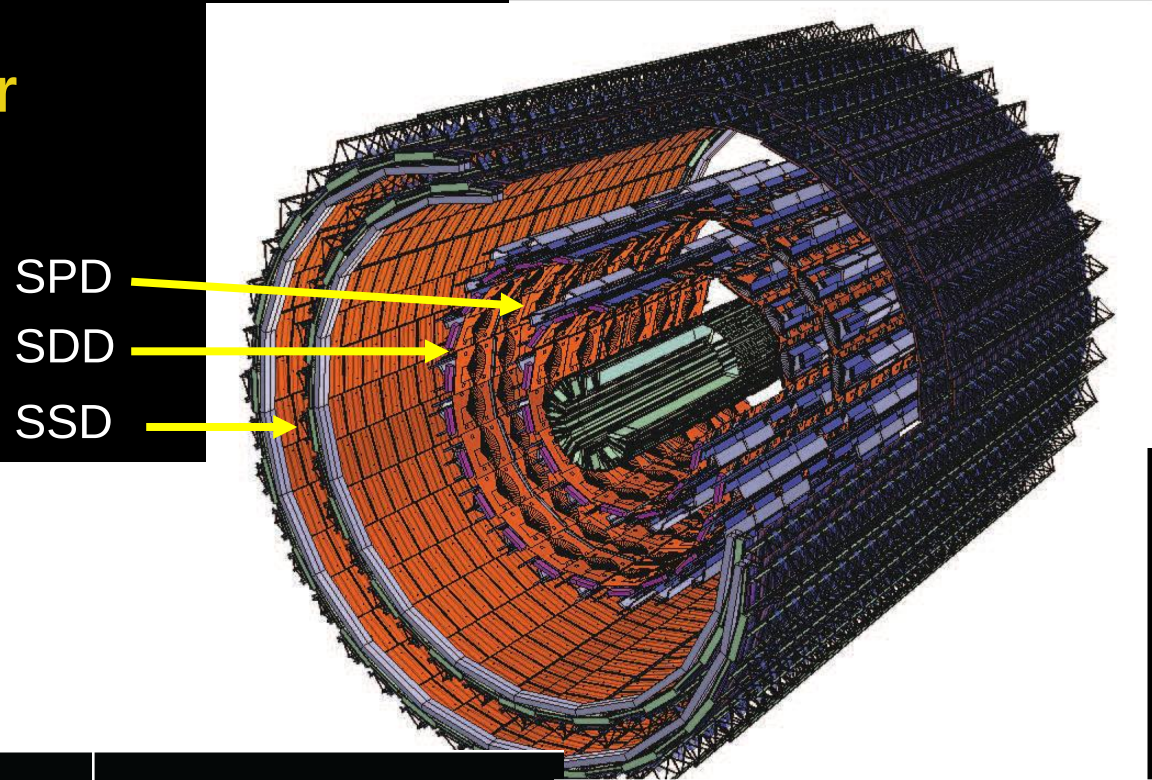
- improved vertex measurement and tracking at low p_T
- preserve particle-identification capability
- high-luminosity operation without dead-time

- new, smaller radius beam pipe
- new inner tracker (ITS) (performance and rate upgrade)
- high-rate upgrade for the readout of the TPC, TRD, TOF, CALs, DAQ-HLT, Muon-Arm and Trigger detectors

- target for installation and commissioning LS2 (2018)
- collect more than 10 nb^{-1} of integrated luminosity
  - implies running with heavy ions for a few years after LS3
- physics program – factor > 100 increase in statistics
  - (today maximum readout ALICE ~ 500 Hz)
- for triggered probes increase in statistics by factor > 10

all known techniques for particle identification:





Layer	Det. Type	Radius (cm)	Length (cm)	Resolution (µm)	
				rφ	z
1	pixel	3.9	28.2	12	100
2	pixel	7.6	28.2	12	100
3	drift	15.0	44.4	35	25
4	drift	23.9	59.4	35	25
5	strip	38.0	86.2	20	830
6	strip	43.0	97.8	20	830

Inner Tracking System

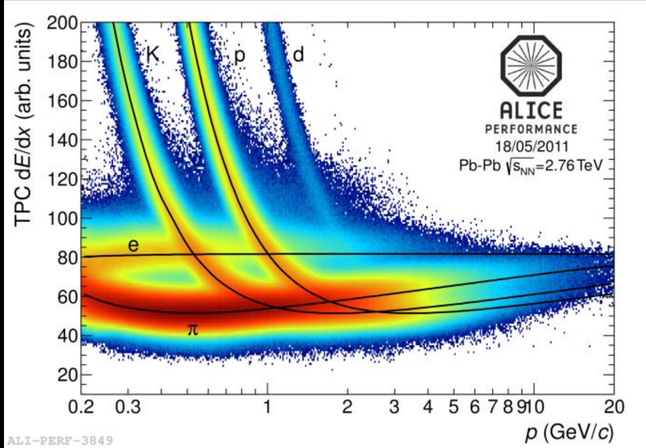
3 silicon technologies

low momentum acceptance

high granularity

low material budget

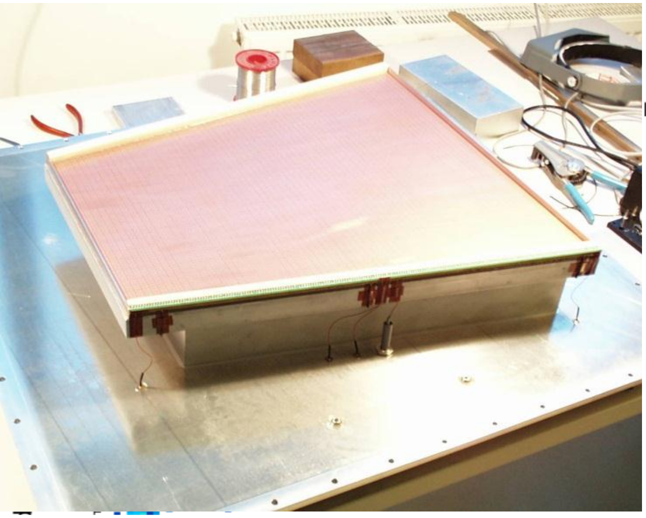
all known techniques for particle identification:

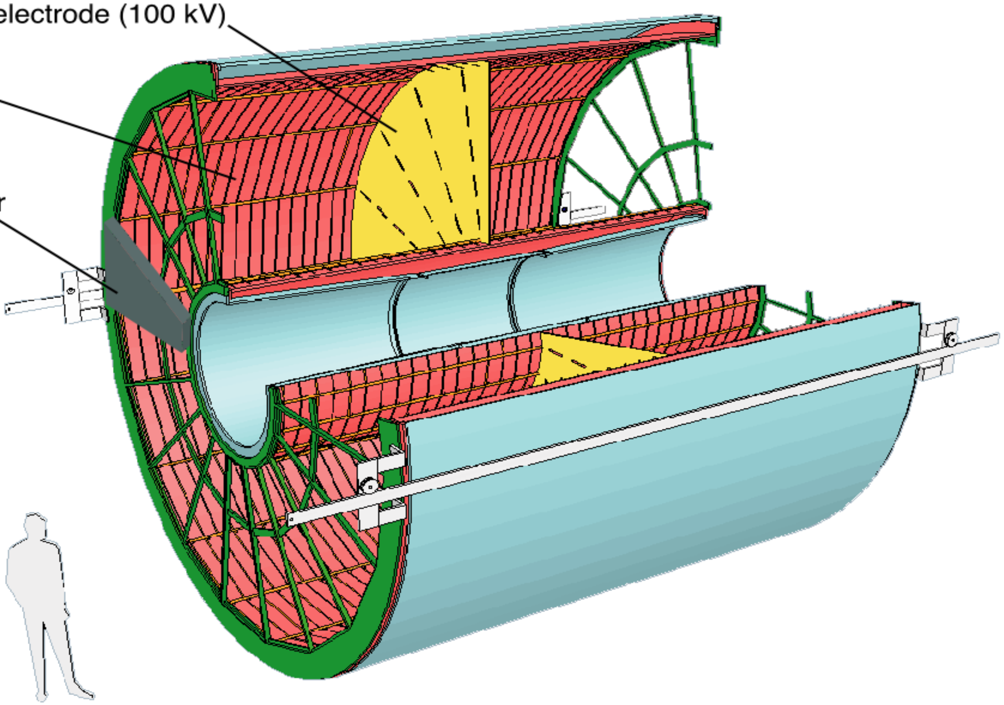


drift gas
90% Ne - 10%CO_2

for tracking and PID via dE/dx

$-0.9 < \eta < 0.9$





Time Projection Chamber
largest ever: 88 m^3, 570 k channels

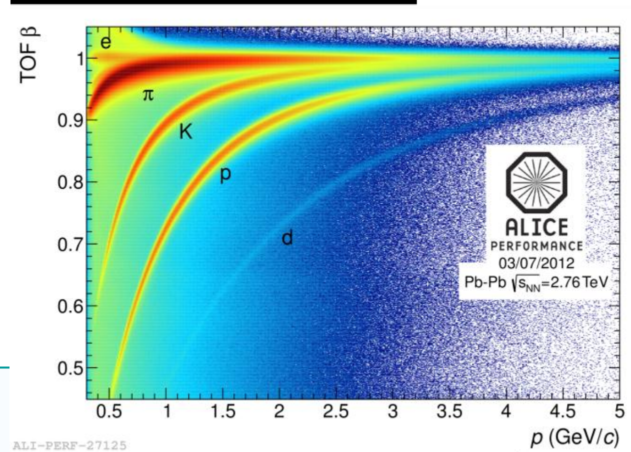
all known techniques for particle identification:

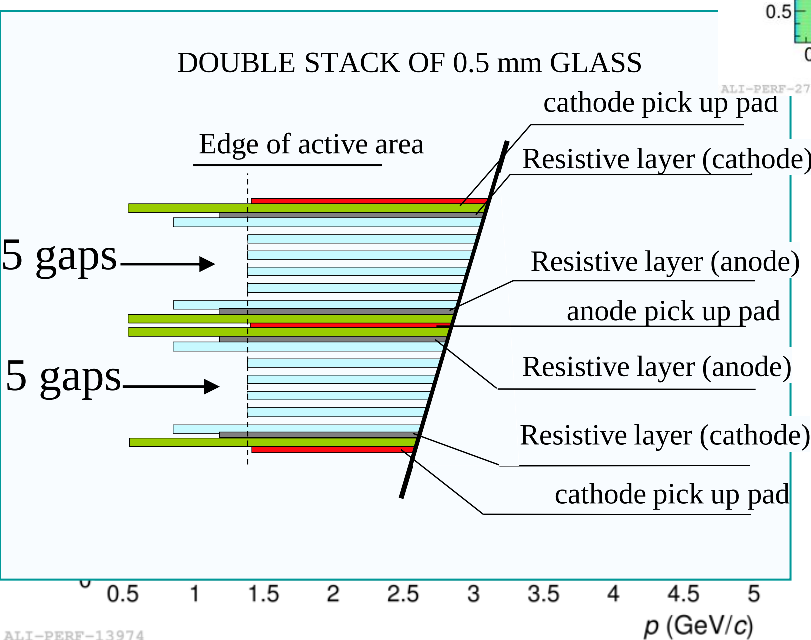
Multigap Resistive Plate Chambers

Time Of Flight

for π, K, p PID
π, K for *p* <2 GeV/c
p for *p* <4 GeV/c

- 0.9 < η < 0.9
full φ





all known techniques for particle identification:

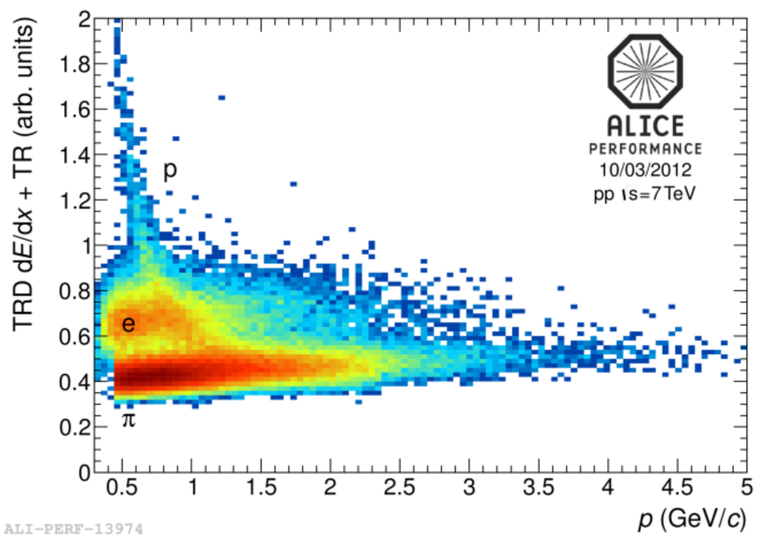
$-0.9 < \eta < 0.9$

Transition Radiation Detector

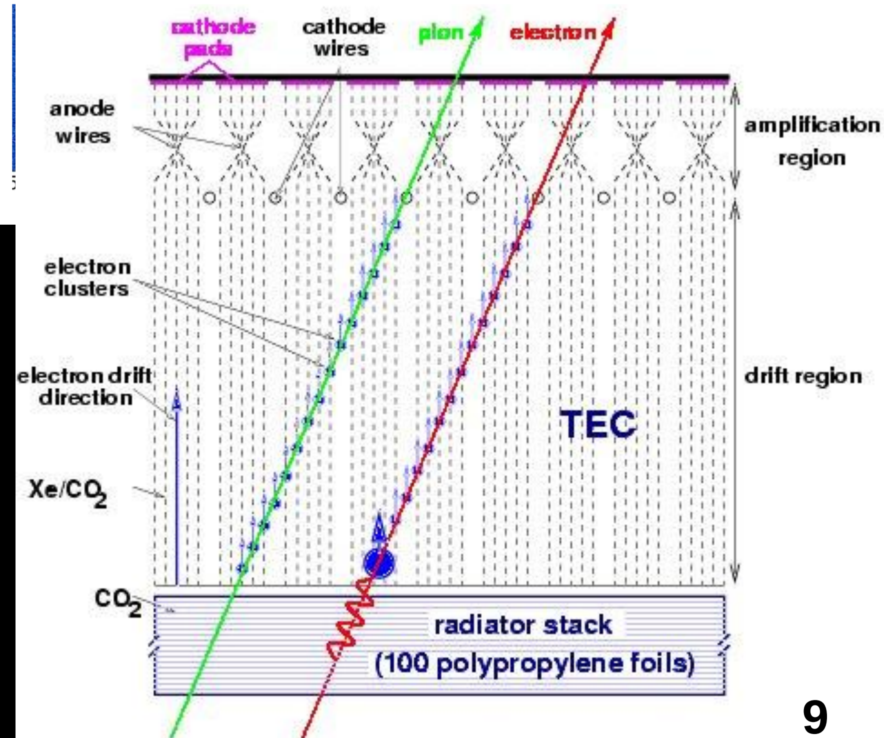
for e PID, p>1 GeV/c for e and high p_t trigger, p>3 GeV/c

Large (800 m^2), high granularity (> 1M ch.)

fiber radiator to induce TR (γ > 2000)

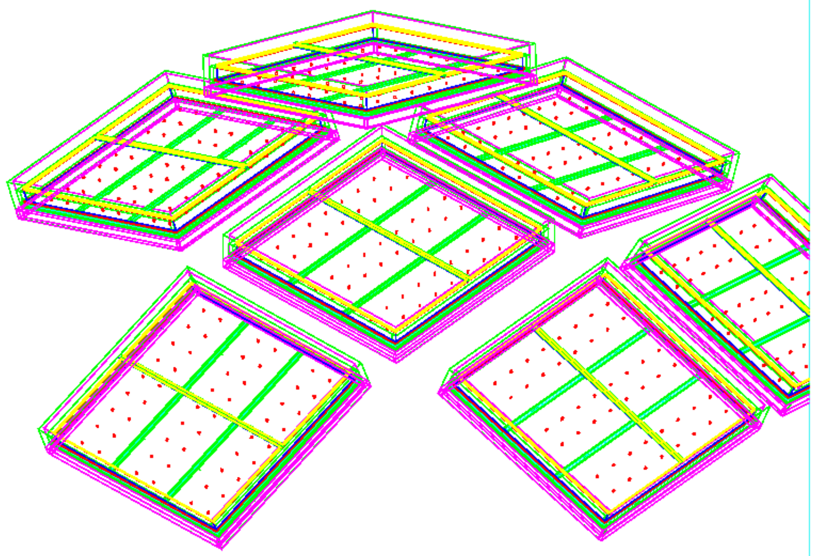


TRD

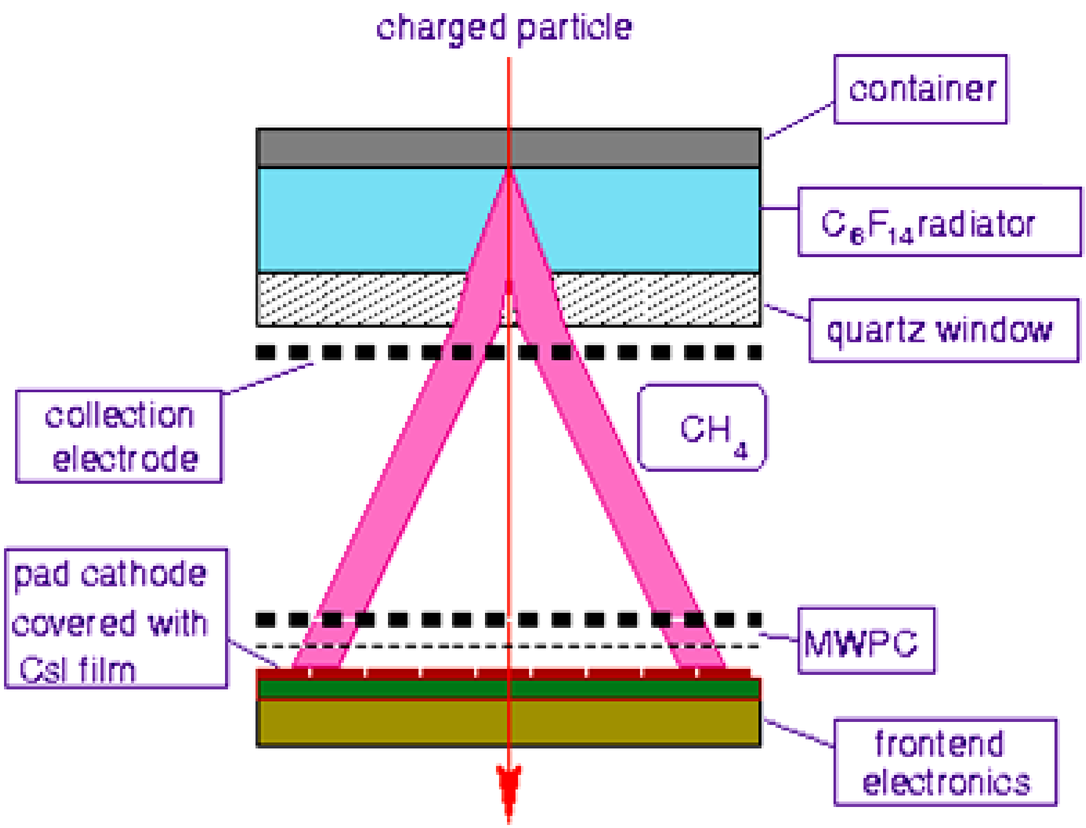


all known techniques for particle identification:

7 modules, each ~1.5 x 1.5 m^2

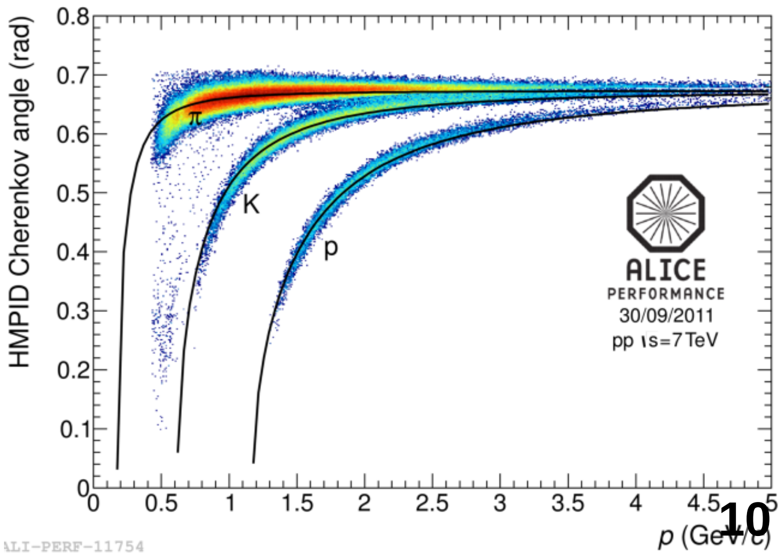


High Momentum Particle Identification



RICH

HMPID



Process Efficiency	SD (%) XC	XA	DD (%)	LP (%)
MB1	**69.3**	**75.5**	**87.5**	**99.9**
MB1.or.ADA1	**69.9**	**88.8**	**94.5**	**100.0**
MB3	**35.1**	**39.8**	**43.1**	**97.8**
MB3.and.ADA1	**13.7**	**36.9**	**35.1**	**95.5**

MB1 = VOC or SPD or VOA

MC studies

No ADA or ADD: GF0 && (!V0A) && (!V0C)

#	ND	SD	DD	CD
	276	531	125	2207
%	ND	SD	DD	CD
	8.8%	16.9%	4.0%	70.3%

ADA and ADD: GF0 && (!V0A) && (!V0C) && (!ADA) && (!ADD)

#	ND	SD	DD	CD
	49	62	4	2123
%	ND	SD	DD	CD
	2.2%	2.8%	0.2%	94.9%

pp 7 TeV PHOJET assuming 100% efficiency