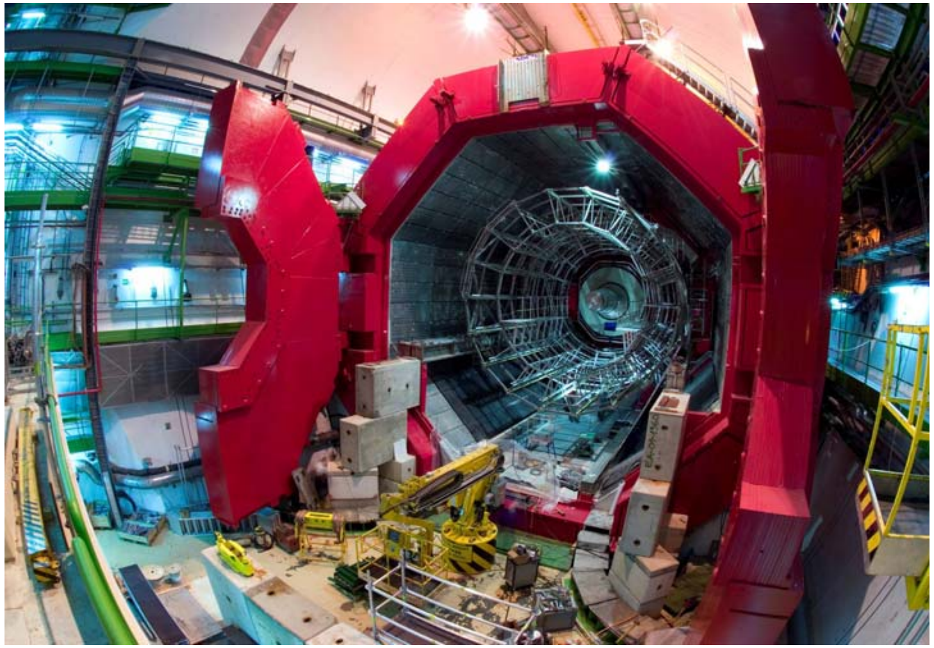
First Physics with ALICE

- the day-one p+p physics program -



Physics at LHC

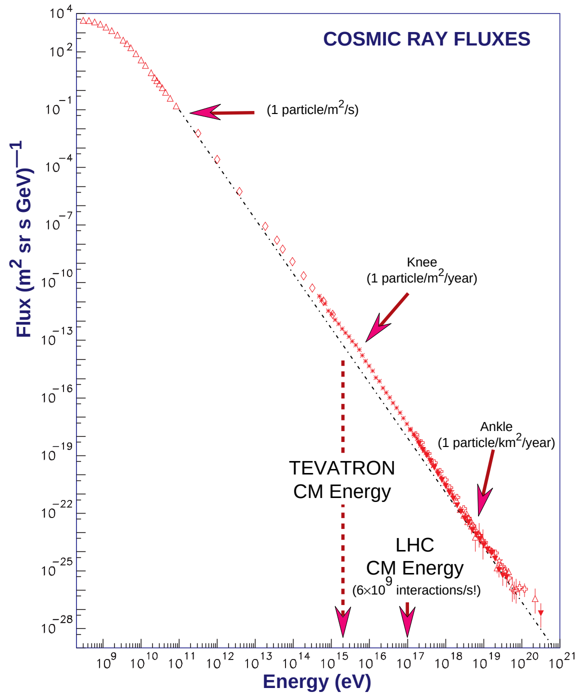
Cracow, July 7, 2006

Claus Ekman Jørgensen, CERN

ALICE p+p Physics

Motivation for p+p program

- soft/MB physics in new energy regime (above the "knee")
- baseline for heavy ions

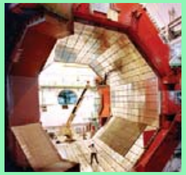


ALICE has unique possibilities at LHC:

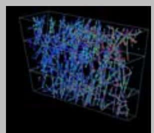
- acceptance at low p_T (~0.2GeV/c)
  - ⇒ relatively low field (0.5T)
  - ⇒ low material budget (X/X_0=7%)
- excellent PID capabilities
  - ⇒ dE/dx (TPC/ITS), TRD, TOF, HMPID, PHOS

ALICE time schedule
(… as it looks now)

TPC installation
- in L3 magnet

TPC sector test
-two sectors tested at point 2



Installation of forward detectors

ITS installation

One beam
-injection energy 450GeV
-beam-gas events
-alignment & calibration

First collisions
-$\sqrt{s}$=900GeV
-extend SPS results

Higher energy
-new physics?

8-2006 Now

9-2007 LHC closure

1-2008 Shutdown

This talk: - detectors for first physics (TPC, ITS, triggers)
- day one physics topics

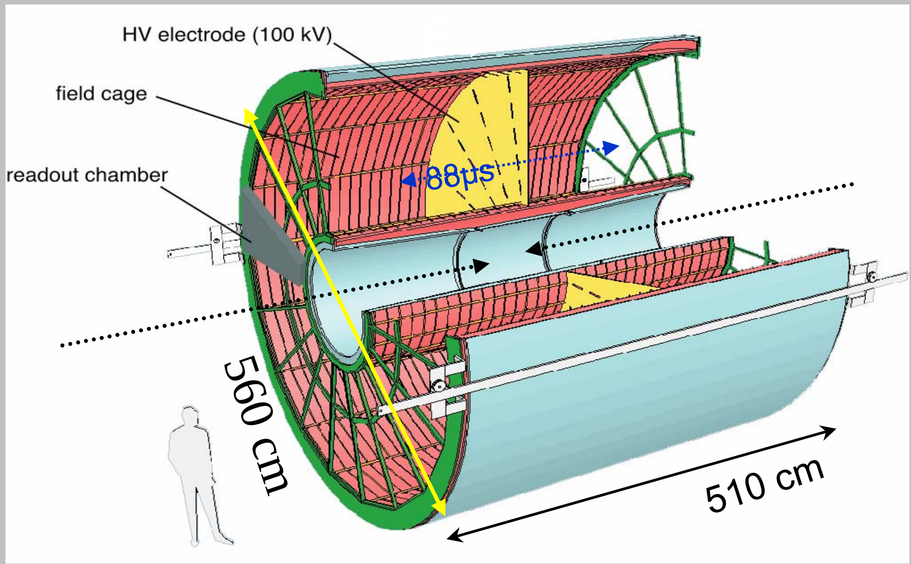
Detectors - TPC

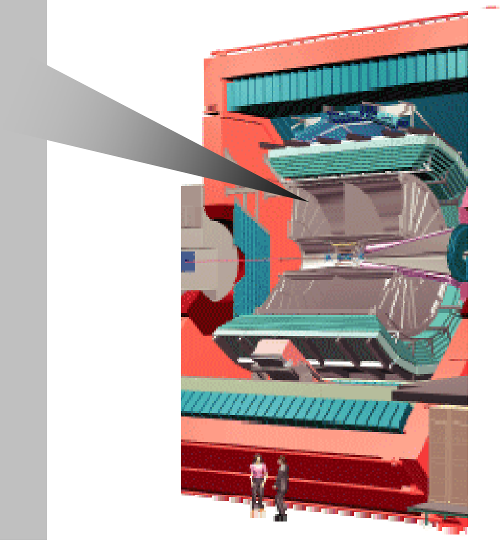
⇒ main tracking device ($|\eta|<0.9$, $p_T>0.2$GeV)
designed for high multiplicity (HI) events

⇒ good efficiency and momentum resolution
~90% efficient for particles with $p_T>1$GeV/c

⇒ PID capabilities
dE/dx measurements (both low pt and on relativistic rise)

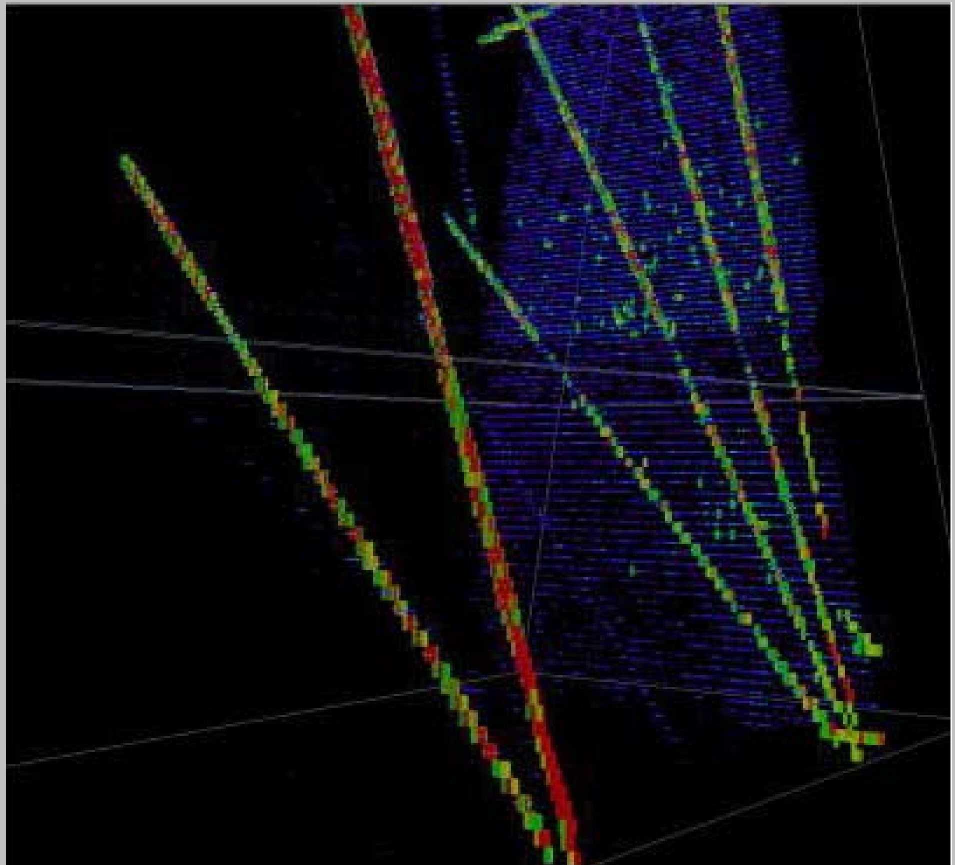
⇒ max drift time 88μs



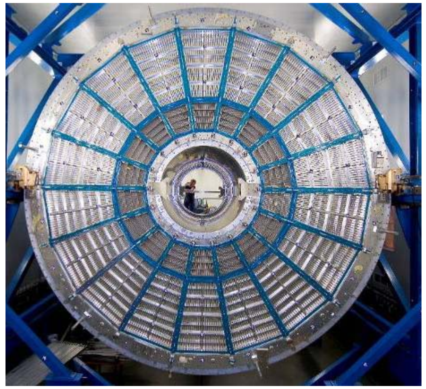


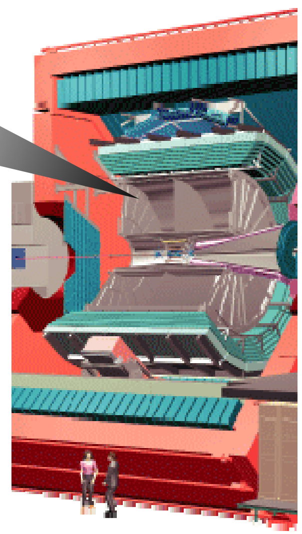
Detectors - TPC

Two sector test (May-June 2006)



laser calibration event





Detectors - ITS

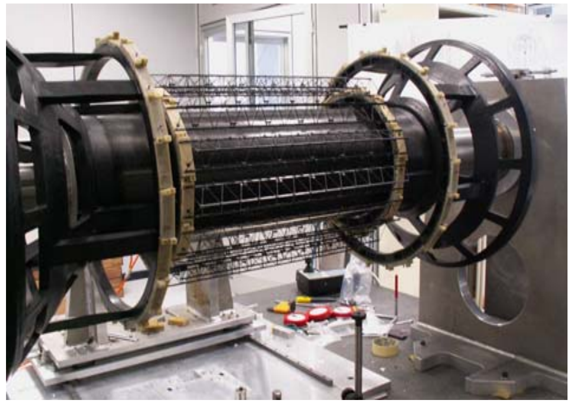
Silicon Pixel Detector

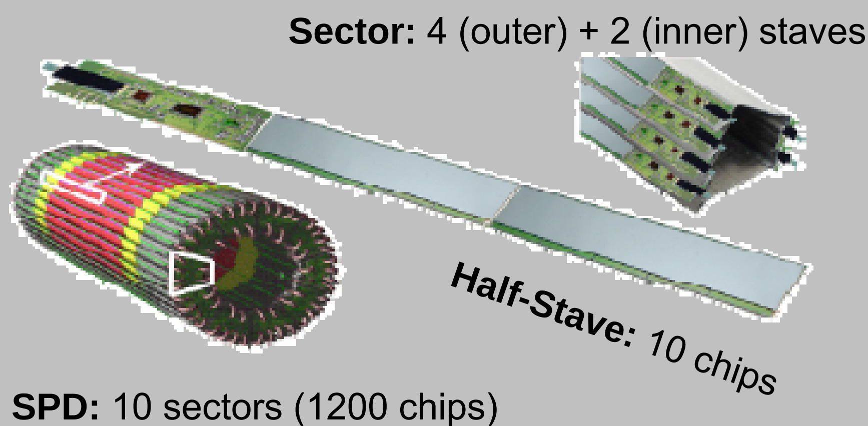
- inner two layers of ITS
- coverage $|\eta|<2.0$ (both layers: $|\eta|<1.4$)
- 1200 chips, total 9.8M channels

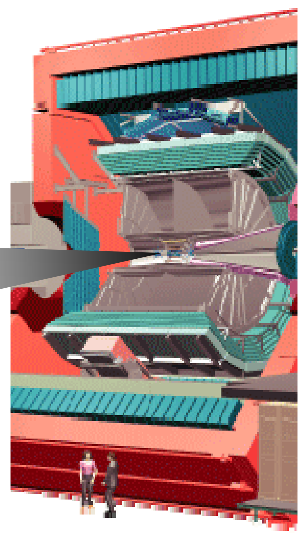
⇒ inner tracking & multiplicity

⇒ vertex finding

⇒ trigger (next slide)





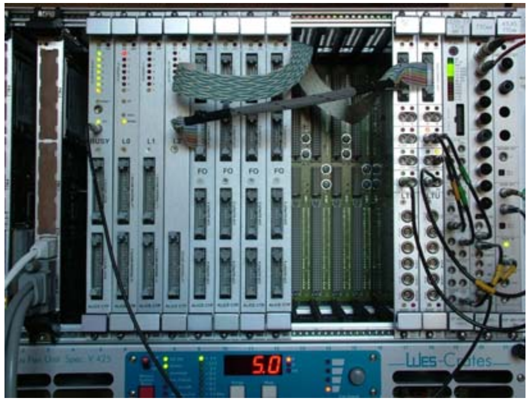


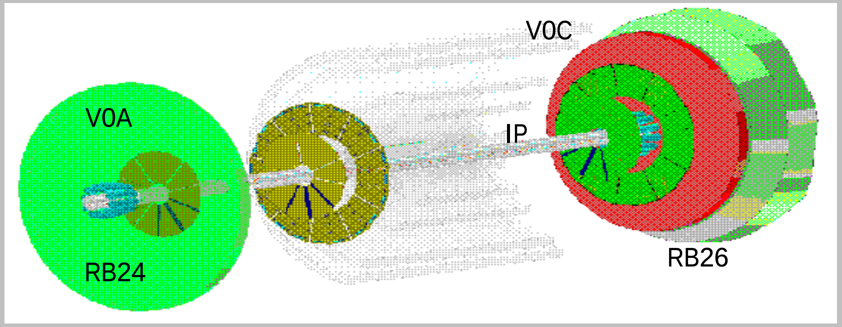
Detectors - Triggers

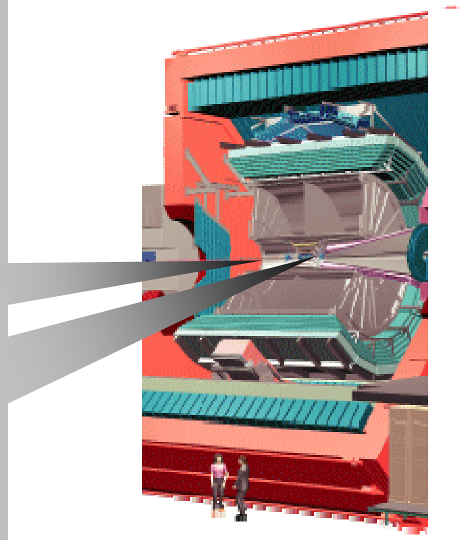
SPD (silicon pixel detector, see previous slide)
- combination of signals from 1200 SPD chips (integrated over 100 ns)
- most simple: global or between chips (SPD.FO)

V0 (two scint. counters at -340cm & 90 cm)
- coverage: $-3.7<\eta<-1.7$ and $2.8<\eta<5.1$
- time windows defined from the LHC bunch crossing time
- beam-beam trigger & beam-gas trigger

+ a number of other triggers (T0, Acorde, TOF, …)



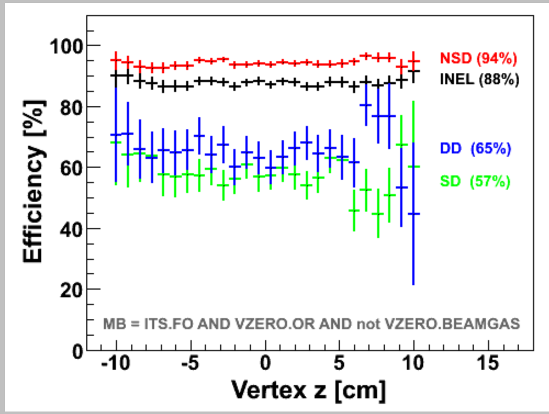


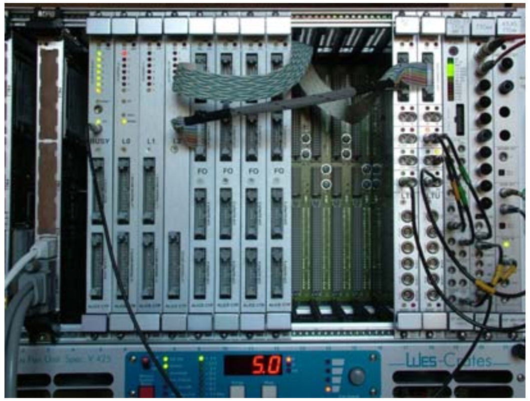


Detectors - Triggers

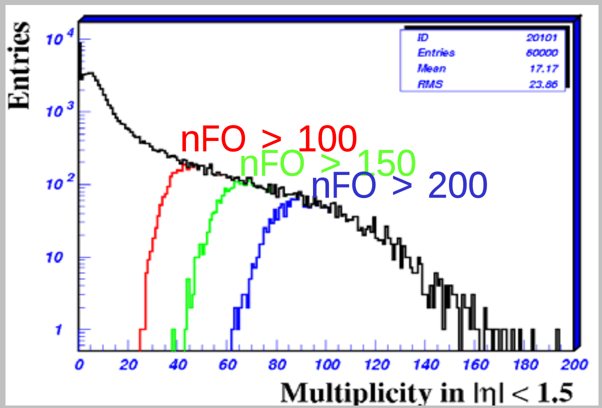
Minimum bias trigger:

SPD.FO & V0.OR & ¬V0.BG
Efficiency (using Pythia):
88% for inelastic collisions
94% for non-single diffractive
65% for double diffractive
57% for single diffractive



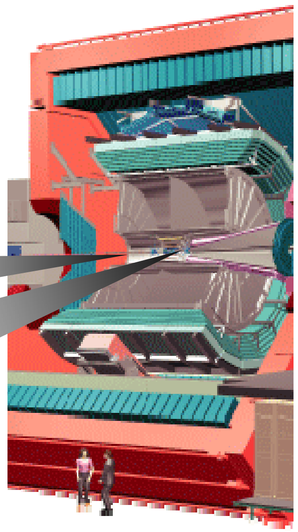


High multiplicity trigger:



Threshold on number of SPD chips fired.

⇒ enhance the high multiplicity sample



ALICE "Day-one" p+p Physics

First physics, 2007 (p+p at $\sqrt{s}$=900 GeV and 2.2TeV?)

- Pseudorapidity density
- Multiplicity distribution
- p_T spectra
- $\langle p_T \rangle$ vs. multiplicity
- and more…

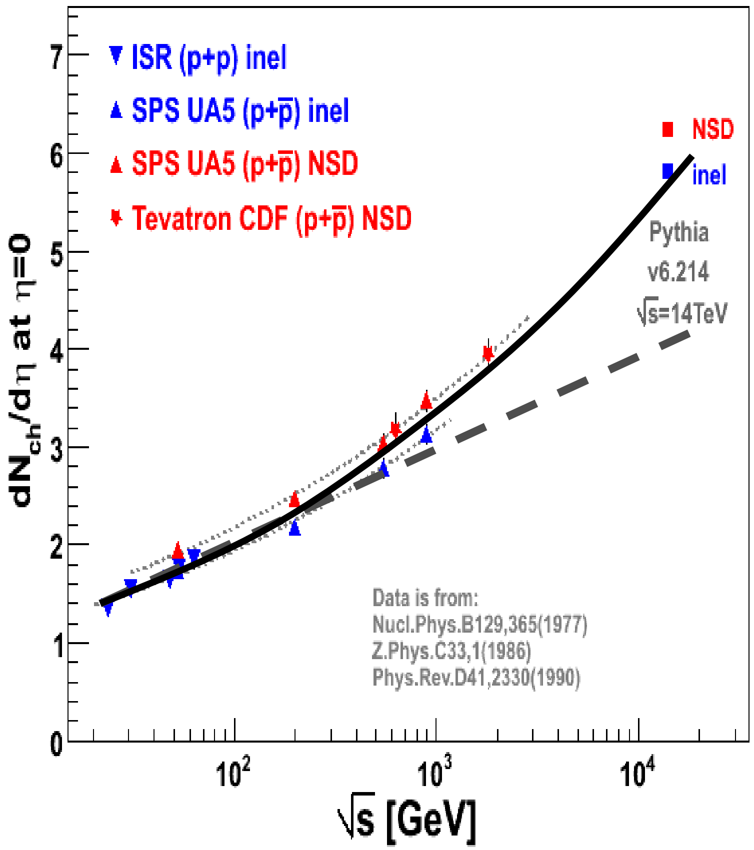
Physics
$\Rightarrow$ what can we learn?

Statistics
$\Rightarrow$ how many events do we need?

Analysis
$\Rightarrow$ how do we measure this?

Pseudorapidity Density

Primary charged particles production at η=0:



$dN/d\eta|_{\eta=0}=a+b\times\log(s)$
- predicted by Feynman: PRL23,1415(1969)

$dN/d\eta|_{\eta=0}=a+b\times\log(s)+c\times\log^2(s)$
-$\log^2$ term due to hard processes
(see for example PLB121,209(1983))

Statistics
⇒ 10^3 events give ~2% statistical errors

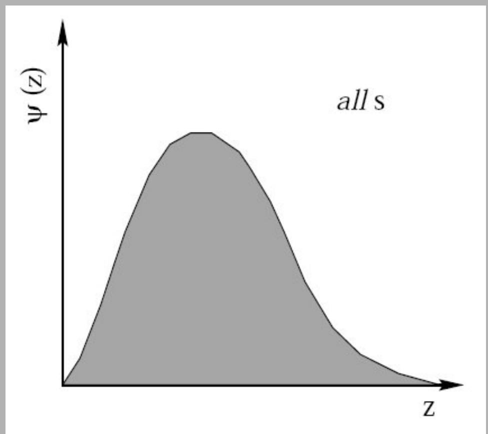
Analysis
⇒ tracklets/clusters in ITS, tracks in TPC
⇒ corrections for:
- tracking/reconstruction eff. (η, p_T, z)
- vertex reco. and trigger eff.

Multiplicity Distribution

1972:
KNO (statistical) scaling law

$$P_n(s) = \frac{1}{\langle n \rangle} \Psi\left(\frac{n}{\langle n \rangle}\right)$$

$\Rightarrow$ shape of distribution is independent of s



NPB 40, 317 (1972)

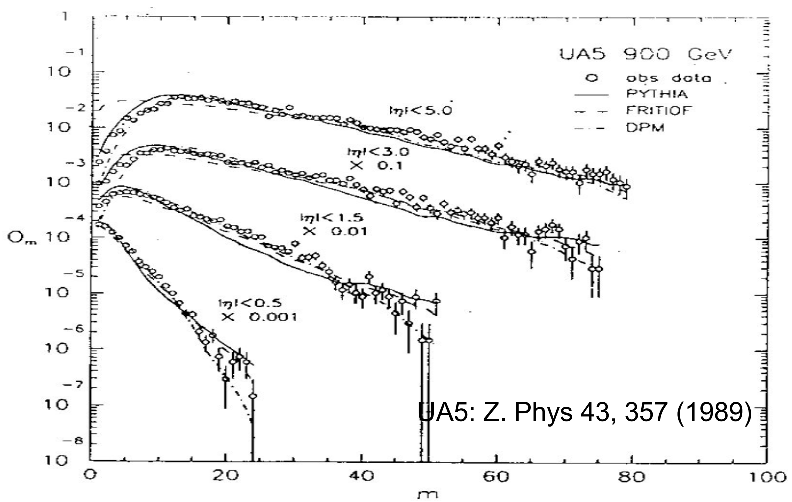
1983: KNO scaling broken

(UA5: PLB121,109,1983 & PLB138,304,1984)

Two mechanisms:

$\Rightarrow$ jet/mini-jet production
- coherent production of particles

$\Rightarrow$ multiple parton interactions
- multiple emission sources



UA5: Z. Phys 43, 357 (1989)

Multiplicity Distribution

Describing the multiplicity distribution:

Slattery, PRL23,1415 (1969)
de Groot, PLB57,159 (1975)
Lian-sou & Ta-chung PRD27,2640 (1983)
…and many more

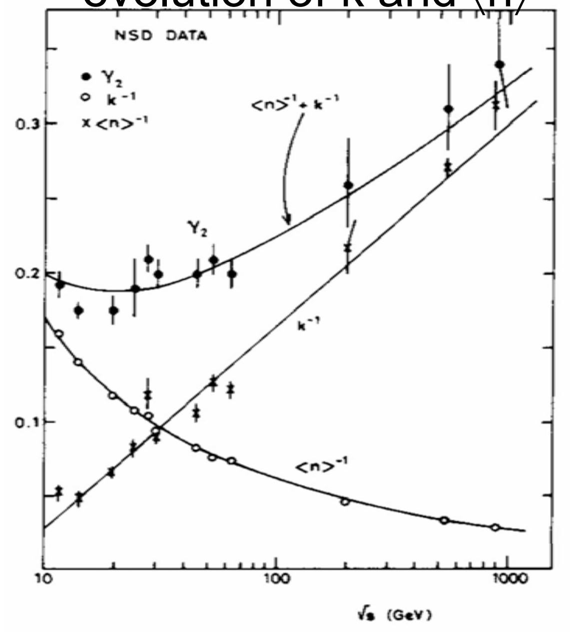
$\Rightarrow$ obeying KNO-scaling

- Negative Binomial Distributions (NB) good description of UA5 and CDF data
  PLB160,199 (1985) & FERMILAB-Conf-93/359-E
  k not constant $\Rightarrow$ breaking of KNO scaling

negative binomial distribution:

$$P_n = \binom{n+k-1}{n} \left(\frac{\langle n \rangle / k}{1 + \langle n \rangle / k} \right)^n \frac{1}{(1 + \langle n \rangle / k)^k}$$

evolution of k and $\langle n \rangle$



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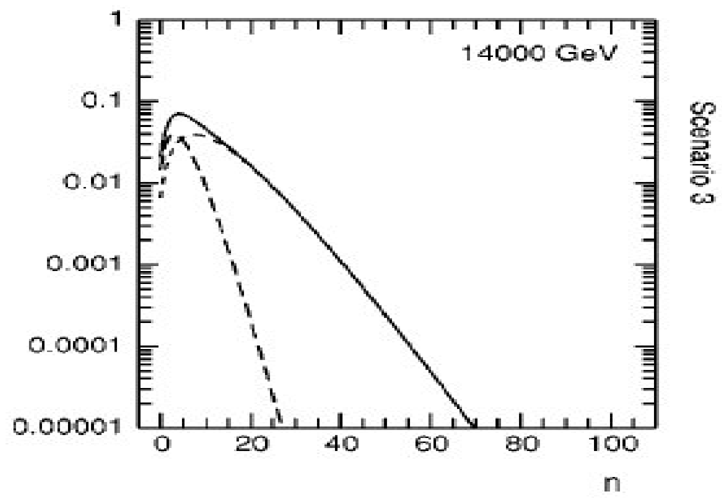
- Two component models
  (see for example PRD60,074027,1999)
  - soft component (obeying KNO)
  - semi-hard component (NB)



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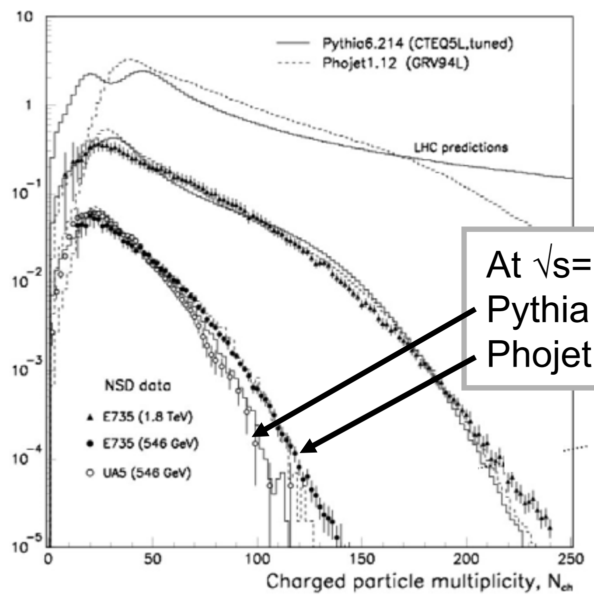
  k not constant ⇒ breaking of KNO scaling

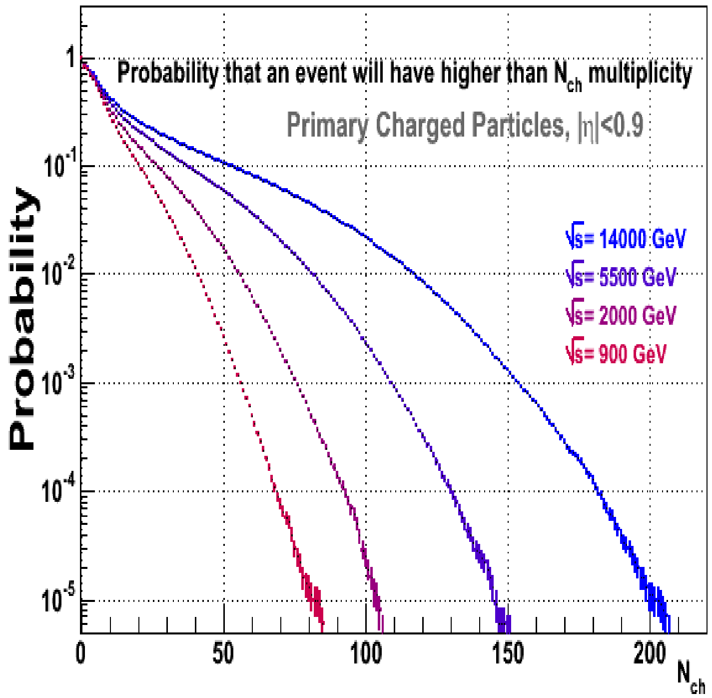
- Two component models
  (see for example PRD60,074027,1999)
  - soft component (obeying KNO)
  - semi-hard component (NB)

- Event generators
  Pythia: pQCD jets & multi parton int.
  Phojet: no multiparton interactions
  Herwig: Negative binomial (per def.)



At √s=546GeV:
Pythia fits UA5
Phojet fits E735

Multiplicity Distribution



Statistics

⇒ $\sqrt{s}$=900GeV: ~10^4 events exceed UA5 $N^{max}_{|\eta|<1.5}$=50 (Z.Phys. 43, 357, 1989)

⇒ $\sqrt{s}$=1800GeV:~10^5 events exceed E735 $N^{max}_{|\eta|<1.5}$=60, (FERMILAB-Conf-93/359-E)

⇒ we can enhance the high multiplicity sample using the SPD trigger.

Analysis

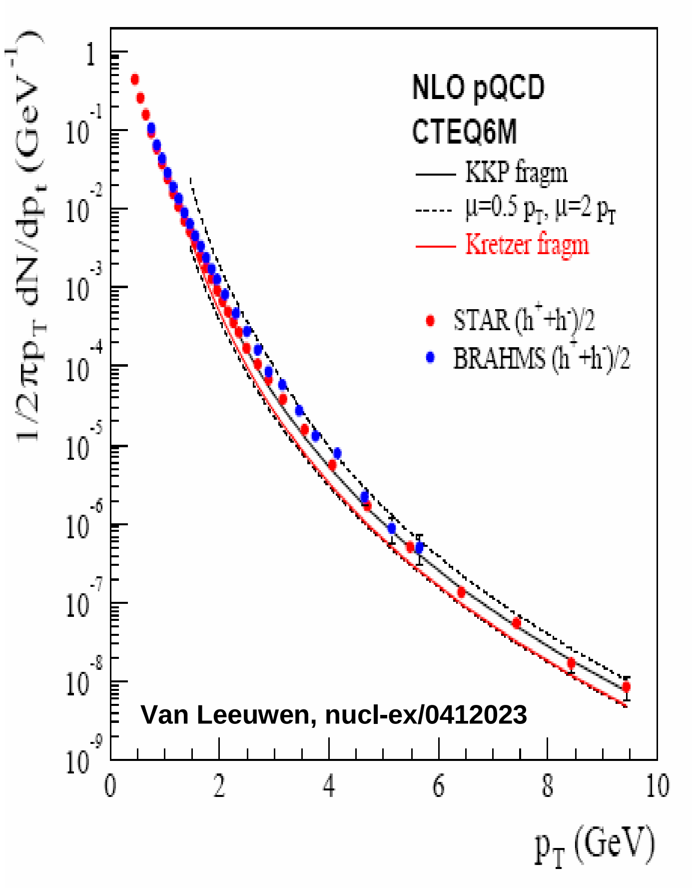
⇒ tracklets/clusters in ITS (|η|<2)

⇒ unfolding measured spectrum (Bayseian, X^2 min, regularization)

⇒ extend to higher η forward detectors

⇒ extrapolating to full η-range

p_T Spectrum



Constrain model parameters

⇒ soft region:
phenomenological description

⇒ hard region:
semi-phenomenological description
- LO & NLO pQCD
K, PDFs, fragmentation functions

$$\frac{d\sigma^h_{pp}}{dy d^2 p_T} = K \sum_{abcd} \int dx_a dx_b f_a(x_a, Q^2) f_b(x_b, Q^2) \frac{d\sigma}{d\hat{t}}(ab \to cd) \frac{D^0_{h/c}}{\pi z_c}$$

p_T Spectrum

Statistics

⇒ $\sqrt{s}$=546GeV: ~10^5 events exceed UA1 p_T^{max}~10 GeV/c (PLB118,167,1982)

⇒ $\sqrt{s}$=1800GeV:~10^5 events exceed CDF p_T^{max}~10 GeV/c (PRL61,1819,1988)

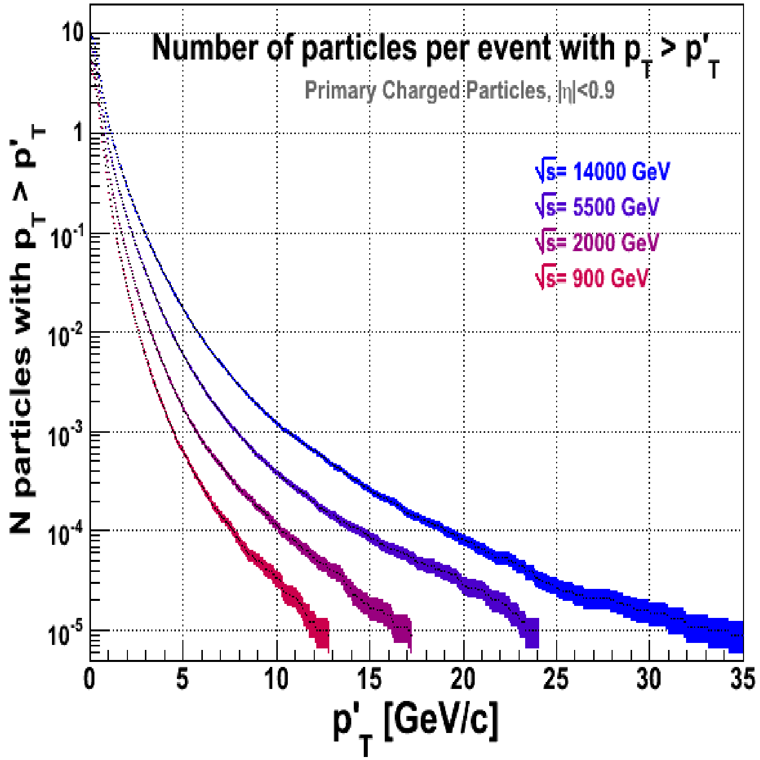
⇒ 10^6 events at $\sqrt{s}$=2TeV give ~20 tracks with p_T>15GeV/c for |η|<0.9

Analysis

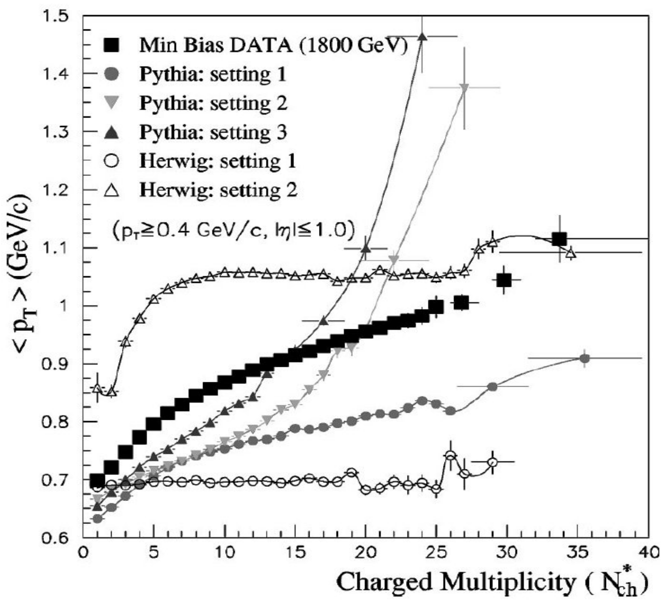
⇒ TPC tracks |η|<0.9, p_T>0.2GeV/c

⇒ corrections for tracking/reco (η, p_T, z)

⇒ correction for vertex and trigger eff.



⟨p_T⟩ vs. multiplicity



Mean p_T grows with multiplicity

⇒ high p_T jets have higher multiplicity
BUT: same behavior in "soft" events
events with no jets/clusters with E_T>1.1GeV
(CDF: PRD65,072005,2002)

Statistics

⇒ we need a few 10^6 event

⇒ Example: CDF PRD65,072005(2002)
$\sqrt{s}$=630GeV : 2.6 M events $N_{ch}^{max} \approx 30$
$\sqrt{s}$=1.8TeV : 3.3 M events $N_{ch}^{max} \approx 35$

Analysis

⇒ similar to p_T and mult. meas.

⇒ need p_T cutoff (0.4GeV/c)

What's next?

Jet properties from Dihadron correlation

like PHENIX: hep-ex/0605039

⇒ extraction of jet fragmentation transverse momentum j_T and partonic transverse momentum k_T

Jets and underlying event analysis

like CDF: PRD65, 092002(2002), PRD70,072002 (& CMS poster by Livio Fano)

⇒ Analyzing charged hadrons multiplicity and p_T in regions around the jet.

And much more

⇒ Spectra: $\pi^{\pm}$,π^0, K, K_S^0,p , Λ, Ξ, Ω, μ…

⇒ Resonances (see ALICE poster on K*(892) & Λ(1520) by F.Riggi)

⇒ γ production

⇒ J/Ψ and Υ (decaying into e^+e^- or $\mu^+\mu^-$)

⇒ …

Summary

ALICE day-one p+p physics at LHC

⇒ production and installation of detectors well advanced
⇒ reco. and analysis software for first physics (almost) ready
⇒ day-one p+p physics program defined

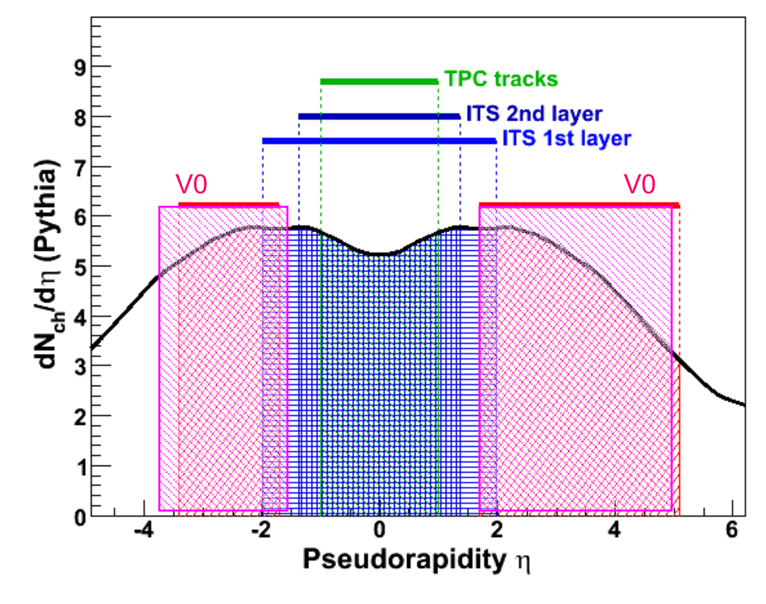
Minimum bias p+p physics

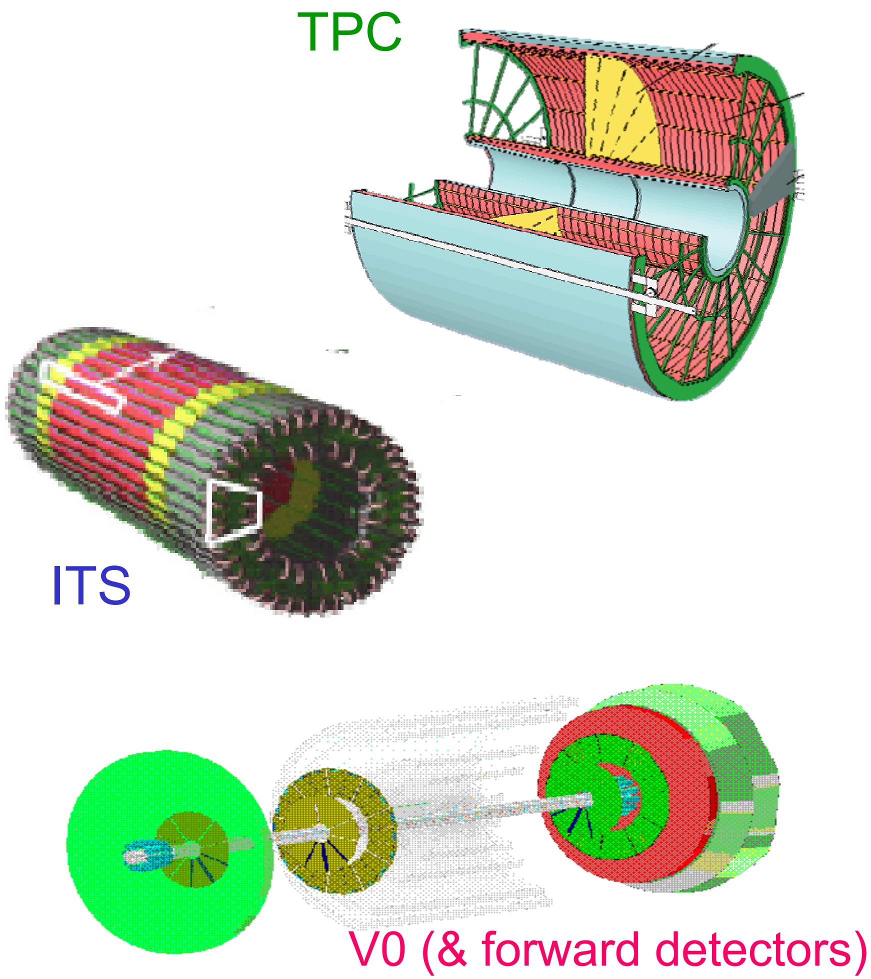
⇒ bulk particle production not well understood/described
(even at lower energies)
⇒ ALICE will play and important role at LHC
- unique window to soft (low p_T) physics
- particle identification in central region

Backup - ALICE Acceptance

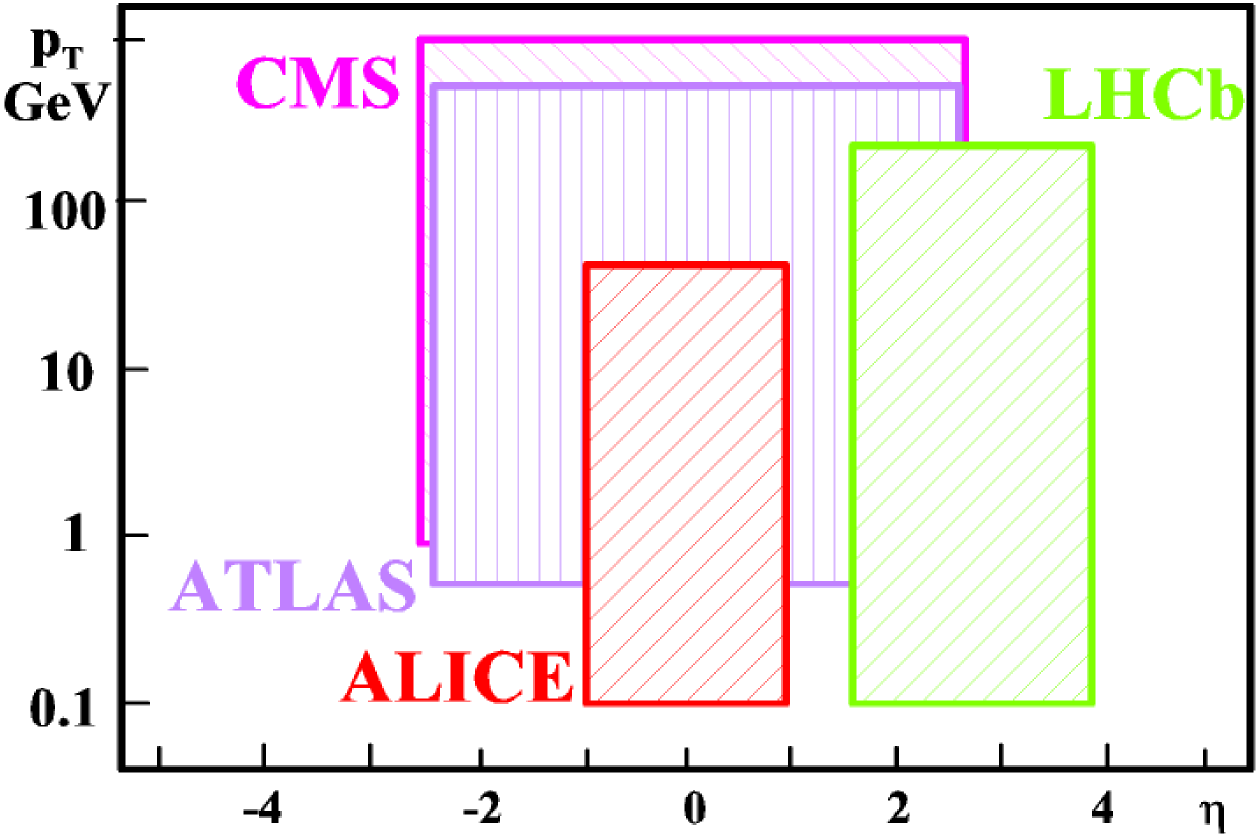
Multiplicity: -3.7<η<5

Tracking (|η|<0.9):
p_T>0.1 GeV/c (pions)
p_T>0.3 GeV/c (protons)

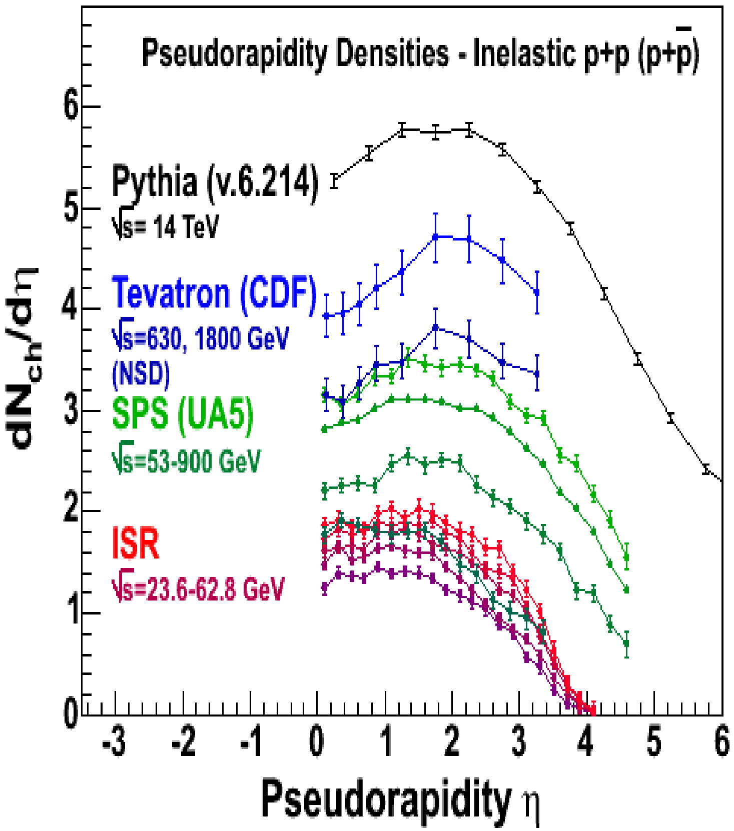




Backup – Acceptance LHC exp.

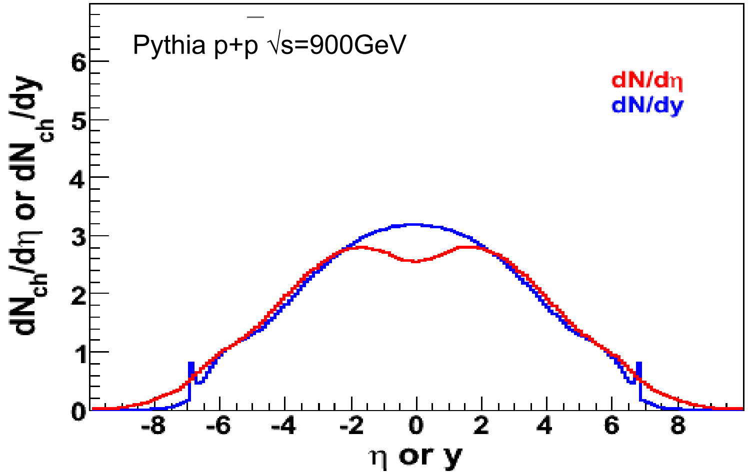


Backup - Pseudorapidity Density

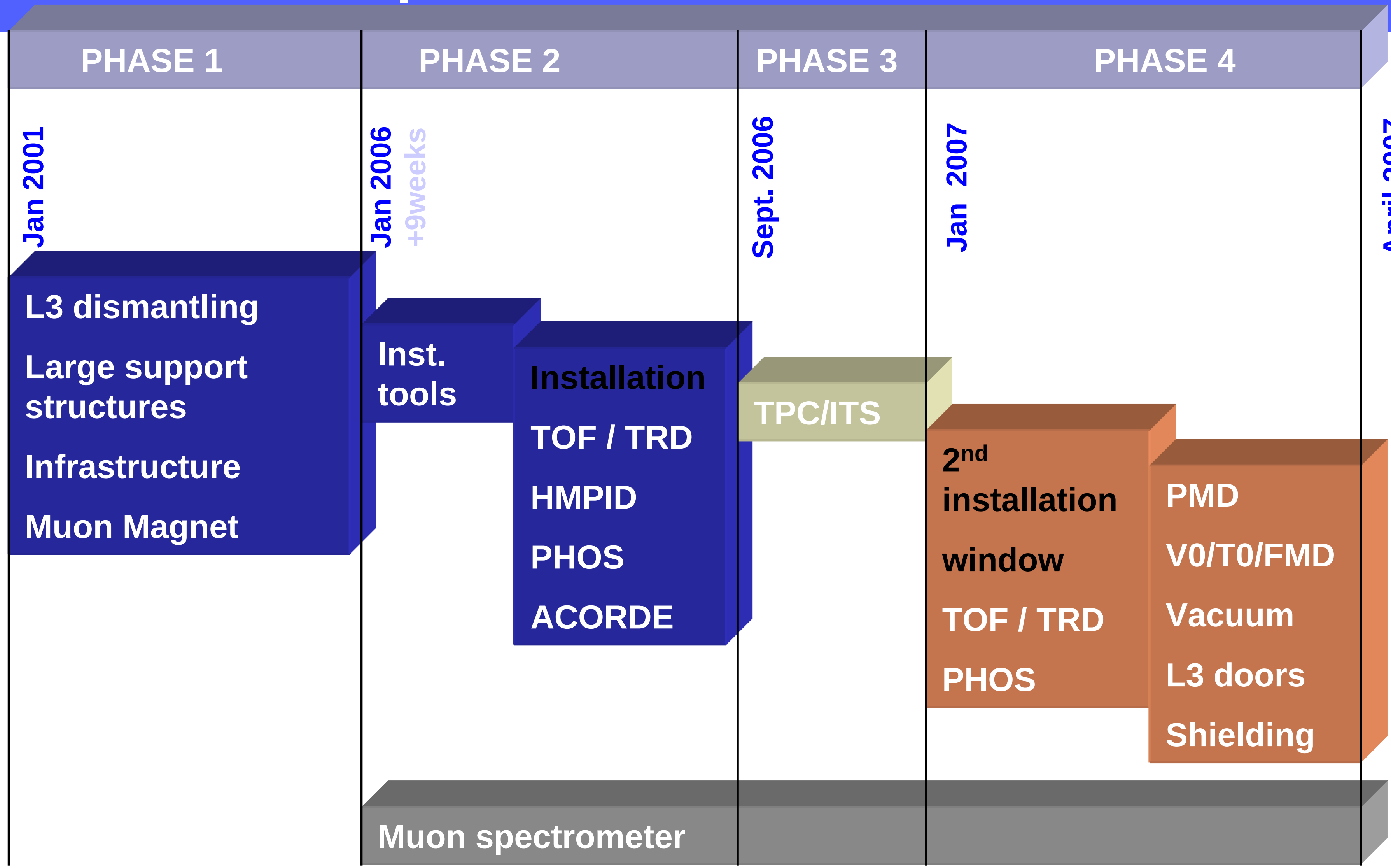


dN/dη, extended η range:

- plateau?
- limiting fragmentation?



Backup - Installation details



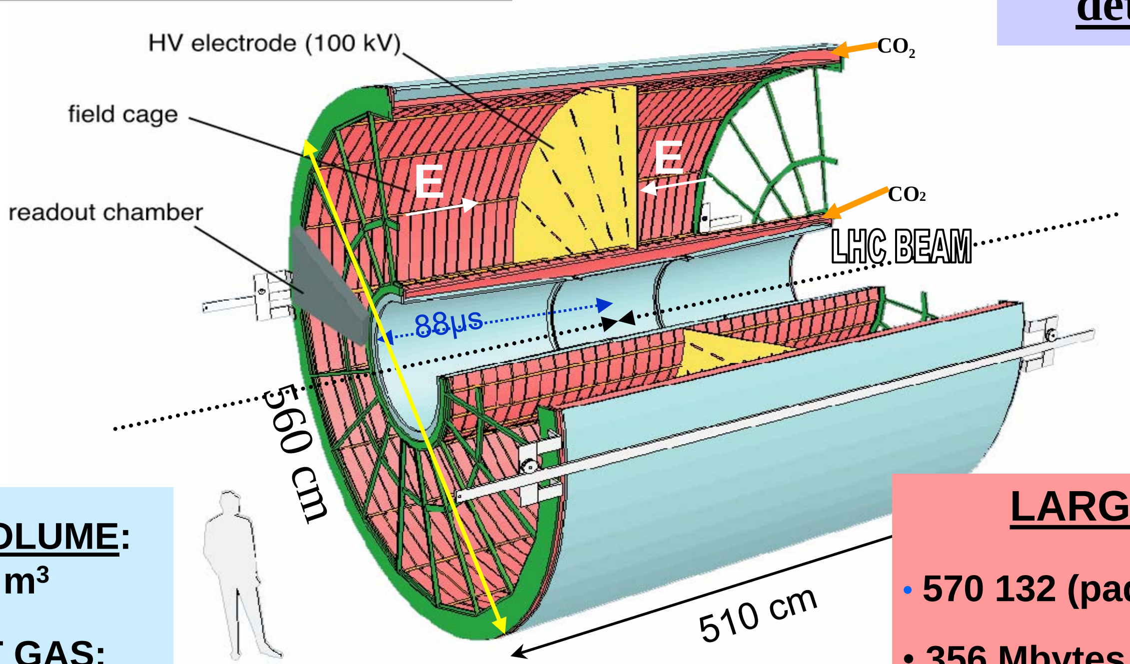
LHC Beam Parameters

Beam Energy (TeV)	**0.45**	**1.2**	**6 to 7**	**6 to 7**	**6 to 7**
Number of bunches	**43**	**43**	**43**	**43**	156
β^* [m]	**10**	**10**	**10**	**10**	10
Crossing Angle [μrad]	**0**	**0**	**0**	**0**	0
Transverse emittance [μm]	**3.75**	**3.75**	**3.75**	**3.75**	3.75
Bunch spacing [ns]	**2025**	**2025**	**2025**	**2025**	525
Bunch Intensity	**$1x10^{10}$**	**$1x10^{10}$**	**$1x10^{10}$**	**$4x10^{10}$**	$4x10^{10}$
Luminosity [$cm^{-2} s^{-1}$]	**$4x10^{27}$**	**$1x10^{28}$**	**$6x10^{28}$**	**$1x10^{30}$**	$3.5x10^{30}$
Inelastic Rate [Hz]	**144**	**450**	**3600**	**57600**	201600

Backup –TPC

Readout plane segmentation
18 trapezoidal sectors
each covering 20 degrees in azimuth

"Russian Doll" principle for detector "containment"



GAS VOLUME:
88 m³

DRIFT GAS:
Ne - CO_2 (90-10)

LARGE DATA VOLUME:

- **570 132 (pads) x 500 (time bins)**
- **356 Mbytes / event**
- **Pb – Pb (@200 Hz) ➔ 71 Gbyte / sec**
- **p-p (@1KHz) ➔ 356 GByte / sec**

Backup – Multiplicity Unfolding

Unfolding by X² minimization

- Sum of differences between measured and guess μ smeared with response (Rij = P(i|j))
- Regularization term $\mathcal{R}$(μ) adds "smoothness"
- Minuit used for minimization

X² calculation

$$\chi^2(\vec{\mu}) = \sum_{i=1}^{n_{meas}} \frac{(n_i - \sum_{j=1}^{n_{true}} R_{ij}\mu_j)^2}{n_i} + \mathcal{R}(\vec{\mu})$$

Bayesian unfolding

- Iterative method using Bayes theorem
  1) P(j|i) is calculated assuming prior P_0
  2) Guess is calculated from P(j|i) and measured
  3) Prior is updated (set to normalized guess)
  4) Go to 1

(d'Agostini, DESY 94-099, June 1994)

Bayes theorem

$$P(j_{true}|i_{meas}) = \frac{P(i_{meas}|j_{true}) \cdot P_\circ(j_{true})}{\sum_{l=1}^{n_{true}} P(i_{meas}|l_{true}) \cdot P_\circ(l_{true})}$$