Proton-proton collisions at ALICE, LHC

Triggering excellent physics

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The ALICE Collaboration and
University of Birmingham

What this talk will be:

- Introduction to ALICE: “A Large Ion Collider Experiment”
  - Physics goals, detectors, trigger capabilities (Birmingham!)
- An overview of my work:
  - Estimating the p-p Diffractive fractions
  - A bigger puzzle than heavy ions? High multiplicity p-p!
  - Trigger plays a key role!

What this talk won’t be:

- About “Large Ion Collisions”...
  - but the physics is interesting I promise!
  - Feel free to invite me back as I now work in Heavy Ions ☺

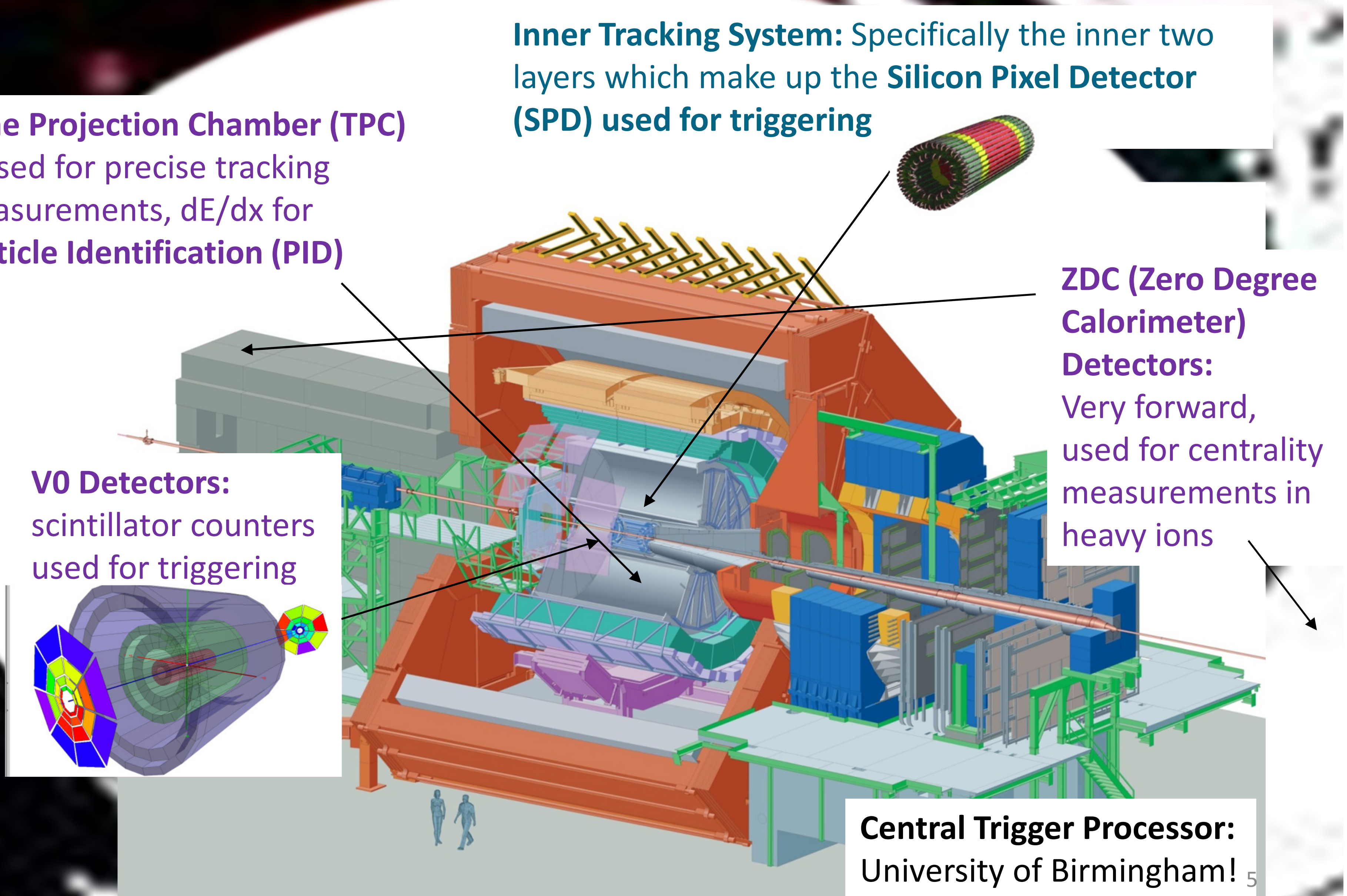
The Large Hadron Collider

- p-p Collisions up to 14 TeV √s (900 GeV, 7 TeV)
  - Up to 2808 25ns bunches/orbit (8 bc/orbit)
  - Interaction rate reduced for ALICE (~0.1/bc)
- Pb-Pb collisions up to 5.5 TeV/nucleon pair

ALICE: A Large Ion Collider Experiment

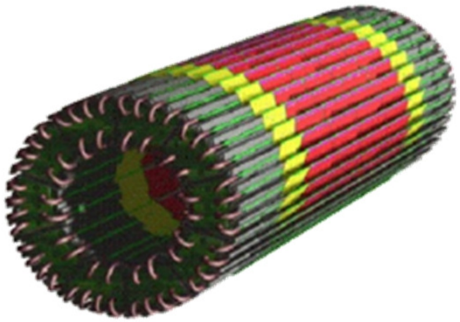
- Aims for heavy ion collisions:
  - "To study the physics of strongly interacting matter at extreme energy densities, where the formation of a new phase of matter, the quark-gluon plasma, is expected...
  - a comprehensive study of the hadrons, electrons, muons and photons produced in the collision of heavy nuclei"
- ALICE has a proton-proton program
  - "To study p-p collisions both as a comparison with lead-lead collisions and in physics areas where ALICE is competitive with other LHC experiments"
  - Particle ID, transverse momentum, SPD trigger algorithms

The ALICE Detector

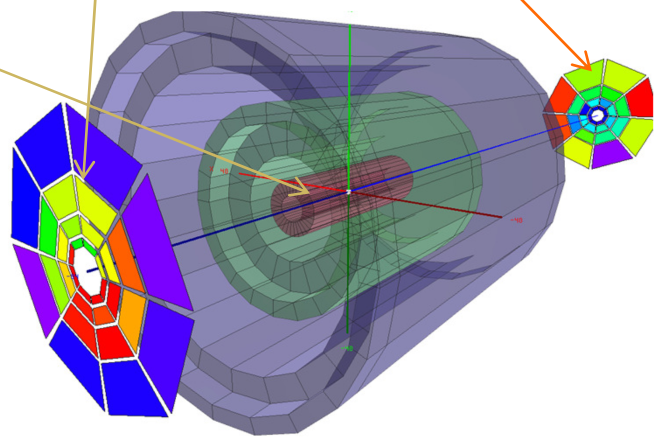


Minimum-bias Triggering detectors:

- Silicon Pixel Detector: |η|<1.95 (first layer)



- V0 Detectors: Each has 32 Scintillator counters.
- V0a: 2.8<η<5.1,
- V0c: -3.7<η<-1.7

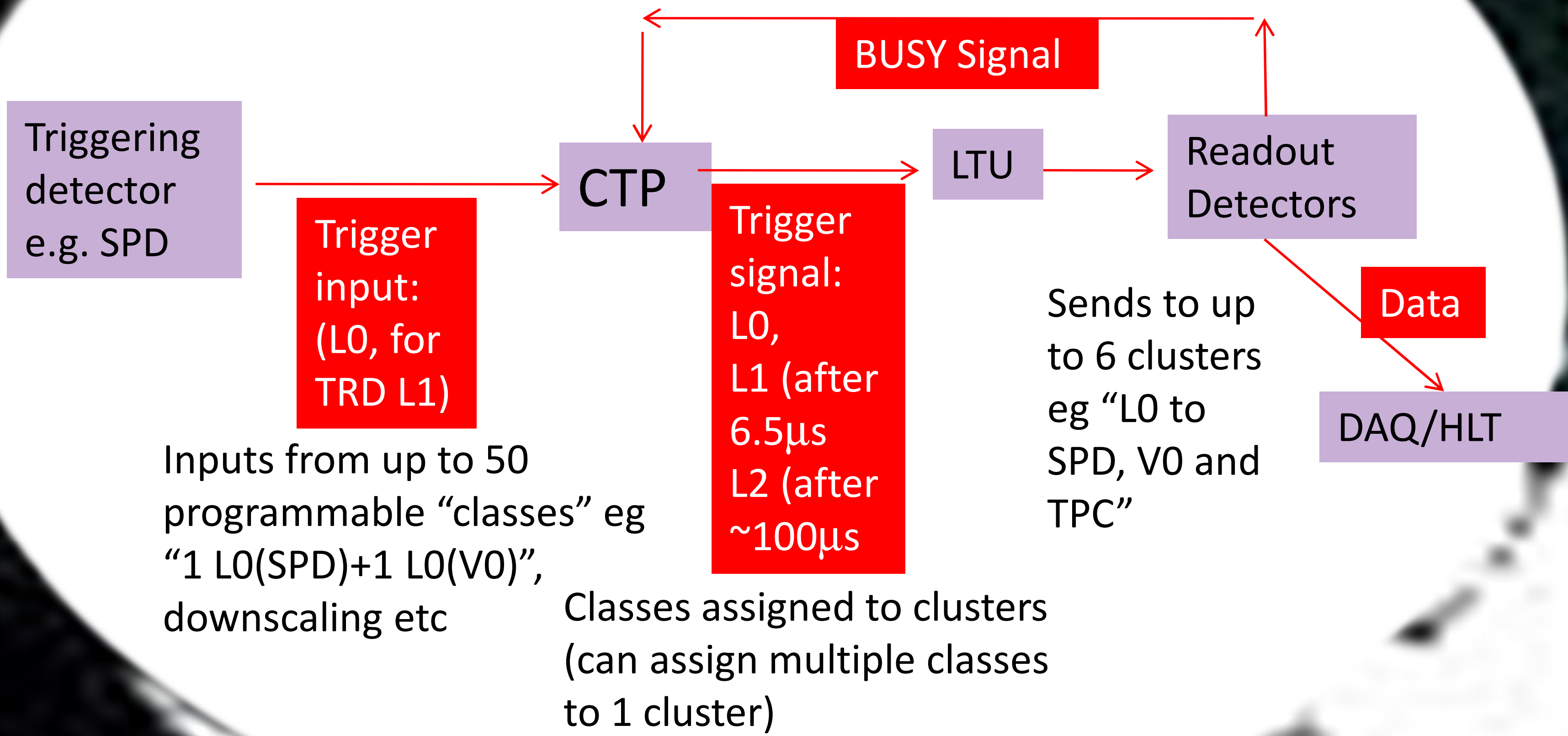


- Many trigger algorithms possible
- Threshold (number of pixels in each layer) can be tuned to select on e.g. **multiplicity**. This is unique to ALICE!
- 1200 pixel chips, nearly 10^7 pixels
- Designed to handle dN/dη up to 2000 (Heavy ions!)

- Semi-forward asymmetric coverage

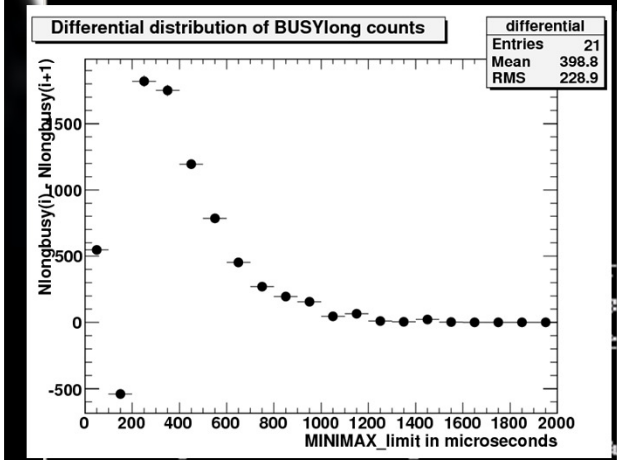
Triggering at ALICE: CTP

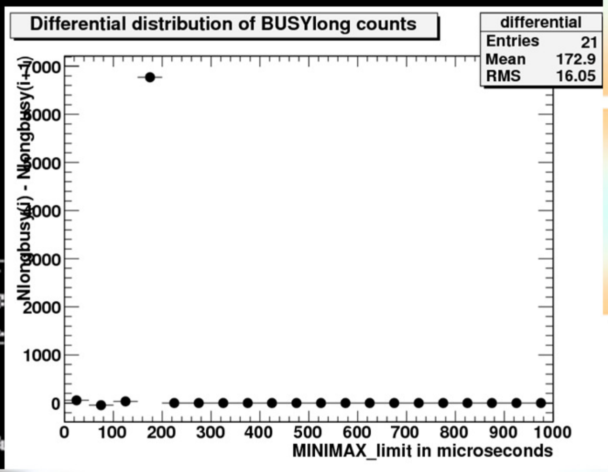
- p-p event rate ~16kHz
- Many subdetectors with varying readout times
- 3 levels of triggering: L0, L1, L2

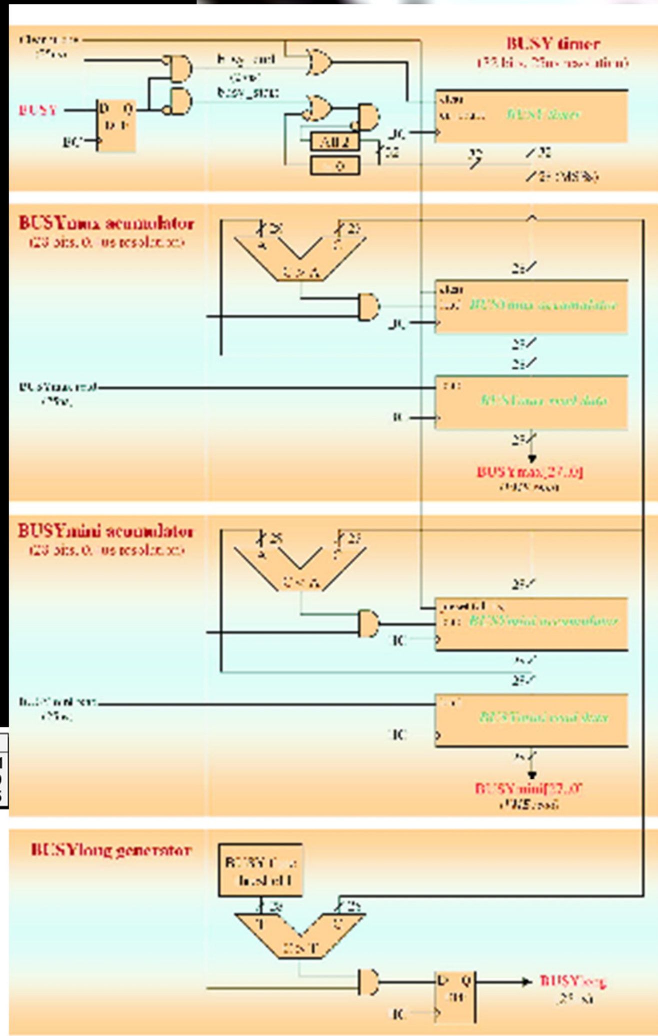


TooBUSY: A Tool for Detector Diagnostics

```
CINT/ROOT C/C++ Interpreter version 5.18.00, July 2, 2010
Type ? for help. Commands must be C++ statements.
Enclose multiple statements between { }.
Welcome to the Jan's ROOT session
root [0] .x busyplot.C
give 5 numbers with 1 space between each (in the following form):
a b c d e
where a is the end of your busysweep range (in microseconds)
b is the start of your busysweep range (in microseconds), or 0
c is the size of each step in the sweep (in microseconds)
d is the time spent measuring the busy PER STEP (in seconds)
and e is the detector number:
To find e, refer to below:
0 = CTP_BUSY
1-24: Detector BUSY (see table)
25-30 = Cluster 1 to 6 BUSY
31 = Test cluster BUSY
DETECTOR TABLE (BASED ON VALID.LTUs 03/10)
1=SDD    2=MUONTRK
3=MUONTRG    4=DAQ
5=SPD    6=TOF
```







Next in importance to having a good aim is to recognize when to pull the trigger - David Letterman

Estimating diffractive fractions in p-p at ALICE

High Multiplicity p-p at ALICE: Data Selection and Analysis Prospects (Strangeness and the Phi Resonance)

Aside

Rapidity y:

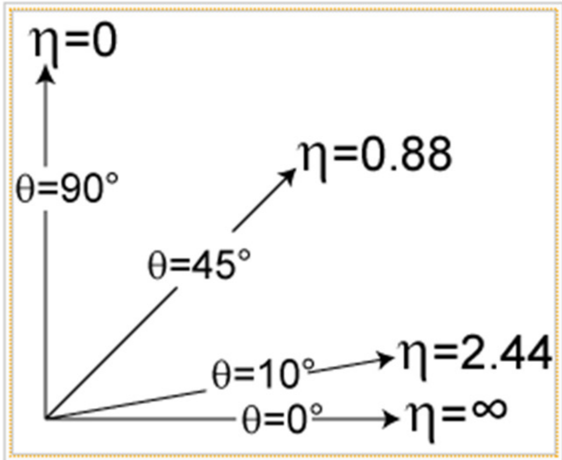
$$y = \frac{1}{2} \ln \frac{E + p_l}{E - p_l}$$

Pseudorapidity η:

$$\eta = \frac{1}{2} \ln \frac{|p| + p_l}{|p| - p_l}$$

$$\eta = -\ln\left[\tan(\frac{\theta}{2})\right]$$

Pseudorapidity η

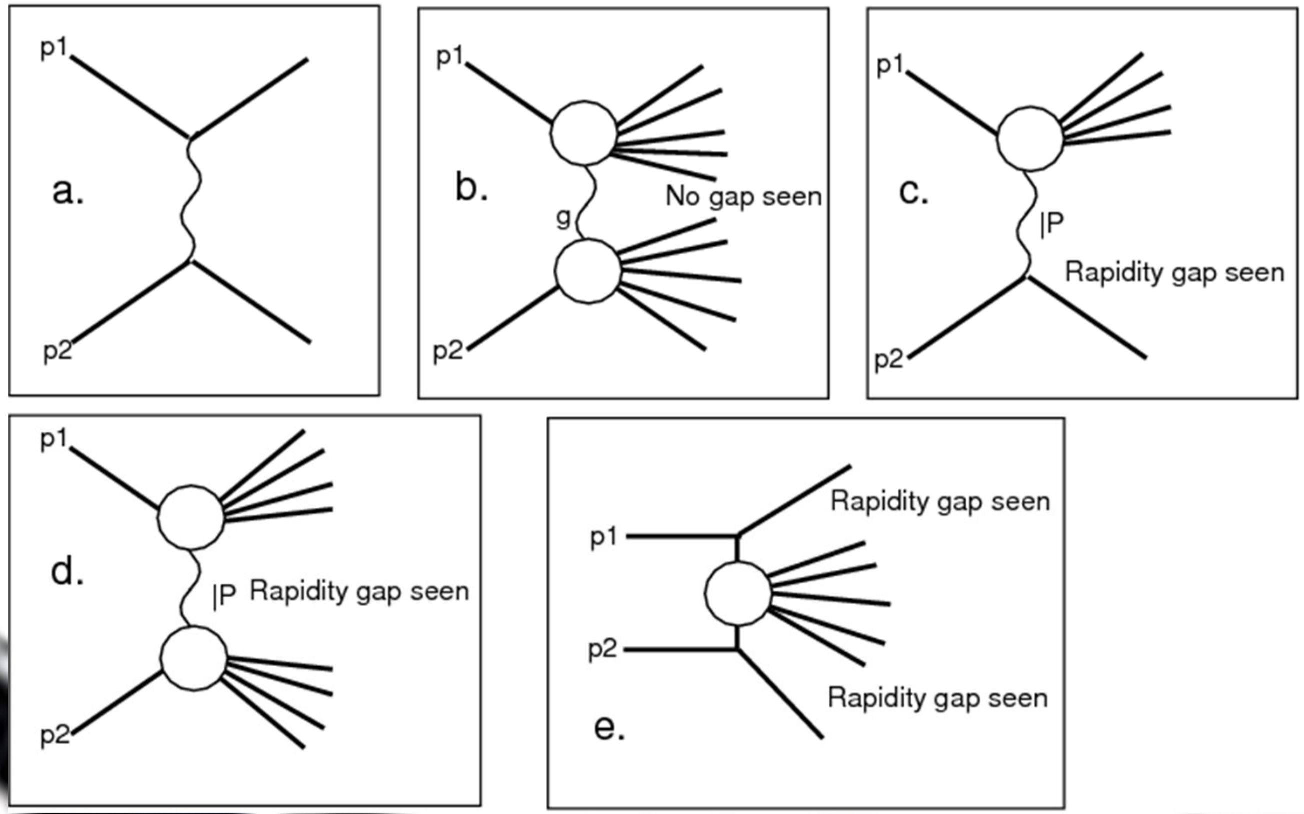


Beampipe ⟶

dN/dη = Multiplicity per "unit" of pseudorapidity

What do we mean by "Diffraction"?

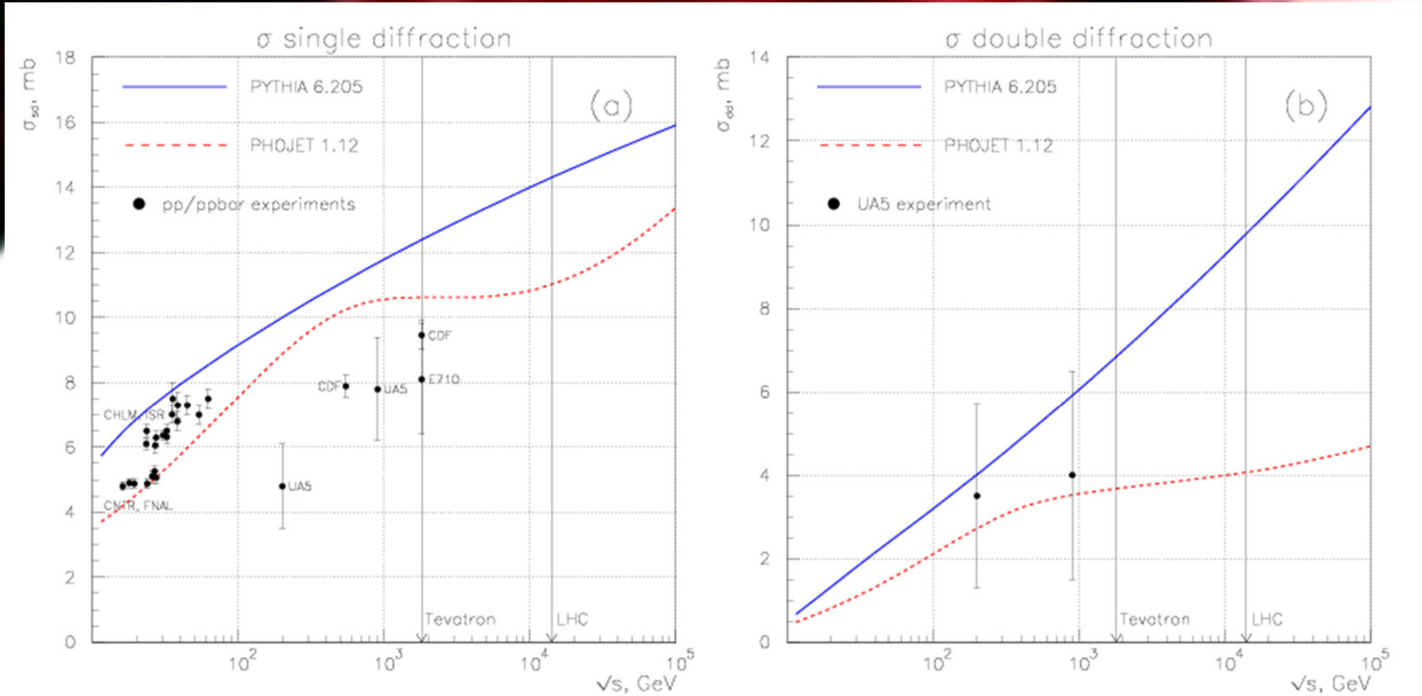
- a. elastic p-p interaction
- b. ordinary inelastic interaction
- c. –e. diffractive events: exchange of colour-neutral "pomeron" (2g exchange?) leads to characteristic gaps in rapidity.
  - c=single diffraction, d=double diffraction, e=central (double-pomeron exchange) diffraction



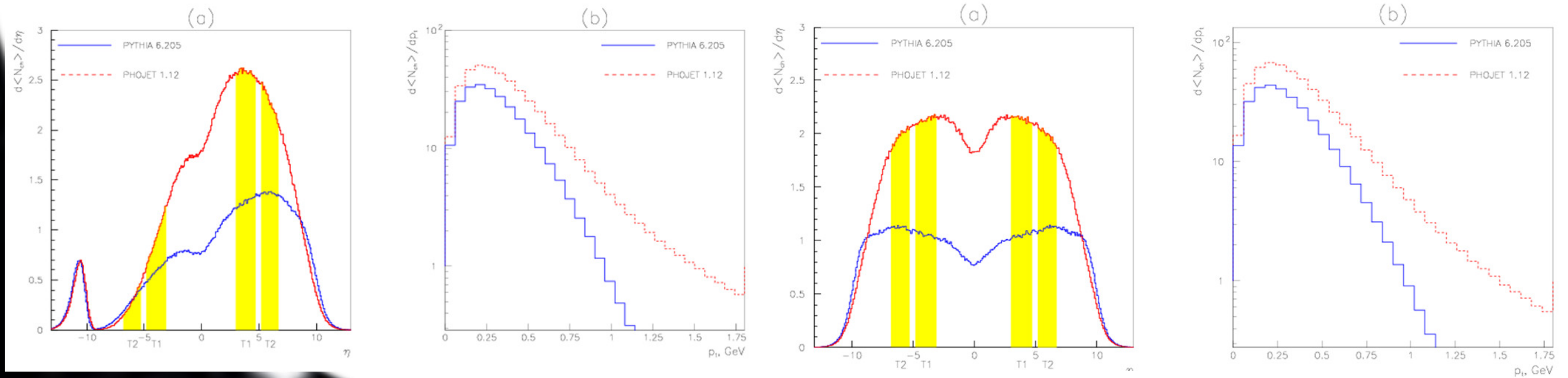
Current Understanding/Models

- Pomeron can be thought of as a leading Regge pole, vacuum quantum numbers
- In QCD Approach this approximates to ladder diagrams, double-gluon exchange to lowest order
- Higher energy at LHC – larger diffractive mass range, different approaches in models
- Energy dependence of cross sections – large uncertainty!

Phojet, Pythia and data: a comparison



TOTEM-NOTE 2004-05



Pythia8 – hard diffraction (reproduces Phojet Pt tail)

Measuring Diffraction: Rapidity Gaps

- Idea
  - Trigger on/select events with rapidity gaps of a given size
  - Identify SD, elastic intact proton(s) with pots
- E.g: CDF, TOTEM (pots), ATLAS
- Warnings for ALICE:
  - Requires trigger with granularity in η - Forward Multiplicity Detector?
  - ALICE has gaps in η coverage
  - Depending on multiplicity, may mis-tag ND event as SD
    - Cannot see elastic events/identify intact proton for SD!
  - Gap survival probability?
  - Would need to redefine "single diffractive" as "measureable single diffractive" and treat with models afterwards - Handle With Care!
- M. Poghosyan working on this. ALICE Upgrade to fill gaps?

Measuring Diffraction: What's The Alternative?

- Idea:
  - Use different trigger-logic combinations that vary in η coverage
  - Measure trigger counts from data
  - Use MC simulation to estimate efficiency of triggers for diffractive events
  - Calculate fraction of diffractive events
- E.g: UA5
- Warnings For ALICE:
  - Detector effects not reproduced in MC will cause large systematics: Handle With Care!
  - Dependent on models' diffraction kinematics as with rapidity gap method (and uncertainty there increases measurement uncertainty) – Handle With Care!

Measuring Diffraction: What's The Alternative?

$$\sigma_{tot} = \sigma_{inel} + \sigma_{el}$$
$$\sigma_{inel} = \sigma_{NSD} + \sigma_{SD}$$

- UA5:
  - A1 and A2: 2 trigger hodoscope arms covering the pseudorapidity range $2 < |\eta| < 5.6$
  - Two triggers: 1: A1 AND A2 and 2: A1 AND NOT A2

$$\sigma_1 = \sigma_{NSD}\varepsilon^1_{NSD} + \sigma_{SD}\varepsilon^1_{SD}$$
$$\sigma_2 = \sigma_{NSD}\varepsilon^2_{NSD} + \sigma_{SD}\varepsilon^2_{SD}$$

$$\varepsilon^{trig}_{proc} = \frac{N^{trig}_{proc}}{N^{gen}_{proc}}$$

  - And given the efficiencies, one can calculate:

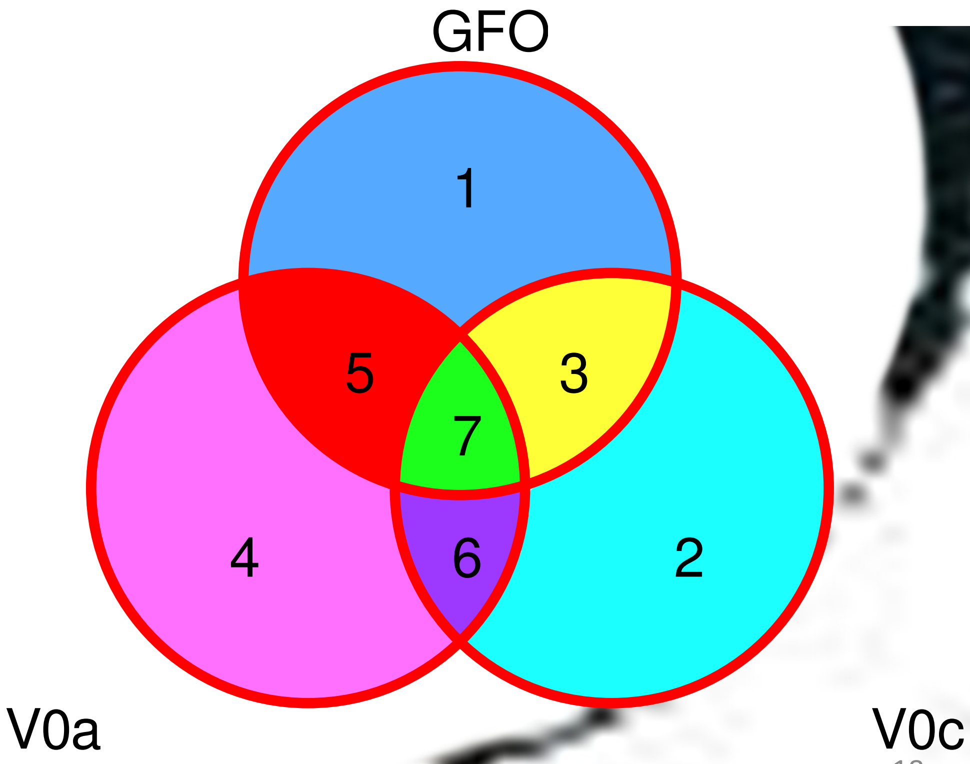
$$\sigma_{SD} = \sigma_1\chi_1 + \sigma_2\chi_2$$
$$\sigma_{NSD} = \sigma_1\chi_3 + \sigma_2\chi_4$$
$$\sigma_{inel} = \sigma_1\chi_5 + \sigma_2\chi_6$$

  - Where χ_i depend on efficiencies

Measuring Diffraction: Extending UA5 Method

- ALICE can use 7 independent logical combinations of triggers using SPD and V0 triggering detectors
  - In fact, all of these are subset of min-bias trigger
    - Can measure Ntrig for each offline using minimum bias data
    - (If beam-beam data is available, can be used to access Tr 0 (000)) but this would be a challenge!

Tr	V0a	GFO	V0c
1	0	1	0
2	0	0	1
3	0	1	1
4	1	0	0
5	1	1	0
6	1	0	1
7	1	1	1



Ntrig Sum(Tr 1-7) = Ntrig (min-bias)
Minbias: V0a OR GFO OR V0C

Measuring Diffraction: The Extended UA5 Method

$$N_{trig} = N_{trig}^{ND} + N_{trig}^{SD} + N_{trig}^{DD} + \cancel{N_{trig}^{NI}}$$

$$N_{trig} = N_{data}\left(\frac{N_{trig}^{ND} N_{data}^{ND}}{N_{data}^{ND} N_{data}} + \frac{N_{trig}^{SD} N_{data}^{SD}}{N_{data}^{SD} N_{data}} + \frac{N_{trig}^{DD} N_{data}^{DD}}{N_{data}^{DD} N_{data}} + \cancel{\frac{N_{trig}^{NI} N_{data}^{NI}}{N_{data}^{NI} N_{data}}} \right)$$

$$N_{trig} = N_{data}\left(f^{ND}\varepsilon_{trig}^{ND} + f^{SD}\varepsilon_{trig}^{SD} + f^{DD}\varepsilon_{trig}^{DD} + \cancel{f^{NI}\varepsilon_{trig}^{NI}} \right)$$

- Efficiencies differ for trigger types with different η coverage – sensitive to kinematic differences between processes
- Various triggers could be used in χ^2 minimization to fit to process fractions

$$N_{calc(i)} = \sum_{j=1,4} a_{ij}\, proc(j)$$

$$\chi^2 = \sum_{trig} \left(\frac{\left(N_{trig\,(i)} - N_{calc\,(i)}\right)}{\sigma(N_{trig\,(i)})} \right)^2$$

Not sensitive to events with “no interaction” in minimum-bias (but would be using beam-beam trigger)

Error Estimation

$$\chi^2 = \sum \frac{(N_{fit}^{trig} - N_{measured}^{trig})^2}{(Uncertainty)^2}.$$

$$\sqrt{N_{measured}^{trig}}.$$

$$\chi^2 = \sum \frac{\left(N^{total}\left(f_{ND}^{fit}\varepsilon_{ND}^{trig} + f_{SD}^{fit}\varepsilon_{SD}^{trig} + f_{DD}^{fit}\varepsilon_{DD}^{trig}\right) - N_{measured}^{trig}\right)^2}{(\text{Uncertainty}_{\text{stat}})^2 + (\text{Uncertainty}_{\text{model}})^2 + (\text{Uncertainty}_{\text{Systematic}})^2}$$

"Model error" to describe uncertainty in kinematics: use MC models available and look at variation in efficiencies

$$\sqrt{\left(\frac{\delta N_{fit}^{trig}}{\delta \varepsilon_{ND}}\right)^2 (\sigma_{\varepsilon_{ND}})^2 + \left(\frac{\delta N_{fit}^{trig}}{\delta \varepsilon_{SD}}\right)^2 (\sigma_{\varepsilon_{SD}})^2 + \left(\frac{\delta N_{fit}^{trig}}{\delta \varepsilon_{DD}}\right)^2 (\sigma_{\varepsilon_{DD}})^2}$$

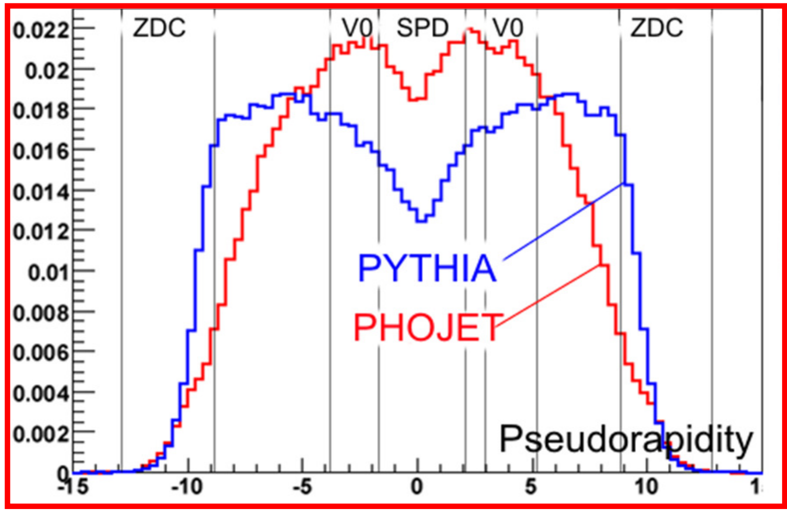
Error propagation (efficiencies are independent)

$$\sqrt{\left(N^{total}\right)^2 \sum \left(f_{proc}^2 \sigma_{\varepsilon_{proc}}^2\right)} \longrightarrow \sqrt{\left(N^{total}\right)^2 \sum \left(f_{proc}^2 \left(\frac{1}{2}\Delta\varepsilon_{proc}\right)^2\right)}$$

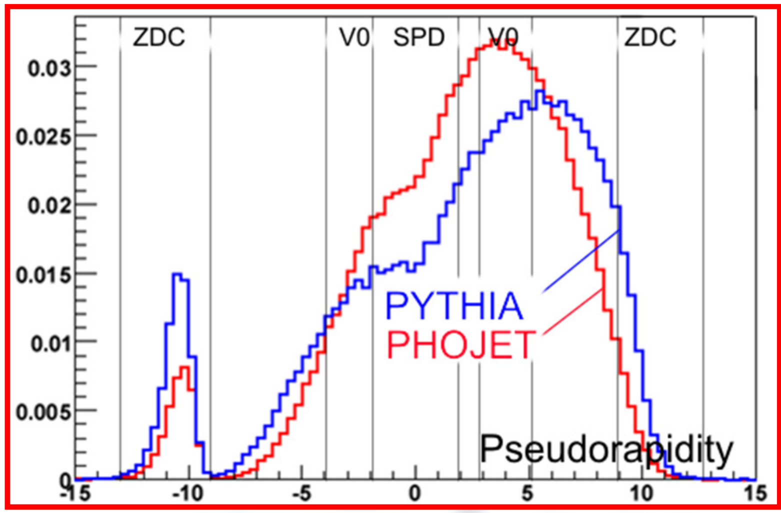
Extending the Method: ZDC (Zero Degree Calorimeters)

- ZDC Neutron and Proton calorimeters cover more forward region, should be more sensitive to the difference between SD and DD with increasing energy
- ALICE ZDC group have defined a “hit” flag, so that an offline ZDC “trigger” can be used
- Using “ZDC_OR_a” and “ZDC_OR_c” – each side uses OR of P and N detectors
- **32 independent trigger combinations** possible
- (28 within minimum-bias)

Double Diffractive Pseudorapidity (10 TeV)



Single Diffractive Pseudorapidity



MC Testing: Example

- Fractions set to 50:50 PYTHIA:PHOJET fractions
- Ntrig for 32 trigger types weighted to 50:50 PYTHIA:PHOJET kinematics
- Each set of MC efficiencies is used to fit to the fractions

PHOJET Coefficients

32 triggers – 4 unknowns + 1 constraint

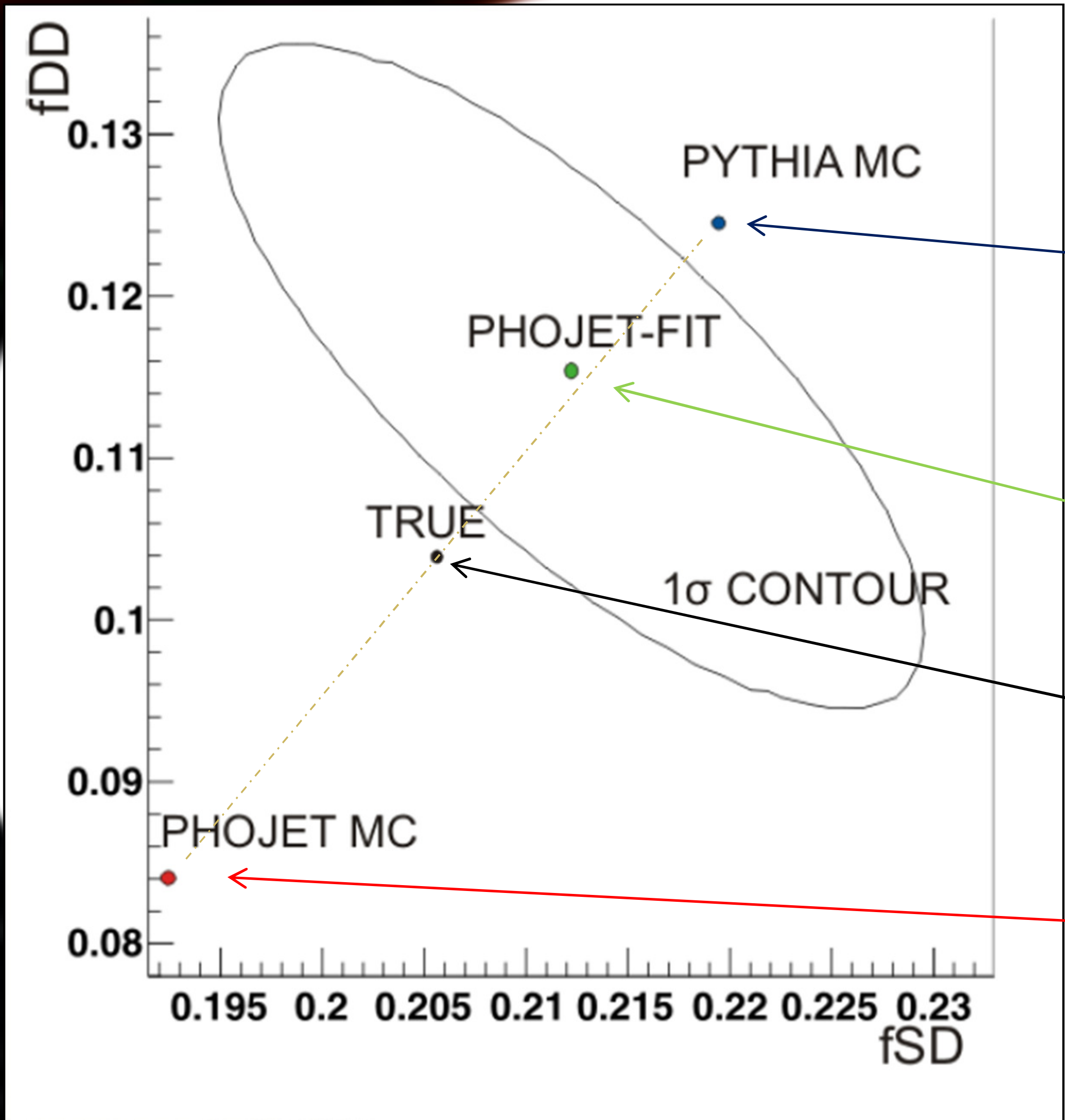
Fraction	ND	SD	DD	NI	$\chi^2/_{dof}$
Generated	0.69	0.206	0.104	0	
Fit	0.657±0.015	0.212±0.017	0.115±0.02	0.0±0.03	18.9/29

PYTHIA Coefficients

Fraction	ND	SD	DD	NI	$\chi^2/_{dof}$
Generated	0.69	0.206	0.104	0	
Fit	0.717±0.009	0.212±0.01	0.071±0.013	0.0±0.022	20.8/29

(errors propagated through fit)

MC Testing: Example



Fit Results vs. MC fractions

PYTHIA (blue) : fSD/fDD in MC

PHOJET-fitted (green) fSD/fDD, with 1σ contour

"True" (black) fSD/fDD for 50 % PYTHIA-PHOJET mix

PHOJET (red) : fSD/fDD in MC

MC Testing: Example

PHOJET Coefficients

28 triggers – 4 unknowns + 1 constraint

Fraction	ND	SD	DD	Nint	$\chi^2/_{dof}$
Generated	0.69	0.206	0.104	0	
Fit	0.67±0.013	0.213±0.017	0.117±0.021	99987±743	16.24/25

PYTHIA Coefficients

Fraction	ND	SD	DD	Nint	$\chi^2/_{dof}$
Generated	0.69	0.206	0.104	0	
Fit	0.71±0.01	0.229±0.016	0.061±0.012	1015501±401	13.52/25

100,000 ALICE EVENTS: 900 GEV

(errors propagated through fit)

MC Testing: Example

PHOJET Coefficients

7 triggers – 4 unknowns + 1 constraint

Fraction	ND	SD	DD	NI	χ^2/dof
Generated	0.69	0.206	0.104	0	
Fit	0.648±0.018	0.182±0.022	0.149±0.028	0.0±0.04	1/4

PYTHIA Coefficients

Fraction	ND	SD	DD	NI	χ^2/dof
Generated	0.69	0.206	0.104	0	
Fit	0.71±0.01	0.205±0.028	0.084±0.027	0.0±0.04	5.13/4

(errors propagated through fit)

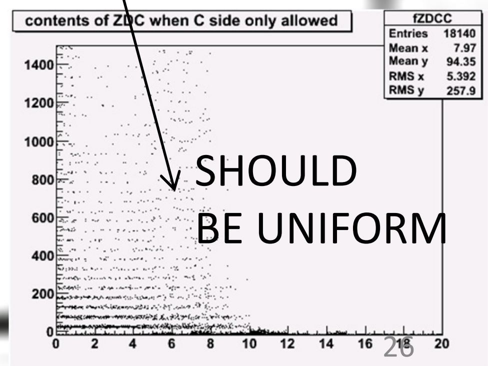
100,000 ALICE EVENTS: 900 GEV

Real Data

- 7 TeV
  - Data: good run used:
    - **1931000 events**
  - Pythia, Phojet and Pythia8 describing same run
    - **>100000 events each**
- 900 GeV
  - Data: good run used
    - **1016000 events**
  - Pythia, Pythia8
    - **>100,000 events**
  - Phojet
    - **<100,000 events (not ideal)**

ZDC Interference in data caused by collimator jaws interfering with beam spot – not reproduced in MC, better in 7 TeV

ZDC MC as yet un-tuned!



Corrections: Beam Gas

- BG: When beam interacts with gas in beam pipe, or E: noise causing an empty event to be triggered on
  - BG events are asymmetric, look like SD
  - Beam-gas events occurring outside of V0 detectors can be vetoed but some remain
- MB Trigger took data from A-side, C-side only beams and E (empty bunch crossings)
  - Using this data, I can correct Ntrig and adjust statistical error accordingly:

(NtrigMB – (NtrigA+NtrigC))+NtrigE (scaled to filling scheme)

Corrections: Beam Gas

Example – using 7 TeV data, 1st 7 trigs

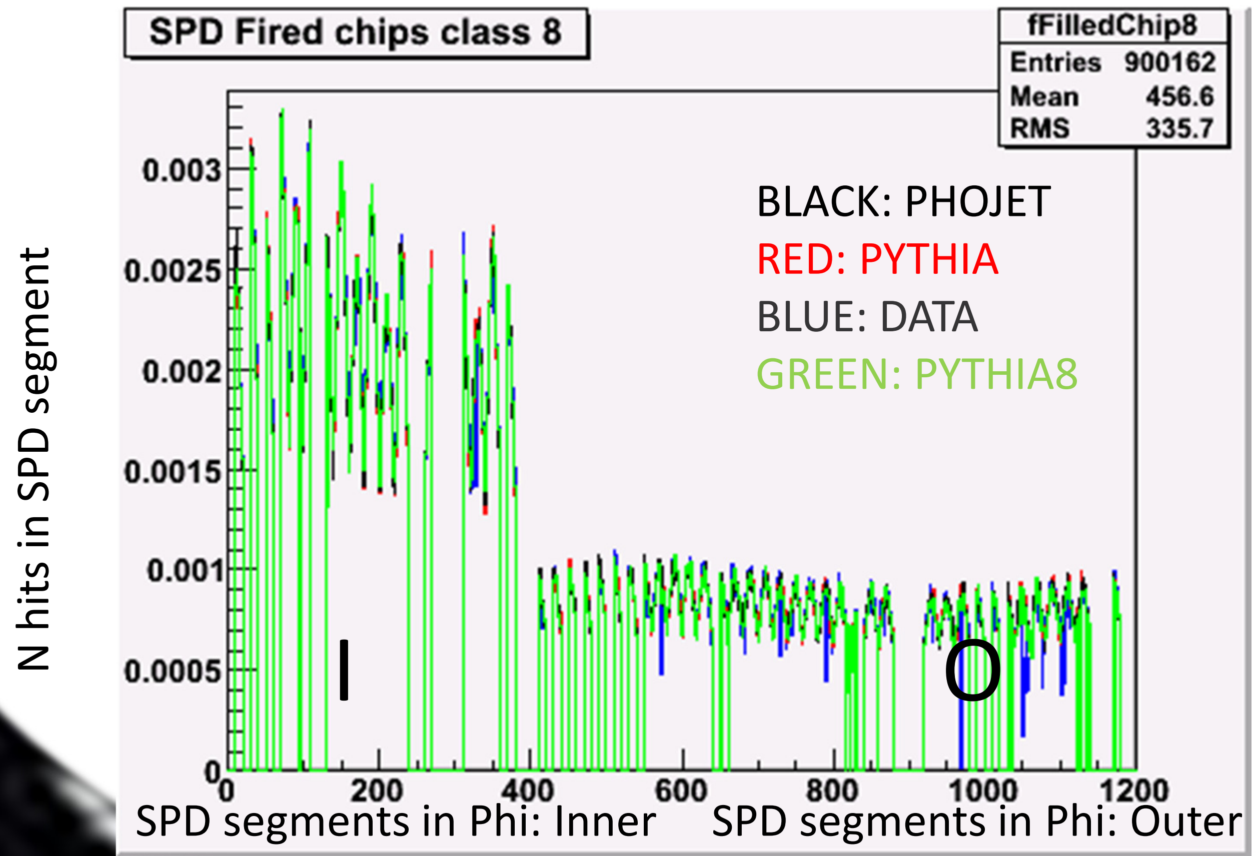
Tr (No ZDC)	V0a	GFO	V0c	Ntrig (first)	Correction: Total	Ntrig after Timing correction	Remaining Correction
1	0	1	0	2384	2070 (1908 E)	280	37 (5 E)
2	0	0	1	2272	104 (28 E)	1466	100 (2 E)
3	0	1	1	3712	97 (0 E)	1847	167 (0 E)
4	1	0	0	4468	492 (397 E)	2074	147 (71 E)
5	1	1	0	3033	29 (0 E)	1524	112 (0E)
6	1	0	1	1370	47 (0 E)	527	2 (0E)
7	1	1	1	87989	394 (0 E)	43443	74 (0E)

$$N_{trig}(final) = N_{trig}(first) - N_{corr}$$

$$\text{Uncertainty}_{\text{stat}}(final) = \sqrt{(N_{trig} + N_{corr})}$$

Quality Checks

- Hit content when trigger fired vs chips in order of ϕ
  - Normalised N hits to 1
    - Checked for all trigger definitions, good for data vs MC



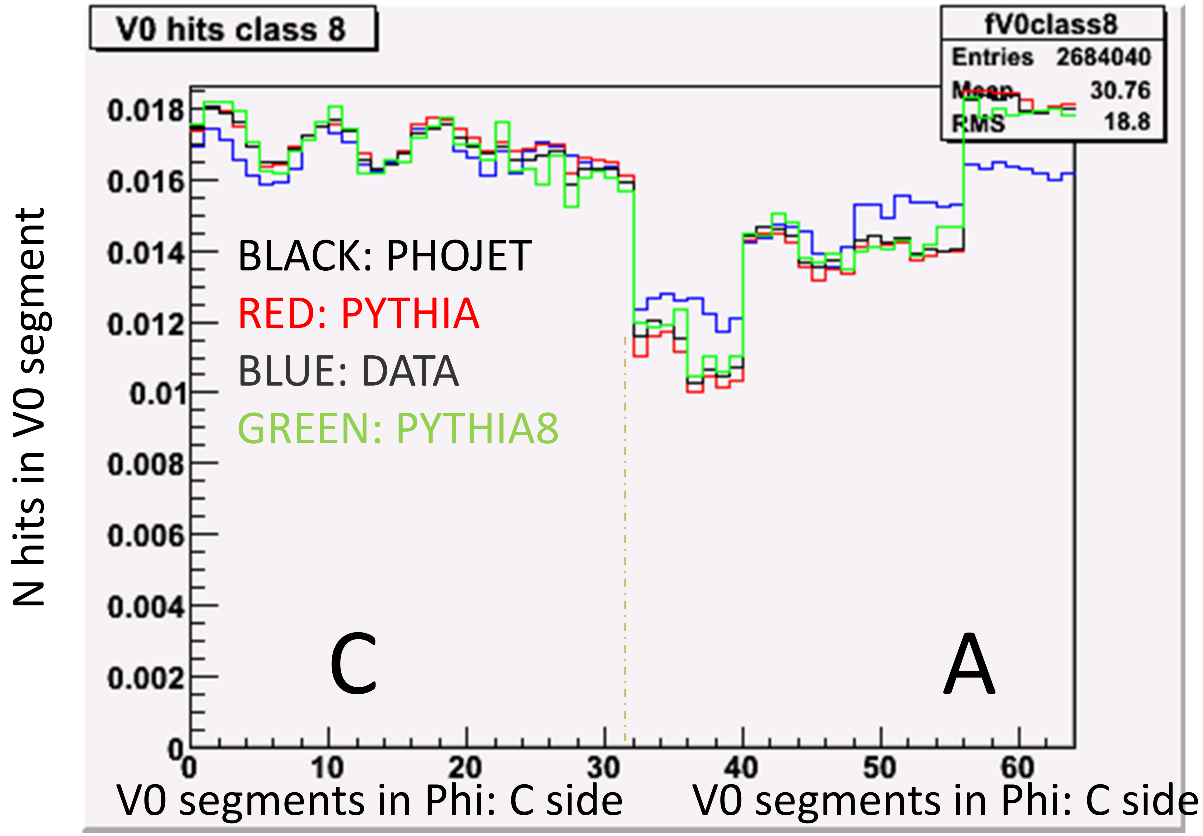
PLOTTED ONLY WHEN TRIGGER CONDITION SATISFIED:

(GFO, VOA, VOC):

(111)

Quality Checks

- Hit content when trigger fired vs slabs, in order of ϕ
  - Normalised N hits to 1



PLOTTED ONLY WHEN TRIGGER CONDITION SATISFIED:

(GFO, VOA, VOC):

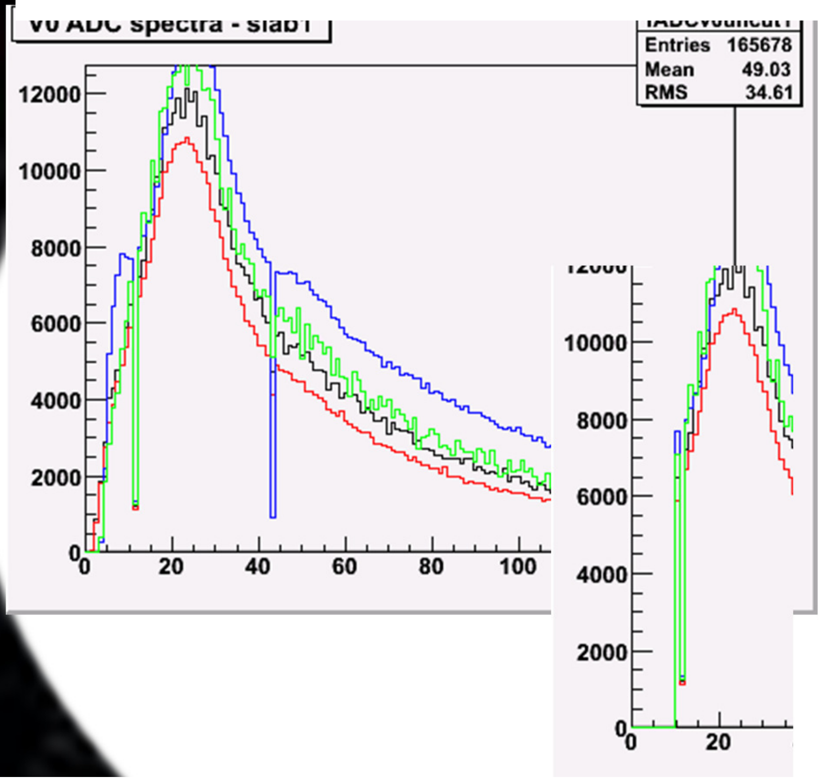
(111)

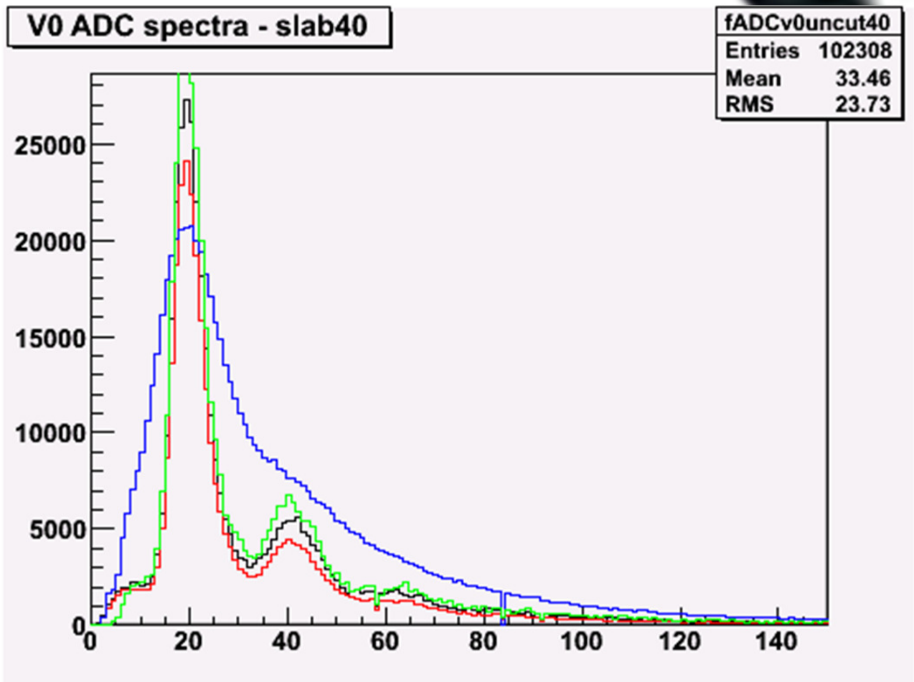
- Checked for all trigger definitions, some discrepancies found (usually A side, not the same for all triggers), 5-10% level
- Caused by limited accuracy of the measurements of detector effects

Quality Checks

- ADC Spectra not perfectly simulated – some holes and a shoulder exist in the data

Also, a few slabs appear to have much less photon exposure than expected





- Can set new threshold slab by slab to remove shoulder and recalculate efficiencies

- Can remove these slabs and recalculate efficiencies

Results

PHOJET Coefficients (Pythia errors)

28 triggers – 4 unknowns + 1 constraint

Fraction	ND	SD	DD	Ntot	χ^2/dof
MC	79.37	13.86	6.77	>1931000	
Fit	63.94±1.69	14.61±1.76	21.45.±2.02	1958000±326440	37/25

PYTHIA Coefficients (Phojet errors)

Fraction	ND	SD	DD	Ntot	χ^2/dof
MC	67.81	19.19	13.0	>1931000	
Fit	71.67±1.02	16.96±1.12	11.33±0.94	1931000±2523	136/25

New: PYTHIA 8 Coefficients (Pythia coefficients)

Fraction	ND	SD	DD	Ntot	χ^2/dof
MC	67.89	19.07	13.04	>1931000	
Fit	68.64±0.73	19.05±0.78	12.27±0.64	193078±2572	285/25

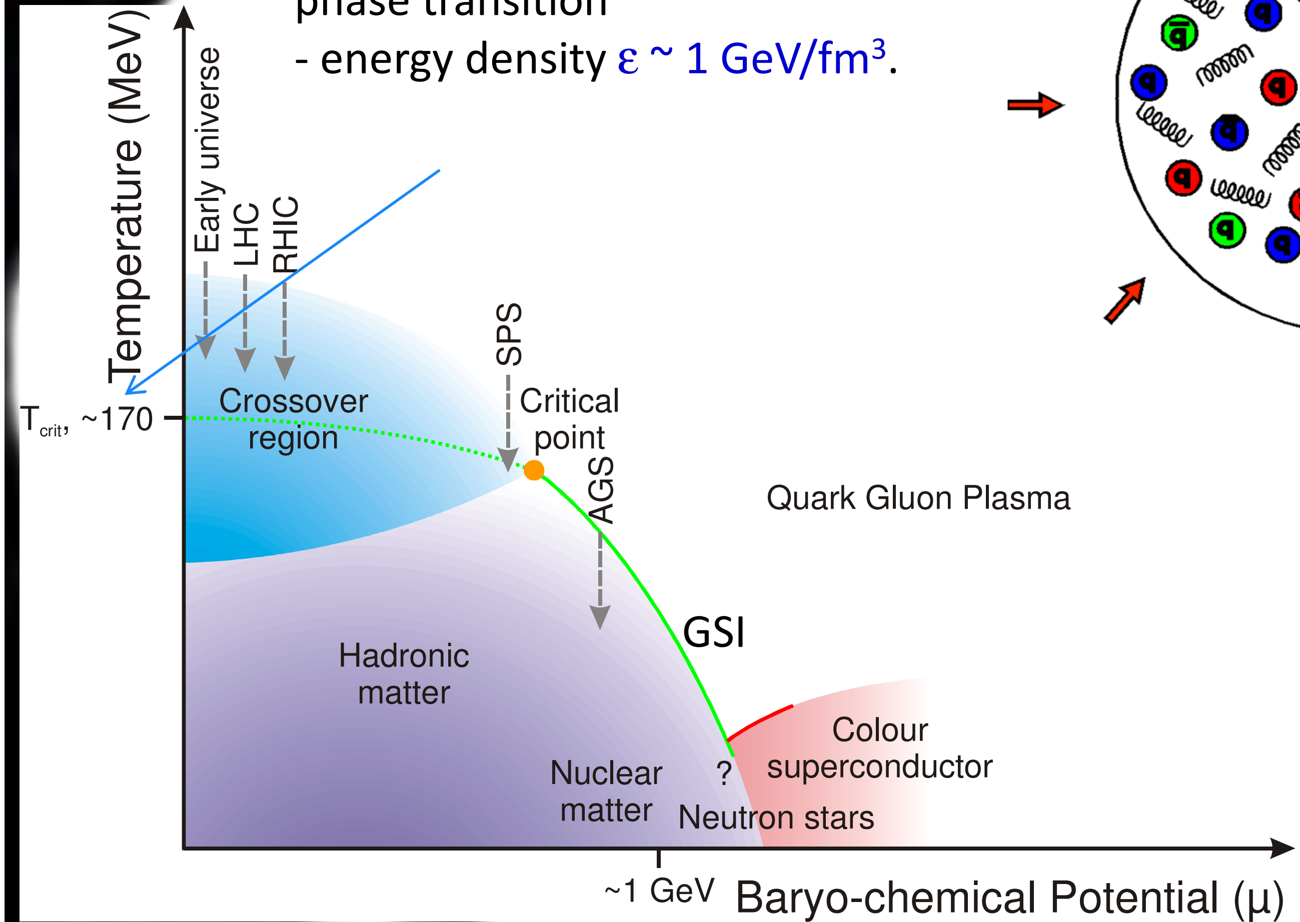
1931000 ALICE EVENTS: 7 TEV

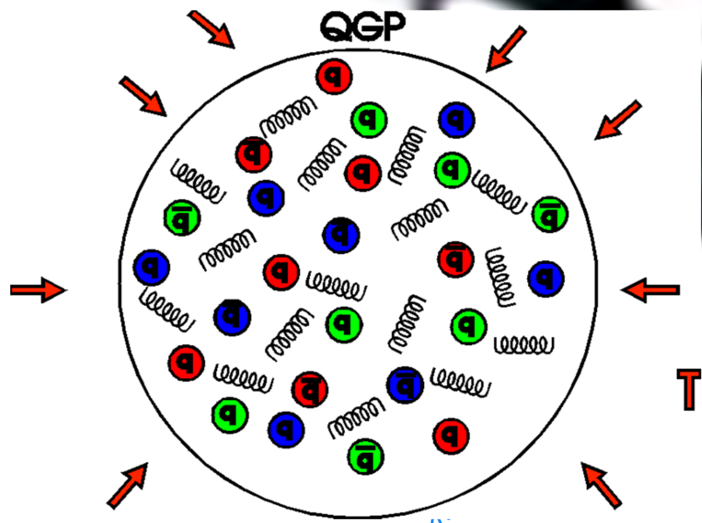
(errors propagated through fit)

Estimating diffractive fractions
in p-p at ALICE
Quark Gluon Plasma*
High Multiplicity p-p at ALICE:
Data Selection and Analysis
Prospects
(Strangeness and the Phi
Resonance)

What is a Quark Gluon Plasma?

Statistical and lattice QCD:
phase transition
- energy density $\varepsilon \sim 1$ GeV/fm^3.





Under extreme conditions of temperature and/or density nuclear matter ‘melts’ into a plasma of free quarks and gluons.

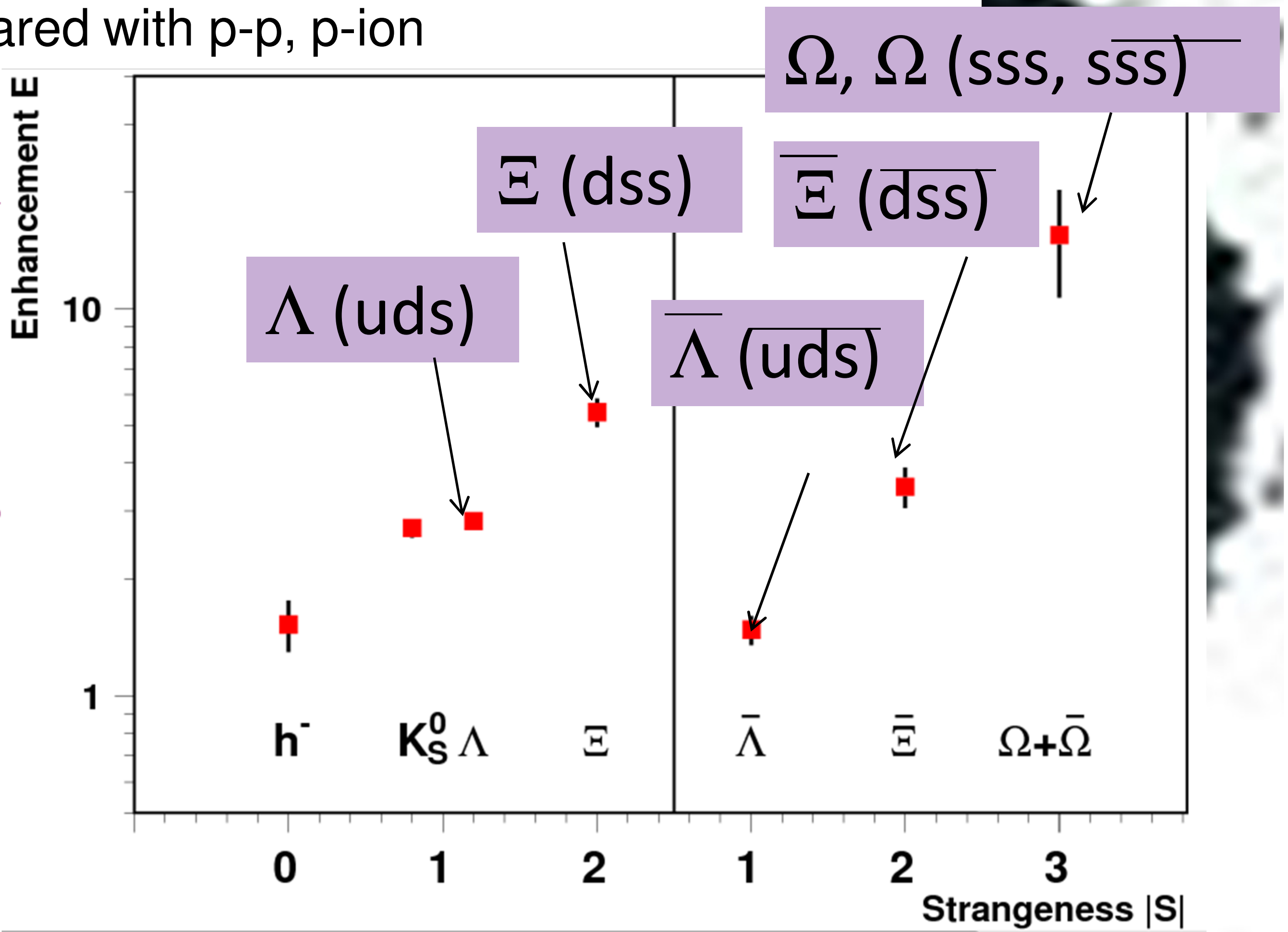
How to spot a QGP in a Heavy Ion collision

- Strangeness enhancement
- Quarkonia screening (vs enhanced heavy quark production)
- Jet Quenching (and punch-through)
- Flow (elliptic – hydro picture?)
- Chiral symmetry: resonance mass shifts?
- Hanbury Brown & Twiss: Bose Einstein enhancement of identical bosons

Strangeness

- Strangeness “enhancement” seen at SPS and RHIC in heavy ion collisions compared with p-p, p-ion

- **Heavy ion collisions**
  - Ratios of strange vs non-strange particles describes a grand-canonical ensemble in thermal equilibrium!
  - Production mechanism? Deconfined partons... quark gluon plasma? (no shortage of strangeness!)
- **p-p collisions**
  - Here, statistical description predicts suppression in p-p as “canonical” (volume?)



*Note, ϕ (SS̄) also experimentally “enhanced” in NA49 158A GeV/c S. V. Afanasiev et al., NA49 Collaboration., Phys. Lett. B 491, 59 (2000) Pb-Pb collisions with respect to p-p (as if doubly strange), NOT predicted by statistical physics

High Multiplicity: Why do we care?

- Bjorken: Energy density relation to multiplicity (number of particles produced) in collision

$$\left\langle \varepsilon(t)_B \right\rangle = \frac{1}{tA}\frac{dE_T(t)}{dy} = \frac{1}{tA}\frac{dN(t)}{dy}\left\langle m_T \right\rangle(t)$$

*excludes minijets

  – Could exceed required energy density for phase transition

  J.D. Bjorken Phys. Rev. D27 (1983) 140

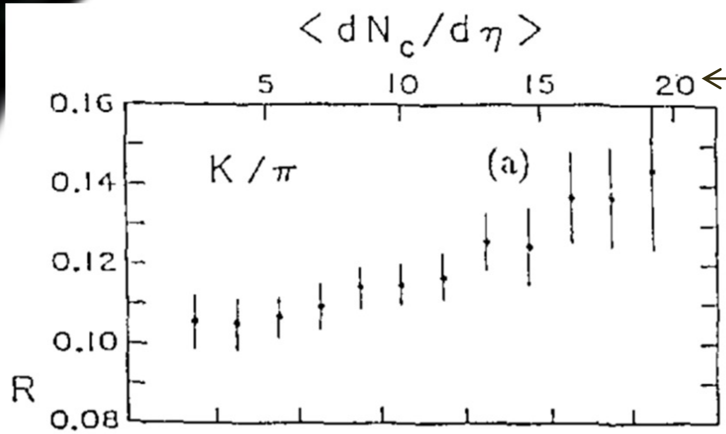
- Bjorken: First to suggest possibility of QGP in p-p collisions

  J.D. Bjorken FERMILAB-PUB-82-059-THY

- How could we probe this?

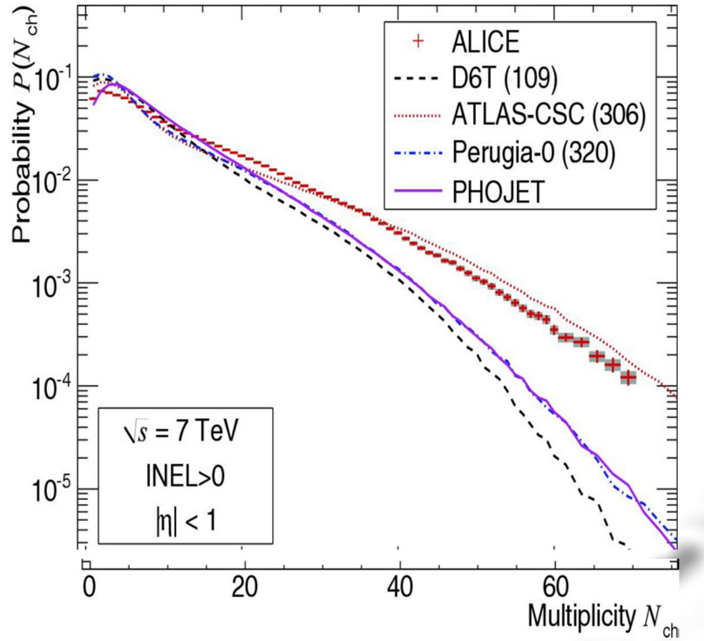
High Multiplicity: Why do we care?

- Previous measurements of strangeness ratios as a function of multiplicity have not been able to probe high enough
  - E.g. p-p at E735, Fermilab 1.8 TeV



$$\frac{dN}{d\eta} \approx 20$$

T Alexopoulos et al, Phys Lett B, 336, 599-604,1994



At LHC, 7 TeV p-p collisions reach much higher multiplicities...

$$\frac{dN}{d\eta} \approx 60$$

Translates to 5-10 GeV/fm^3, comparable to Au Au at AGS, Cu Cu at RHIC

High Multiplicity: Why do we care?

- INTERESTING QUESTIONS:
  - Can p-p collision be classed as a statistical system?
    - First guess = no – N participants = 2...
    - High gluon/sea quark density at LHC energy, estimated number of **partons ~30** for $P_T > 3$ GeV
  - Is there an “effective volume” effect? Is there some other effect causing strangeness suppression in p-p?
    - “Canonical suppression” may be less at high energy density
    - J. Rafelski: saturation in QGP may not be the same as in hadronic matter

Candidates for Analysis at High Multiplicity

Search for QGP signatures as seen in Au-Au, Cu-Cu collisions at RHIC (similar environment)

- Radial flow
- Yields e.g. Strangeness*
- Elliptic flow

Estimating diffractive fractions in p-p at ALICE

Quark Gluon Plasma*

High Multiplicity p-p at ALICE: Data Selection and Analysis Prospects (Strangeness and the Phi Resonance)

Strangeness at High Multiplicity: A Feasibility Study

- Estimated required statistics at High Multiplicity

Yields	N (Min Bias)	N (High Mult)
$\pi/K/p$	10,000	5,000
$\Lambda/\overline{\Lambda}$	200,000	50,000
ϕ	300,000	300,000
$\Xi/\overline{\Xi}$	1,500,000	500,000

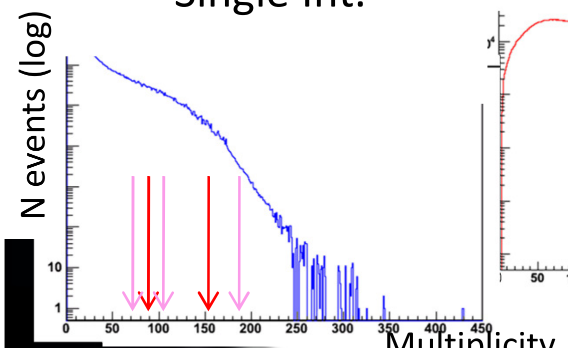
- Reasonable significance in Pt bins up to 3.5 GeV, 10% statistical error max
- Assuming only TPC information is available
- Estimated for HM = 5-7*dN/dη

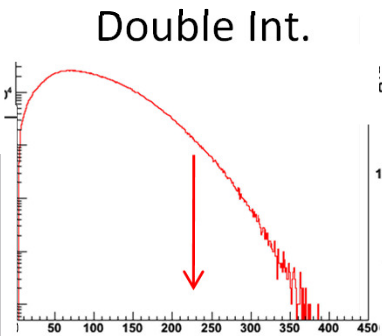
Pile-up!

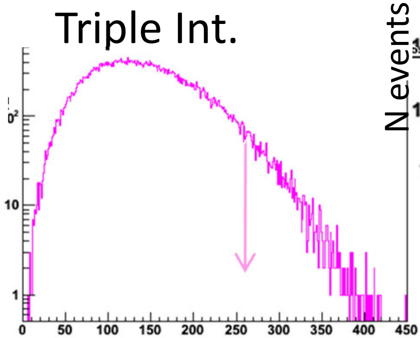
- When triggering on high multiplicity events, selecting those with multiple interactions in the same bunch crossing becomes comparatively likely
  - These events will be removed offline using a multiple vertex finding algorithm, assumed efficiency 95%*
- The probability of multiple interactions can be described by Poisson statistics using the interaction rate μ:

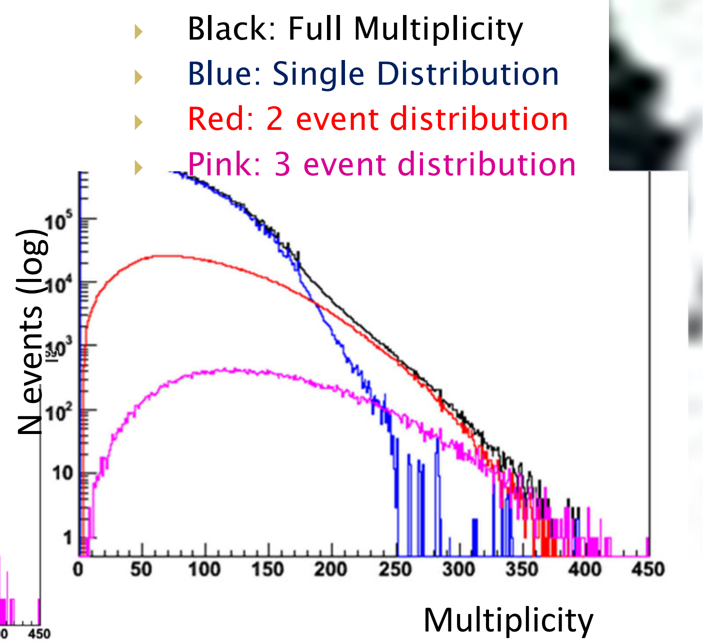
$$P(n) = \frac{\mu^n e^{-\mu}}{n!}$$

A two/three interaction distribution can be reproduced using the convolution of pairs/triplets of multiplicity using the single shape*









$$x_i = \int_0^{m'} \frac{1}{N_{events}} \frac{dN}{dm} dm$$

One can then describe the full multiplicity shape using the true single shape and Poisson statistics

Strangeness at High Multiplicity: A Feasibility Study

- Assumptions made based on 3 months "optimal running" scenario
  - 70% time dedicated to full 1 kHz MB running, 30% rare trigger time
  - Max rare trigger rate 100Hz – Assume HM max 10 Hz
- Min acceptable purity of triggered sample for single-interaction events – 5%

Yield Analyses	N (HM) Required	Max Threshold	Corresponding min dN/dη	C (*<dN/dη>)
π/K/p	5,000	255 (95% pile-up), 1 Hz	64	~8.5
Λ/Λ	50,000	236, 2.4 Hz	59	~7.8
ϕ	300,000	208, 7.2 Hz	52	~6.9
Ξ/Ξ	500,000	199, (10.6 Hz)	50	~6.6

*for <dN/dη> ~7.5

"Have an aim in life - then don't forget to pull the trigger." - Anon

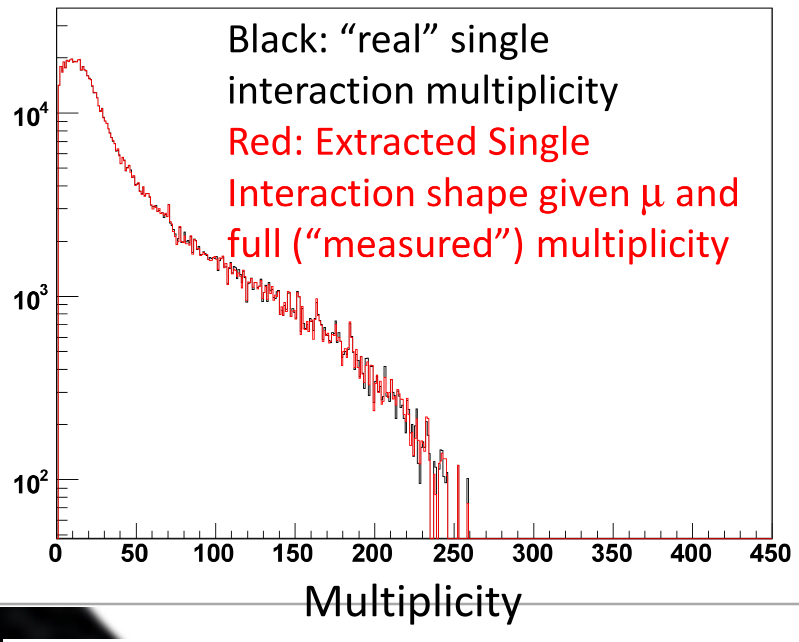
Estimating diffractive fractions in p-p at ALICE

Quark Gluon Plasma*

High Multiplicity p-p at ALICE: Data Selection and Analysis Prospects (Strangeness and the Phi Resonance)

Understanding our Background: Iterative Extraction of Single-Interaction Multiplicity

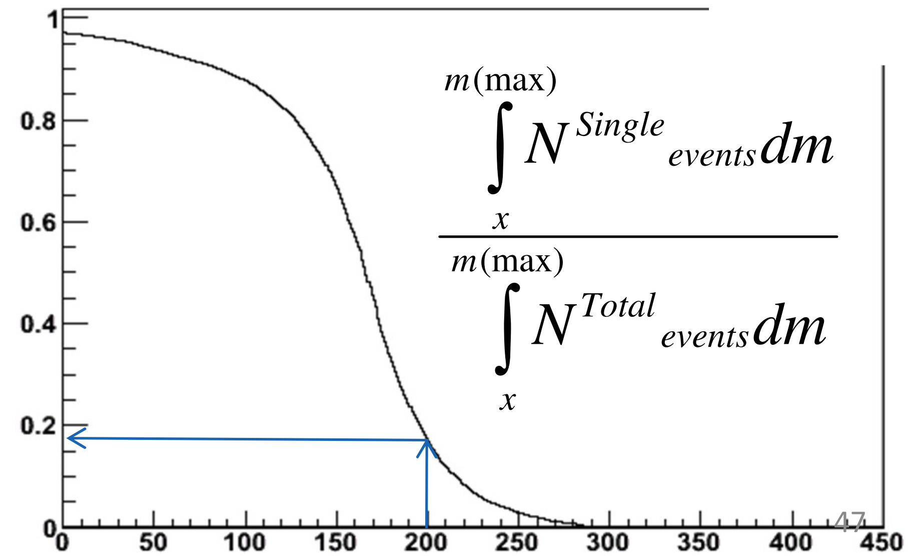
Extracted Single interaction shape using Poisson statistics and an iterative fitting method, with limit of >10 on last bin



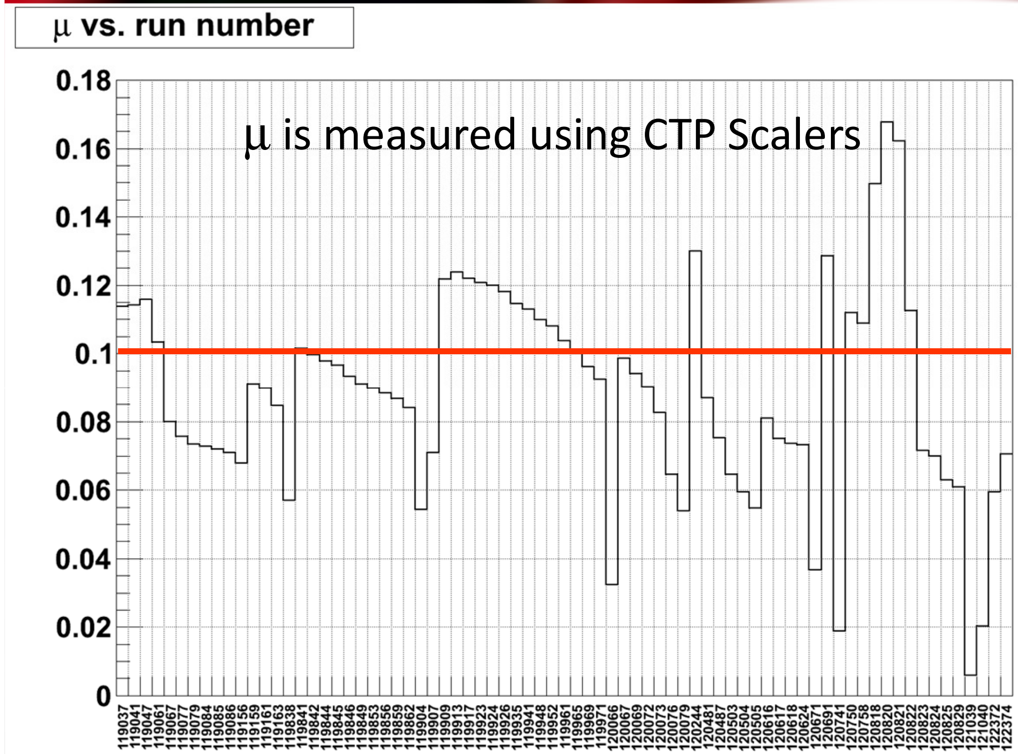
- Extracted purity provides the fraction of single events which would be kept after pile-up removal, for a given threshold

- Iterative method of extracting the single shape
  - Uses only full multiplicity distribution and interaction rate μ
  - Estimates pile-up shape and removes from full distribution
  - This converges to true single shape
- Can now see where pile-up becomes a problem for HM trigger

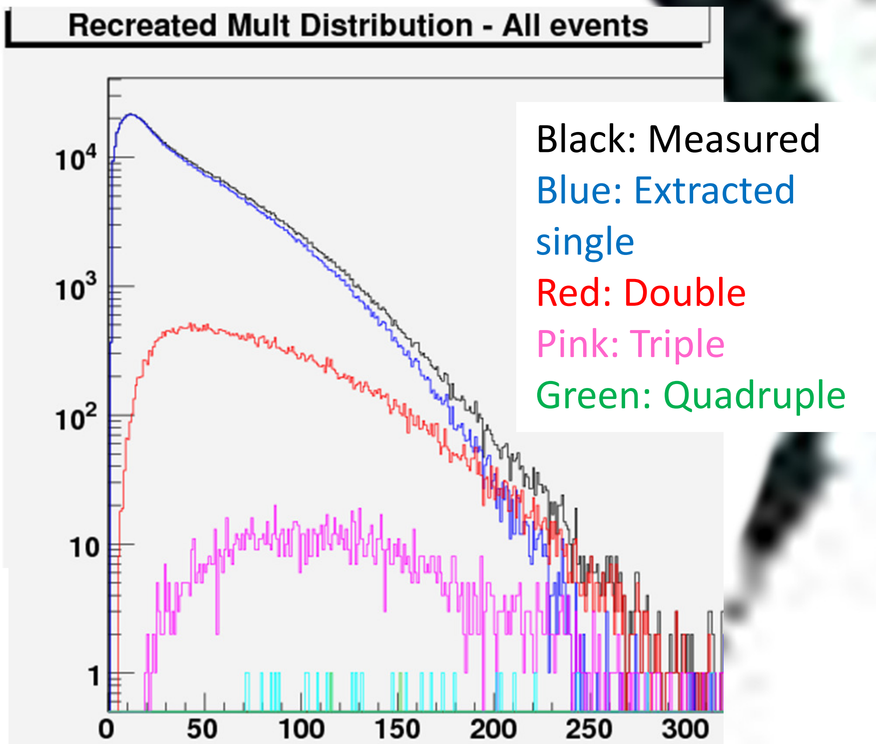
Purity: N Single events remaining/total remaining



Iterative Extraction of Single-Interaction Multiplicity: Real data



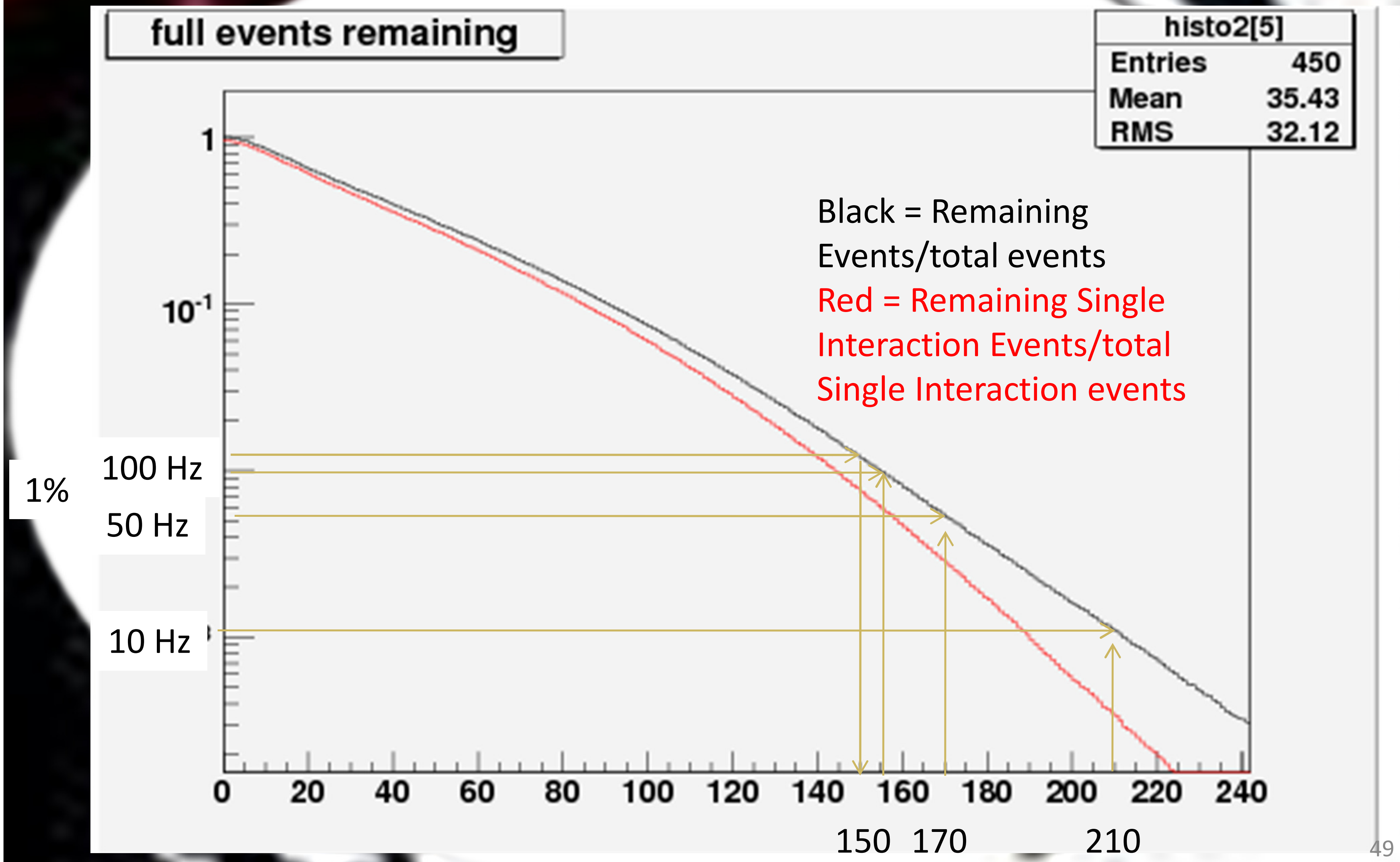
Counters at high multiplicity allow for an approximation to the tail shape



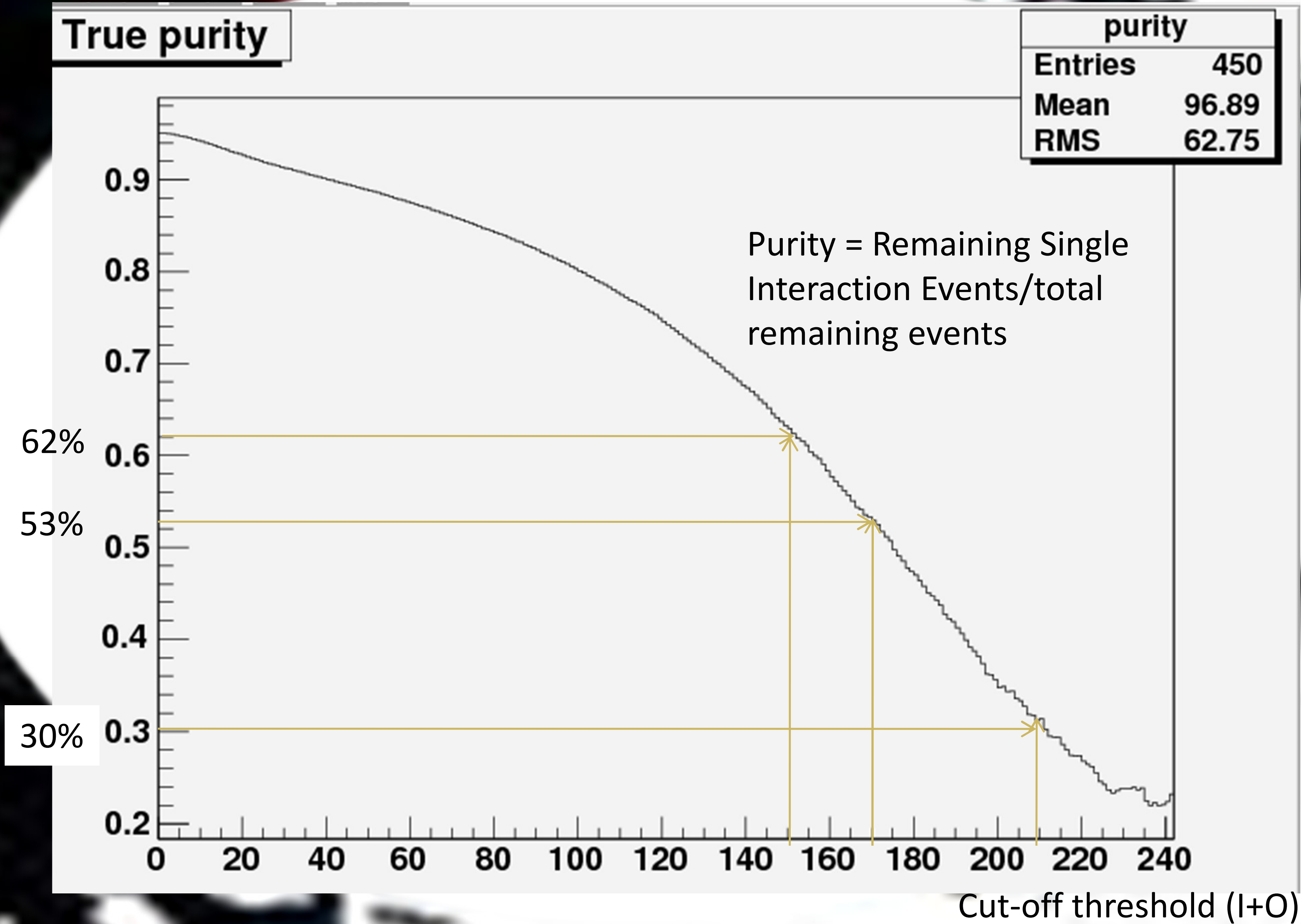
Inner+Outer multiplicity

Measured pixel chip multiplicity (inner + outer) is used to extract single and pile-up interaction shapes. As a function of multiplicity, this information tells us about the rate and purity of a sample for a given threshold

Fraction of rate as function of cut off



Understanding our Background: Purity



Threshold for High Multiplicity Data-Taking

Threshold depends on maximum rate for rare trigger (avoid downscaling), purity fraction and whether threshold is useful for physics

		Threshold (fired chips)		
Rate (Hz)	Fraction (%)	Inner + Outer	Outer	Purity (%)
100	**1.114**	**150**	**73**	**63**
	1	155	76	60
50	0.557	170	81	55
10	0.1111	210	103	32

Early look at minimum bias HM data already showing signs of interest: see QM11...

There might be 1 finger on the trigger, but there will be 15 fingers on the safety catch
- Harold MacMillan

Further Work and Things to Consider

High Multiplicity

- REMOVAL of pileup was assumed to be 95% but is still needed to be tuned
- Method works by identifying extra vertices: dependent on multiplicity and separation of vertices
- Efficiency improves with higher multiplicity
- Arvinder Palaha of University of Birmingham has done this – close to 100% pure!
- PID is available from TPC but combining this with other PID detectors effectively is still being tuned
- Plamen Petrov of University of Birmingham is working on this

Further Work and Things to Consider

High Multiplicity

- Analysis issues:
- Minijets? How can we remove these/estimate their contribution?
- Impact parameter/centrality?
- p-p 2 Particle Correlations?
  - Patrick, Lee Barnby, Roman Lietava?

Further Work and Things to Consider

Diffraction

- Improvement in data/simulation?
- Upgrades to ALICE?
- Rapidity gap measurements
- TOTEM data

Thanks for your time.....

....Questions?