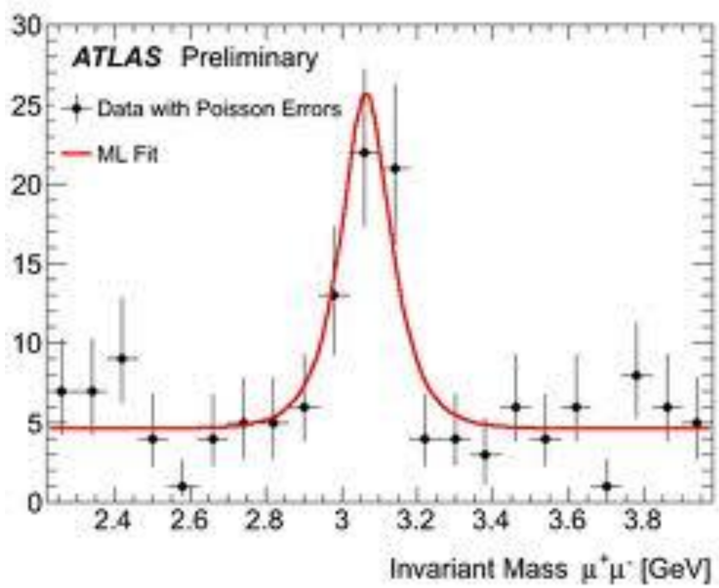
# Resonance Formation

- $\pi^0 \rightarrow 2\,\gamma$; $J/\psi \rightarrow \ell^+\ell^-$; $D^0 \rightarrow K^-\pi^+$; $D^- \rightarrow K^-\pi^+\pi^-$
  - combinatorial background
  - a peak sitting on the background



- Need to know the number, SIGNAL
- Some need-to-know issues:
  - Construct an **invariant mass** of $\gamma\gamma$, $\ell^+\ell^-$, or $K\pi(\pi)$

| No. of $\pi^0$ | No. of $\gamma$ | No. of $2\gamma$ pairs | No. of $2\gamma$ pairs with invariant mass of $\pi^0$ |
|---|---|---|---|
| 1 | 2 | 1 | 1 |
| 2 | 4 | 6 | 2 |
| 5 | 10 | 45 | 5 |
| 10 | 20 | 190 | 10 |
| 50 | 100 | 4950 | 50 |
| 100 | 200 | 19900 | 100 |

What range of invariant mass; BKG for ‘rare’ particles

# Some Need-to-Know Issues

- Particle detection efficiency (and acceptance)
- Track id
  - Known only with a certain probability, depending upon cuts
- Track momentum
  - Momentum dependent resolution

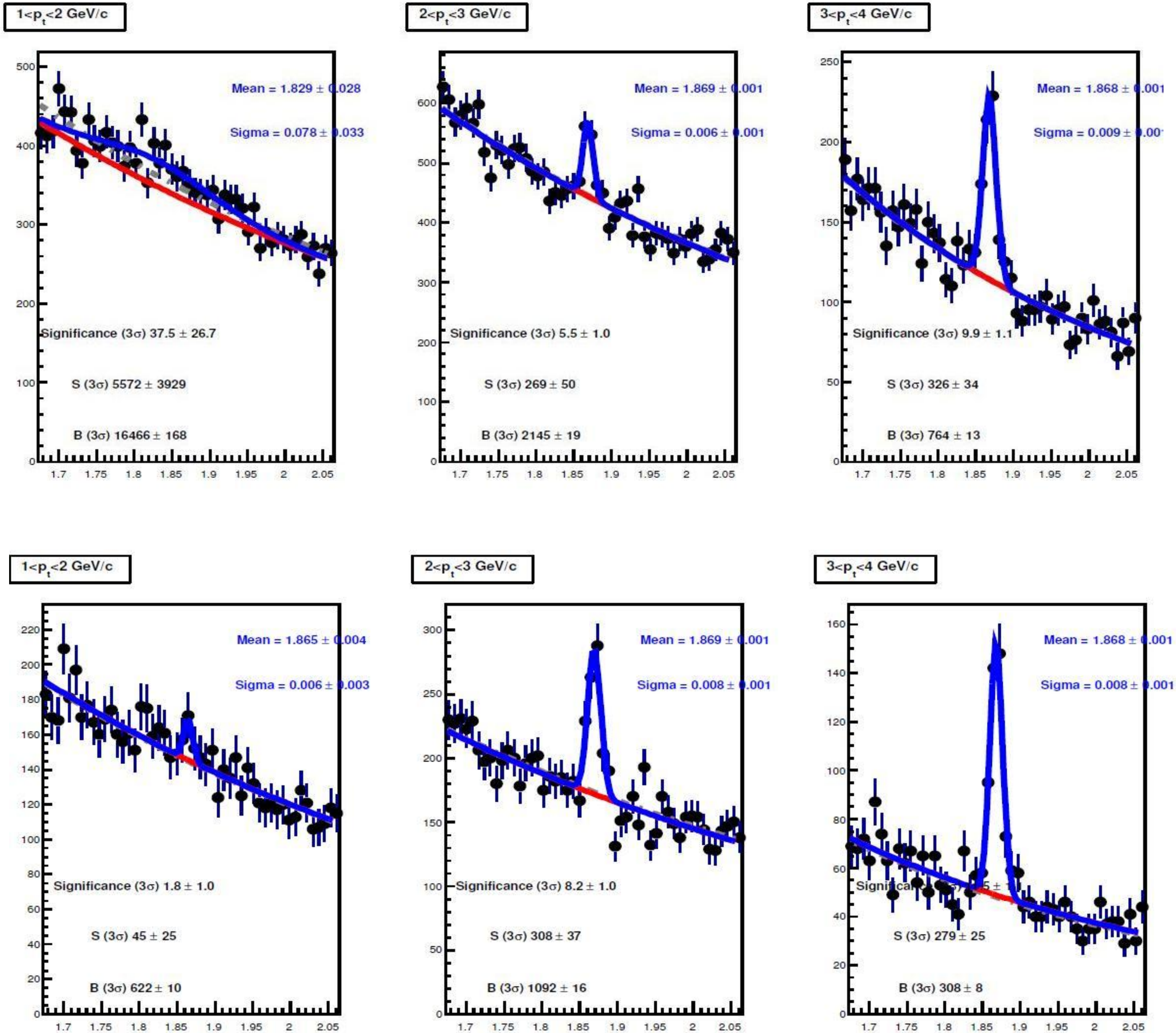
- Need to know the Signal S: (say number of D-mesons)
- Continuous combinatorial background B
- Find Significance $\mathcal{S} = S/\sqrt{(S+B)}$

- How do we do this?
  - choice of mass region?
- The width of the resonance peak primarily due to the experimental resolution.

- Significance (pentaquark)

  S = 60, B = 68 events

  S is 5.3 std. deviation away




$D \to K\pi\pi$ in pp at $\sqrt{s}$ = 7 TeV. Bottom panels use strict PID for particles with $p_T < 2$ GeV/c. Gain Significance but increase systematic error(s).

(Ph.D. thesis (ALICE) Giacomo Ortona at Turin University

- Know the background
  - Region away from the peak
    - Polynomial
    - Exponential
    - Sum of the two
- Fit the combined data to bkg + Gaussian
- Extract signal and bkg

- Functions other than Gaussian also …….

- J/ψ resonance

  $\rightarrow \ell^+\ell^-$ Invariant mass spectra of pairs

- Combinatorial bkg in unlike sign pairs
- Like sign pairs (should) produce a similar bkg
- Normalise the bkg in region away from signal
  - Normalisation of the bkg: (counting numbers)
  - What if different efficiencies/acceptance for different charges
- Kinematic cuts to improve the signal

- Total yield can be obtained by correcting the measured yield for
  - efficiency, acceptance, branching ratio
- Obtain cross section

- Use the method of maximum of likelihood
- Signal and Background are two parameters

$$D_k = n_0 \left[ A \exp(-\frac{(x_k - x_0)^2}{2\omega^2}) + B \right]$$

$$P(N \mid D) = \frac{D^N e^{-D}}{N!}$$

$$P(N_k \mid A, B, I) = \frac{D_k^{N_k} e^{-D_k}}{N_k!} \quad \textit{in each bin}$$

PRIOR (A,B | I ) = const for A≥0 & B≥0

= 0 otherwise

Parameter estimation II

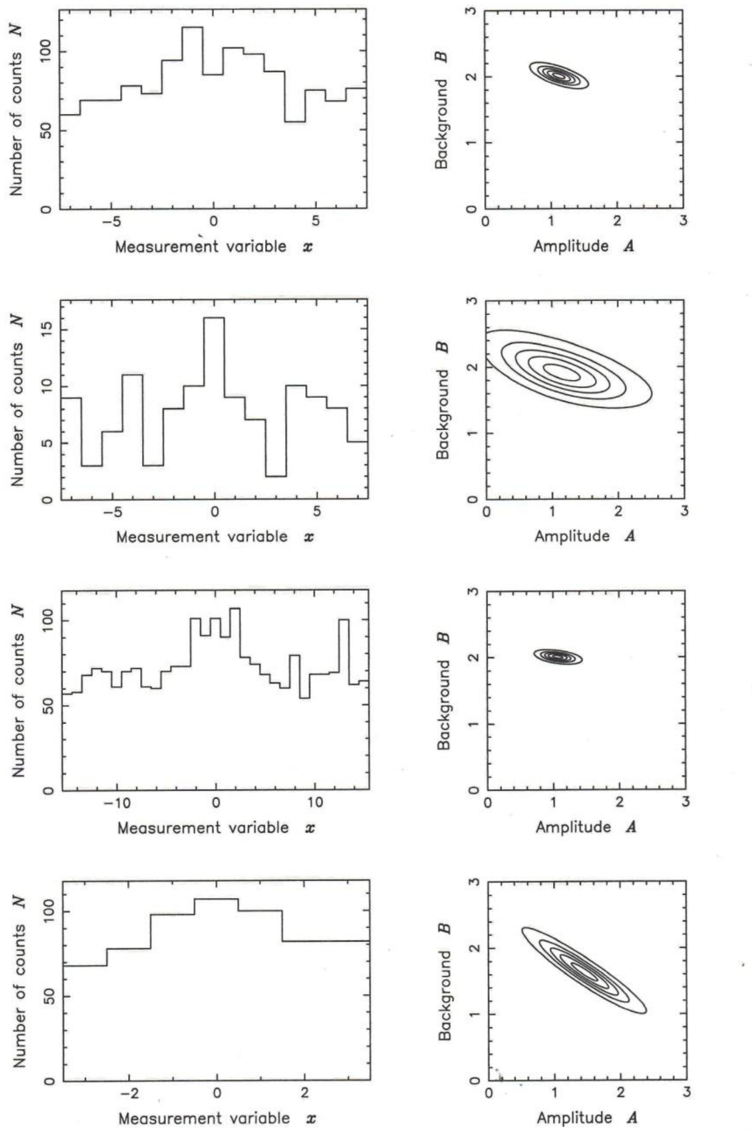



**Fig. 3.3** Poisson data and the resulting posterior pdfs for the amplitude $A$ of a Gaussian signal peak, centred at the origin with a FWHM of 5 units, and the flat background $B$, for four different experimental set-ups.

(i) Data generated in the given range of x. Obtained contours for probabilities 90%, 70%, 50%, 30%, 10%.

(ii) Same as above, 1/10$^{th}$ of data. The effect of prior is seen as a cutoff at zero

(iii) Data increased to include numbers far away from the peak. Helps to determine bkg better

(iv) Data region decreased. We lose B and we lose A.

A strong correlation between signal and background.

- A result from PHENIX at RHIC(nucl-ex/0305030)
- J/ψ yield measured in

  → $e^+e^-$ channel
- Measure no. of opposite sign pairs
- Measure no. of like sign pairs
- Shape and yield of mass distributions are well reproduced by event mixing methods.
  - Mostly uncorrelated (Dalitz decay, photon conversion, semi-leptonic decays…..)

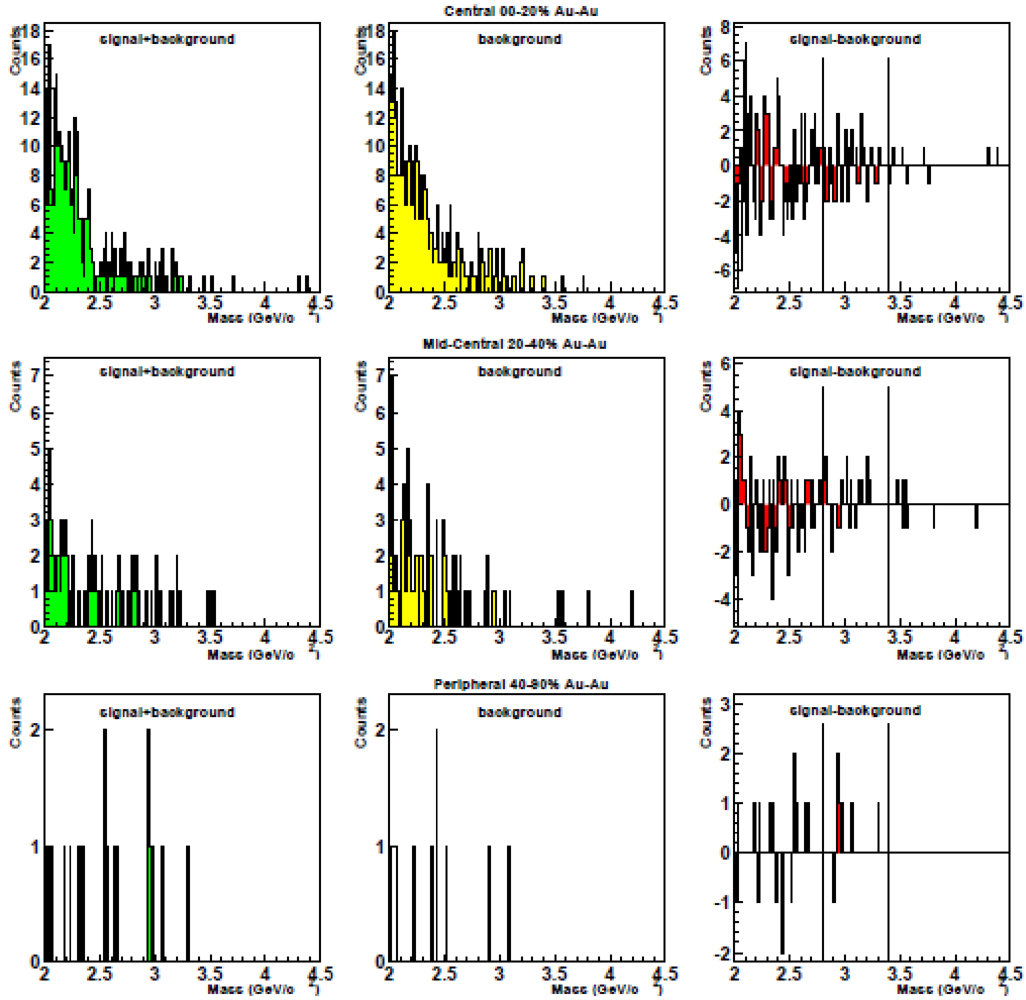



FIG. 1: (Color online) Dielectron invariant mass distribution in Au-Au reactions (top row: most central, 0-20% central, middle row: mid-central, 20-40% central, and bottom row: peripheral, 40-90% central) for unlike sign pairs containing signal+background (left column), like sign pairs containing only background (center column) and the subtracted difference (right column).

| Centrality | Unlike Sign Counts | Like Sign Counts | Most Likely Signal | 90% C.L. |
|---|---|---|---|---|
| 00-20% | 33 | 41 | 0 | 9.9 |
| 20-40% | 16 | 8 | $8^{+4.8}_{-4.1}$ | 14.4 |
| 40-90% | 7 | 2 | $5^{+3.1}_{-2.6}$ | 9.3 |

$$L(\nu_l, \nu_u) = \frac{\nu_l^{\;N_l} e^{-N_l}}{N_l!} \frac{\nu_u^{\;N_u} e^{-N_u}}{N_u!}$$

$$L(\nu_s) = \int_0^\infty \int_0^\infty L(\nu_l, \nu_s)\delta(\nu_s - \nu_u + \nu_l) d\nu_l d\nu_u$$

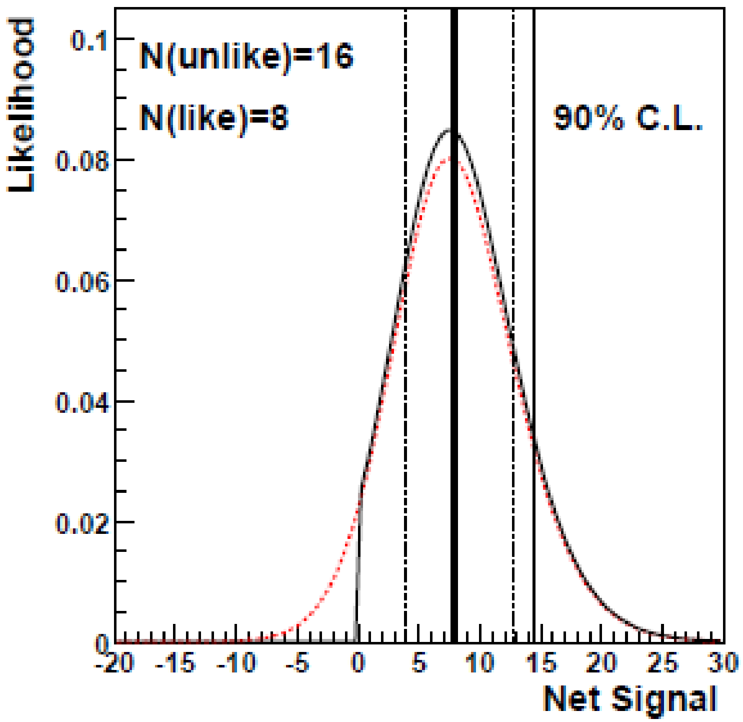



FIG. 2: (Color online) The Poisson statistical likelihood distribution as a function of the expected net signal. The distributions are for the mid-central case of $N_{unlike}$=16 and $N_{like}$=8. The dashed curve is the likelihood distribution, and the black is after eliminating the unphysical net signal less than zero and re-normalizing. Vertical lines are shown to indicate the most likely value (8), the 68% confidence interval values, and the 90% confidence level upper limit.

20-40% centrality
68% confidence interval
90% confidence limit

plus ultra………