Measurement of the pp inelastic cross section using pile-up events

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On behalf of the CMS experiment

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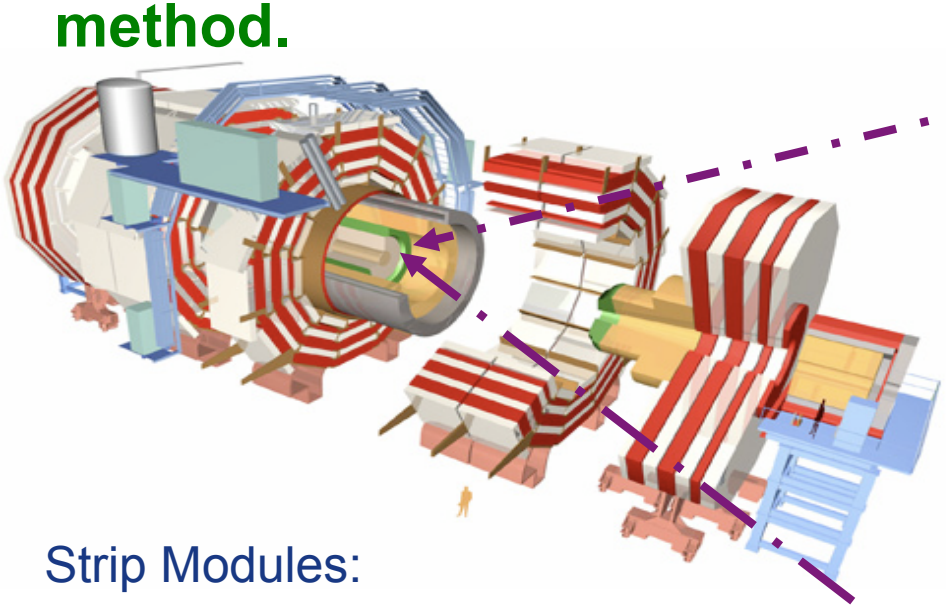
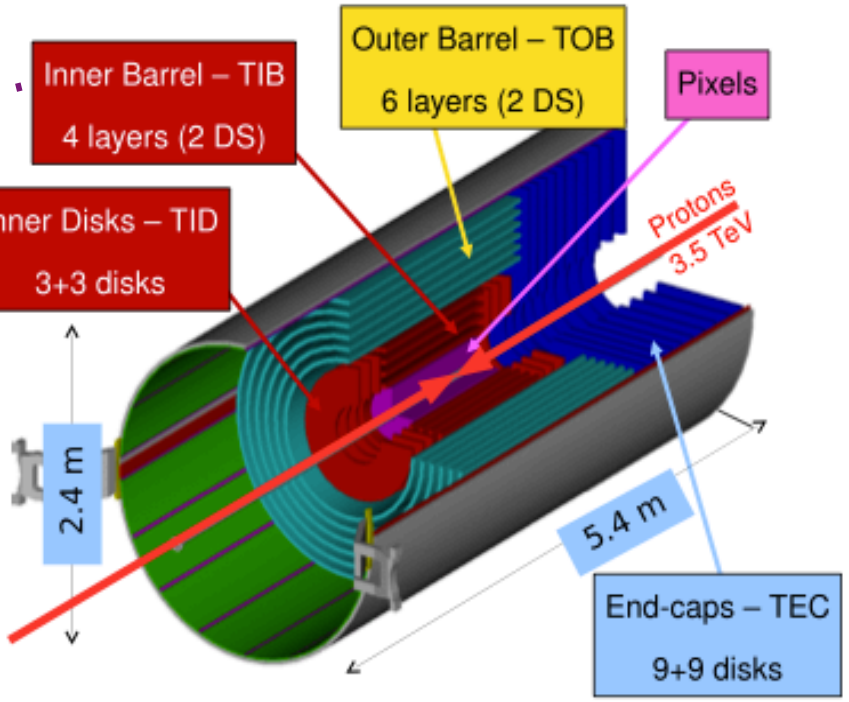
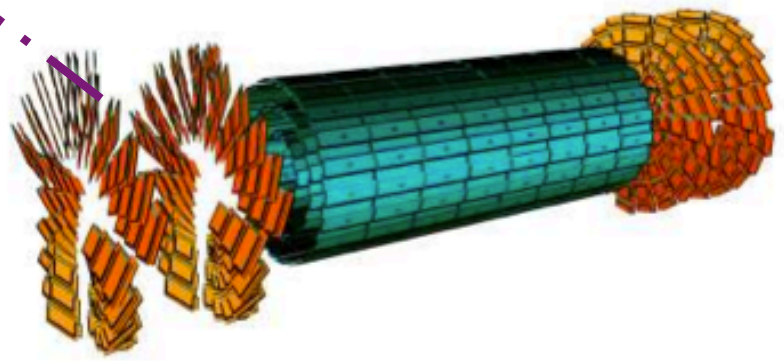
CMS Detector

This analysis has made an extensive use of the CMS tracker system: its excellent spatial resolution plays a key role in this method.





- Strip Modules:
  - 15148 modules (pitch 80-205 μm)
  - Single point resolution 20-60 μm
- Pixel modules:
  - 1440 pixel detectors
  - 100(r) x 150(z) μm^2
  - σ= 9 μm along r
  - σ= 20 μm along z



Basic Concepts

- **We measure the inelastic pp cross section using pile-up (PU) events:**

The probability of having n_{pileup} depends on the total σ(pp) cross section.

$$P(n_{pileup}) = \frac{(L\cdot\sigma)^{n_{pileup}}}{n_{pileup}!}\cdot e^{-(L\cdot\sigma)}$$

- **The pile-up depends on the "Luminosity per bunch crossing (L_{bx})": max. during 2010 = ~0.6 10^{30} cm^{-2} s^{-1}**
  → Cross checked using the number of triggers in each bunch ($L * \sigma = N_{events}$)

- **Pile up events are recorded by a high efficient stable trigger (e.g. Double ee, pt > 10GeV)**

- **The goal of the analysis is to count the number of vertexes as a function of luminosity**

Vertex Definition

- **We select PU event large enough to make a vertex:**
  - **We count vertexes requiring at least 3 tracks with $|\eta|<2.4$ && $p_t>$ 200 MeV**
  - **Each track should have at least 2 pixel hits && 5 Strip hits**

- **We define "real" those vertexes generated in pp scattering and "fake" those created by other mechanisms. Fake come mostly from:**
  - **Real secondary vertexes (i.e. generated by long lived particles)**
  - **Split secondary vertexes (i.e generated by the vertex algorithm splitting a single vertex in two)**

Fake vertexes have been studied with Pythia generated without PU (i.e. at most one interaction -> secondary vertex is fake by definition)

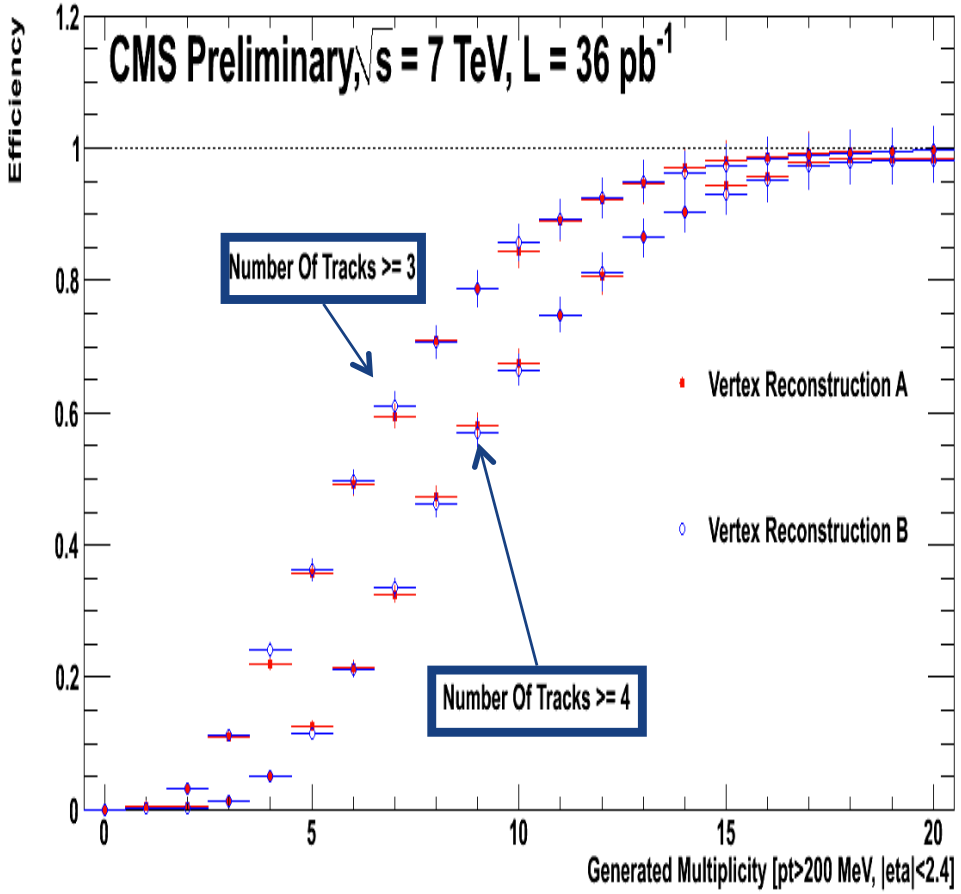
Fake vertexes rate ~ $1.5\ 10^{-3}$

Vertex Reconstruction Efficiency

- Using a full GEANT simulation of the tracker detector we studied the vertex reconstruction efficiency.

- The most important parameter is the vertex multiplicity: vertexes with < 17 tracks are not always reconstructed

- The algorithm reconstructs vertexes separated by more than 0.06 mm.
  The "blind distance" is largely independent of the number of tracks in the vertexes.



Need to correct the PU distribution for the missing fraction of events at low multiplicity and for vertex merging

Unfolding Method

The visible number of vertexes needs to be corrected to obtain the "real" number. This is done in luminosity bins (14).

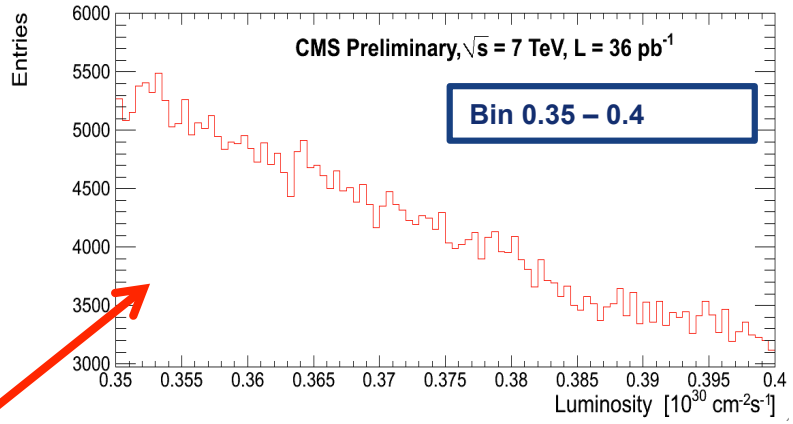
An unfolding technique is used, according to the following steps:

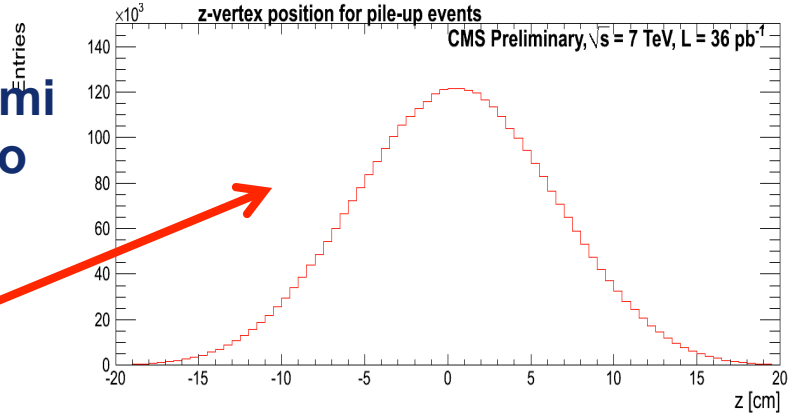
1) Generate the "true" vertex distribution in luminosity bins (convolution of measured lumi + poisson). Use the true vertex distribution to generate events with n vertexes

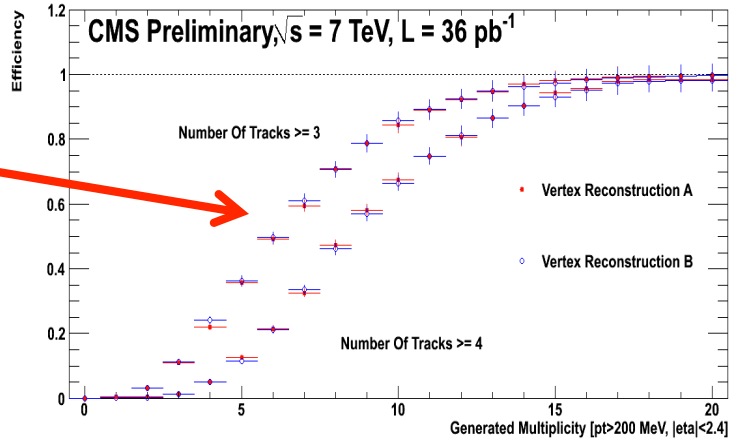
2) Assign to each of the generated vertex a multiplicity and a position in z according to the data distribution

3) For vertexes with low multiplicity decides whether or not they are selected. Vertexes closer together than 0.06 cm are merged

4) Fill the calculated "visible" distribution

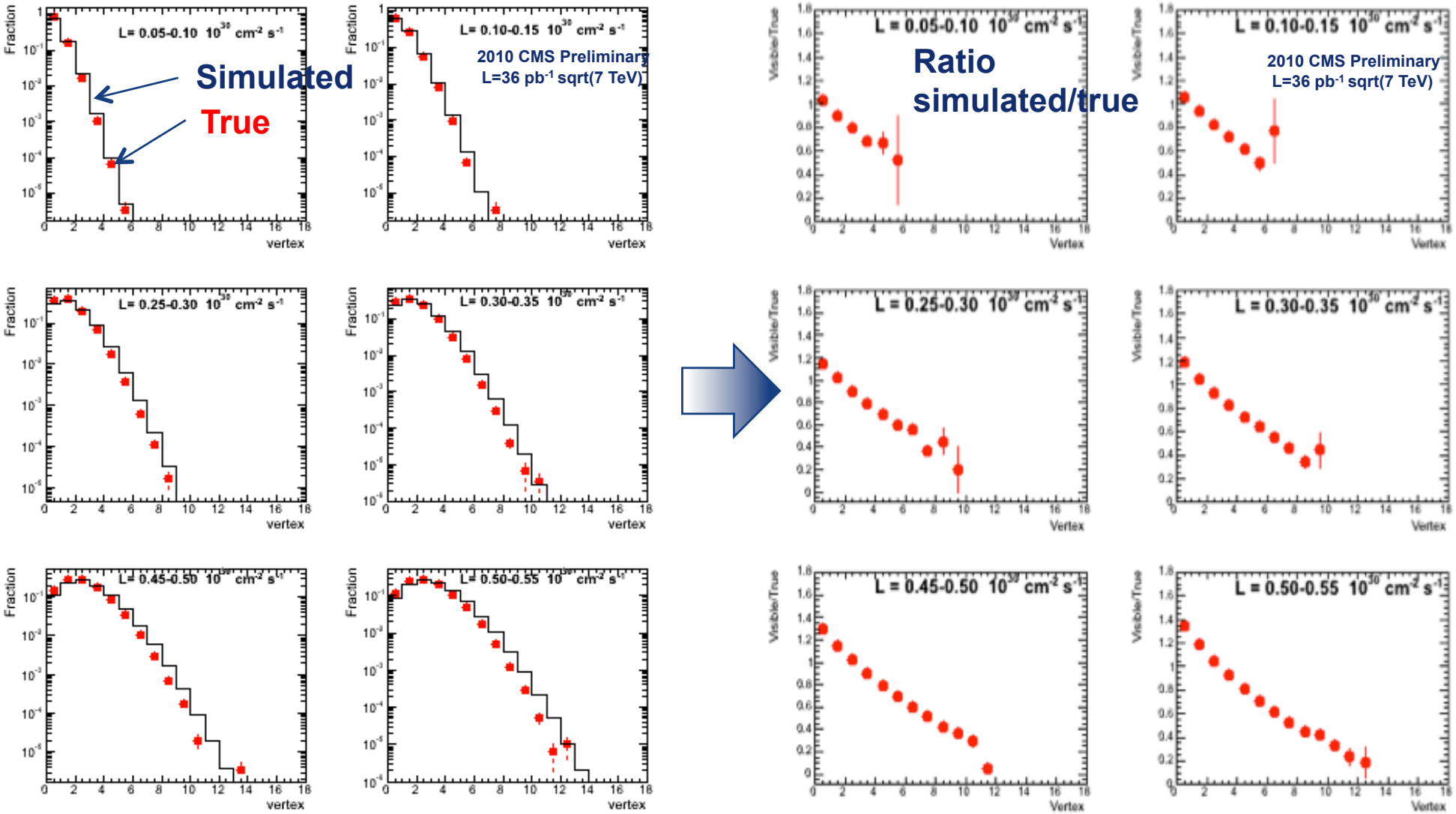






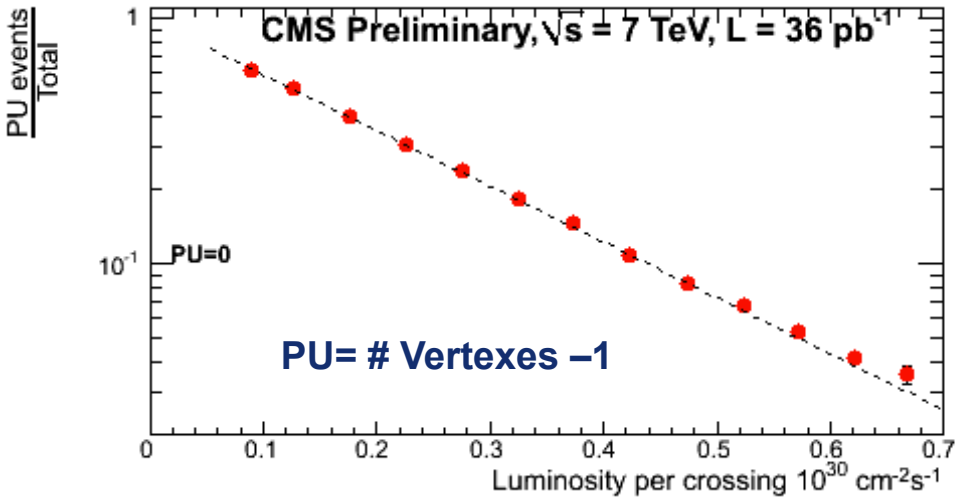
Generate a migration matrix

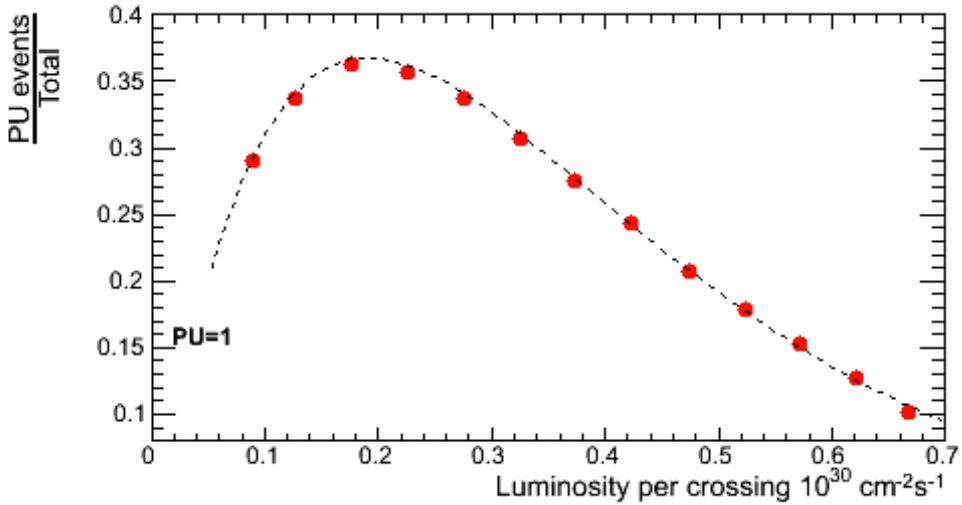
The simulation produces a set of "corrections" that we need to apply to the reconstructed vertex distributions

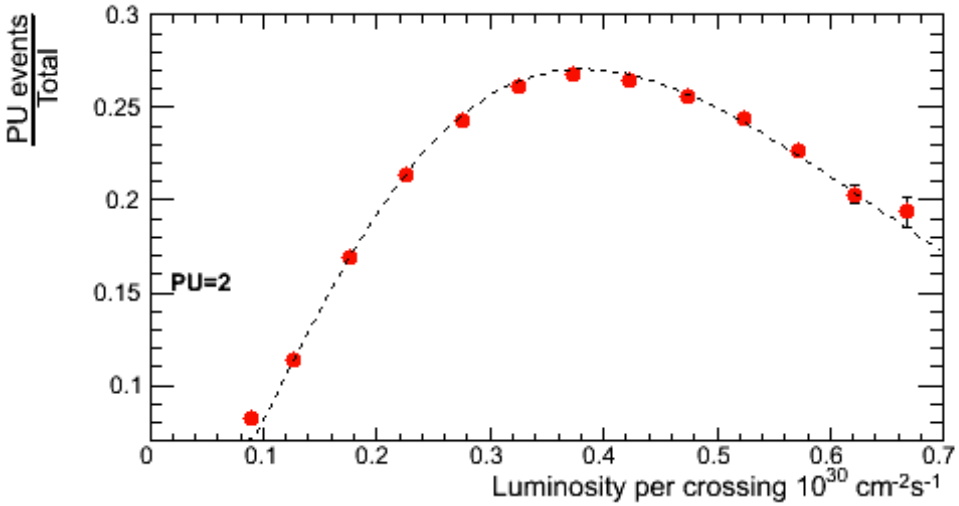


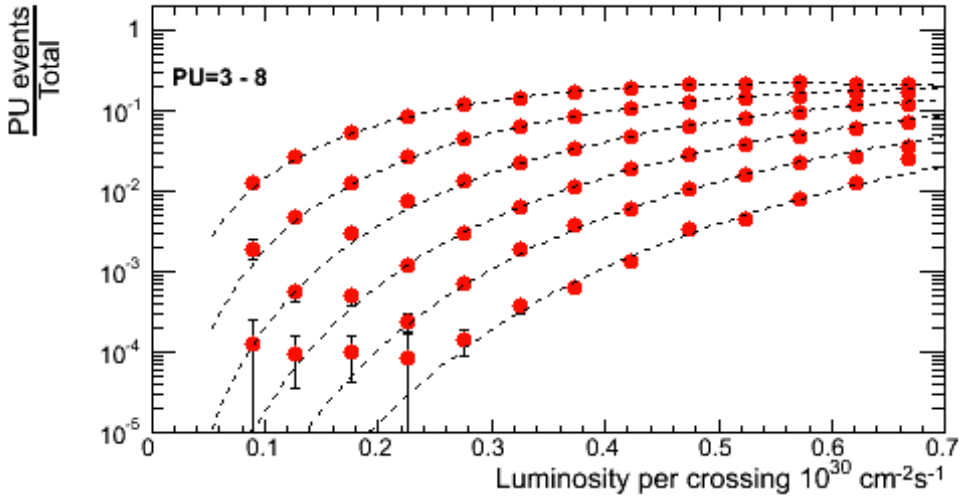
Result - fits

Using the correction functions, we unfold the measured vertex distributions to obtain the correct distributions which we fit with a Poisson function:

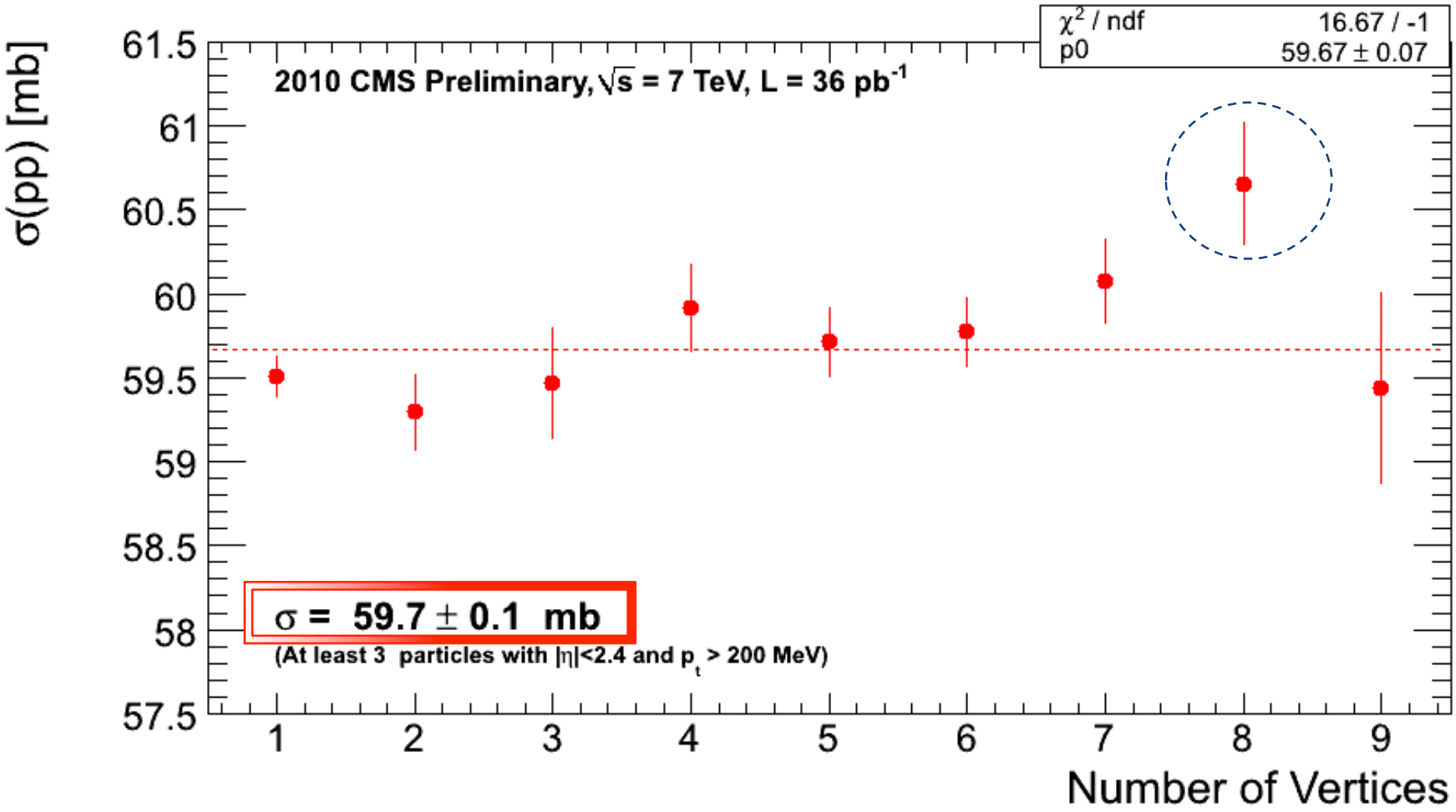








Results - Cross section



For each of the PU distribution we obtain a value of the cross section and then these 9 values are averaged

Systematic Checks

- We have performed 2 types of systematic checks:
  - **Variation of the luminosity values (±4%)**
  - **Modification of some of the analysis parameters**

Luminosity	$\Delta\sigma_{vtx}$
Scale the luminosity by +4%	-2.3
Scale the luminosity by -4%	+2.4

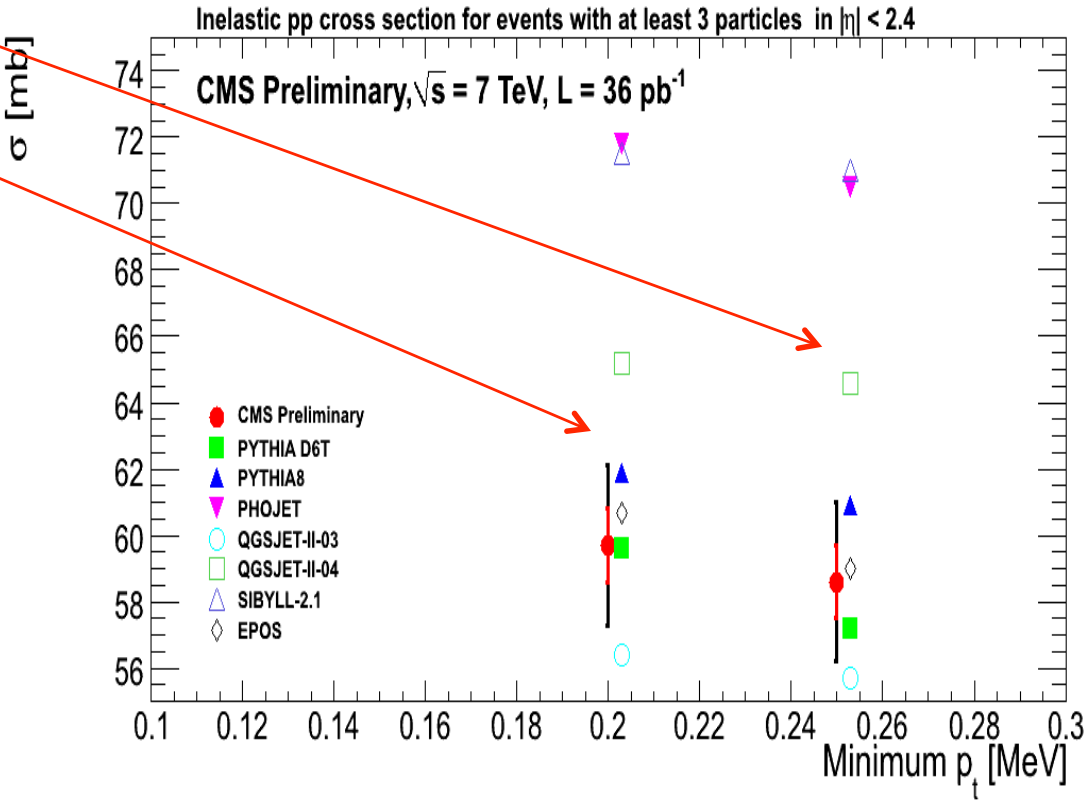
Analysis parameters	$\Delta\sigma_{vtx}$
Perform Analysis on a different dataset	+0.9
Change the fit upper limit from 0.6 to 0.5 $\cdot 10^{30} cm^{-2} s^{-1}$	0.3
Change the fit lower limit from 0.05 to 0.15 $\cdot 10^{30} cm^{-2} s^{-1}$: $\Delta\sigma_{vtx} = -0.3$	-0.3
Reduce the z-vertex range from 20 to 10 cm	-0.1
Change the ε correction by 2%	-0.4
Change the ε correction by -2%	0.3
Impose the minimum distance of ±1mm between two vertices	0.1

$$\sigma_{vtx} = 59.7 \pm 0.1(Stat) \pm 1.1(Syst) \pm 2.4(Lumi)\ mb$$

Comparison with models and estrapolation

N_{trk} Pt (MeV)	3 200	4 200	3 250	4 250	σ_{tot}
CMS	59.7	58.6	58.9	57.3	
Pythia 6 DW-Pro	59.4	57.2	58.2	55.8	71.4
" D6T	59.6	57.2	58.7	55.7	71.4
" ProPT0	59.4	56.8	57.8	54.7	71.4
" AMBT1	59.6	57.5	58.5	56.0	71.4
" Z1-LEP	59.9	57.8	59.0	56.4	71.4
Pythia 8	61.9	60.8	61.3	60.3	71.4
Phojet	71.8	70.5	71.2	69.8	77.52
Q-II-04	56.4	55.7	54.2	53.2	69.7
Q-II-03	65.2	64.6	63.0	62.0	77.5
SYBILL-2.1	71.5	71.0	70.2	69.3	79.6

We compare our results with several MC models evaluating their predictions for the same interval that we measure



Model	σ (mb)
Pythia 8	*69.3*
Pythia 6	*72.4*
Phojet	*65.1*
Q-II-04	*74.8*
Q-II-03	*71.8*
SIBYLL	*66.9*

The total inelastic σ can be evaluated in a MC dependent way to be within 66.9 and 74.8 mb

Conclusions

We measured the pp inelastic cross section for events with 3 or more particles, |η|<2.4, pt>200 MeV.

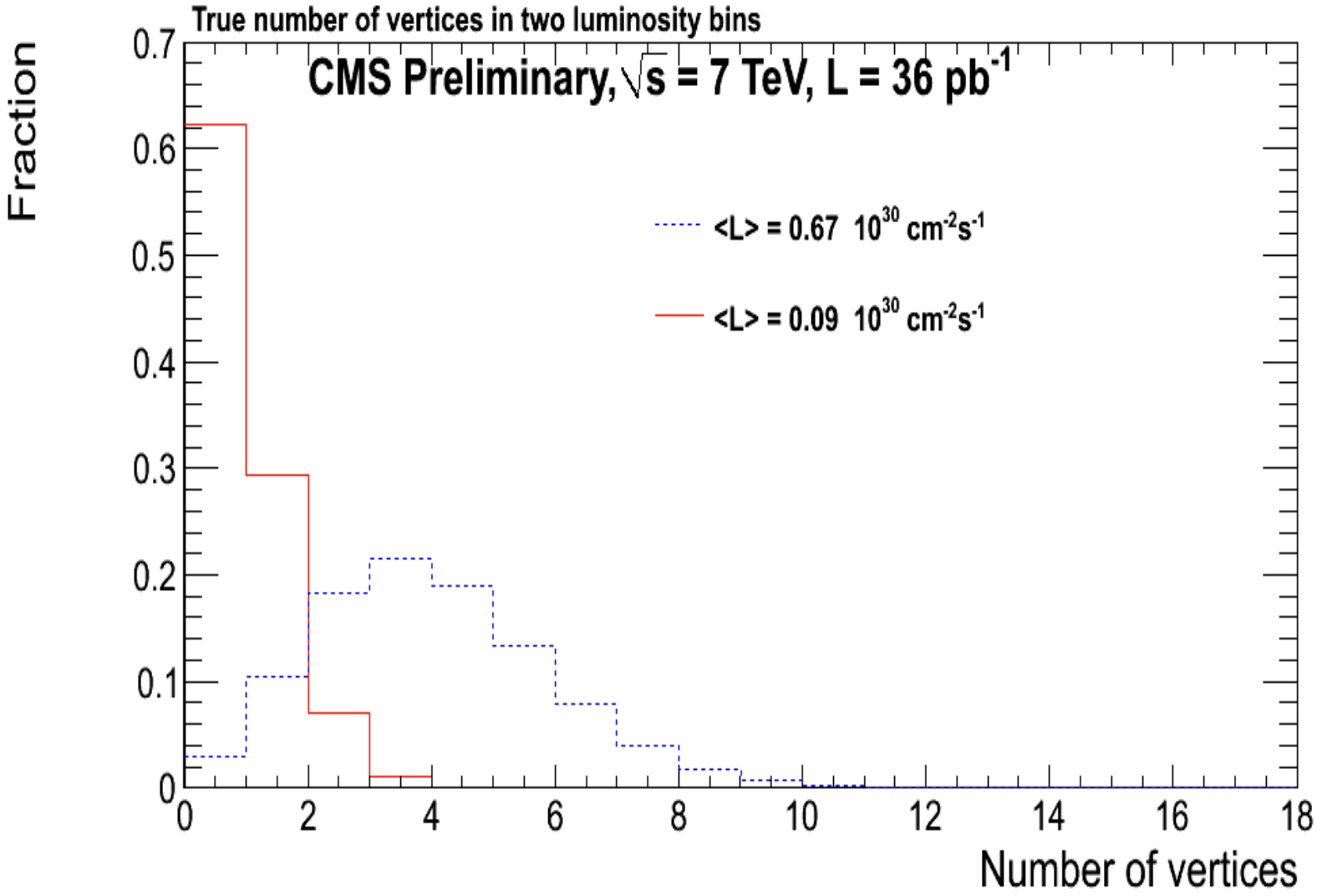
σ_{vtx} = *59.7 ± 0.1(Stat) ± 1.1(Syst) ± 2.4(Lumi) mb*

Using MC models for the extrapolation to the total inelastic cross section yields:

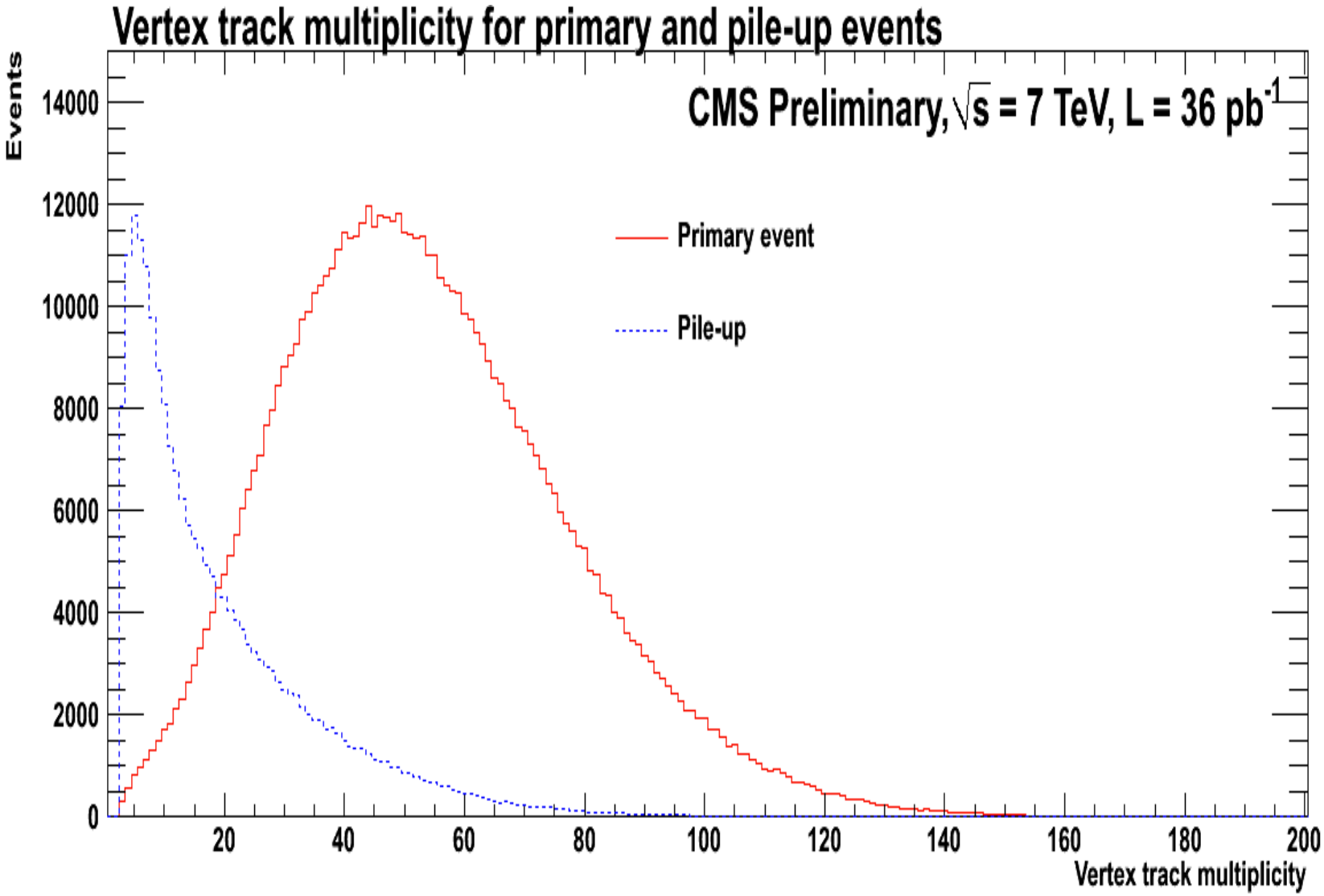
66.8 <= $\sigma_{inelastic}$ <= *74.8 mb*

Spares

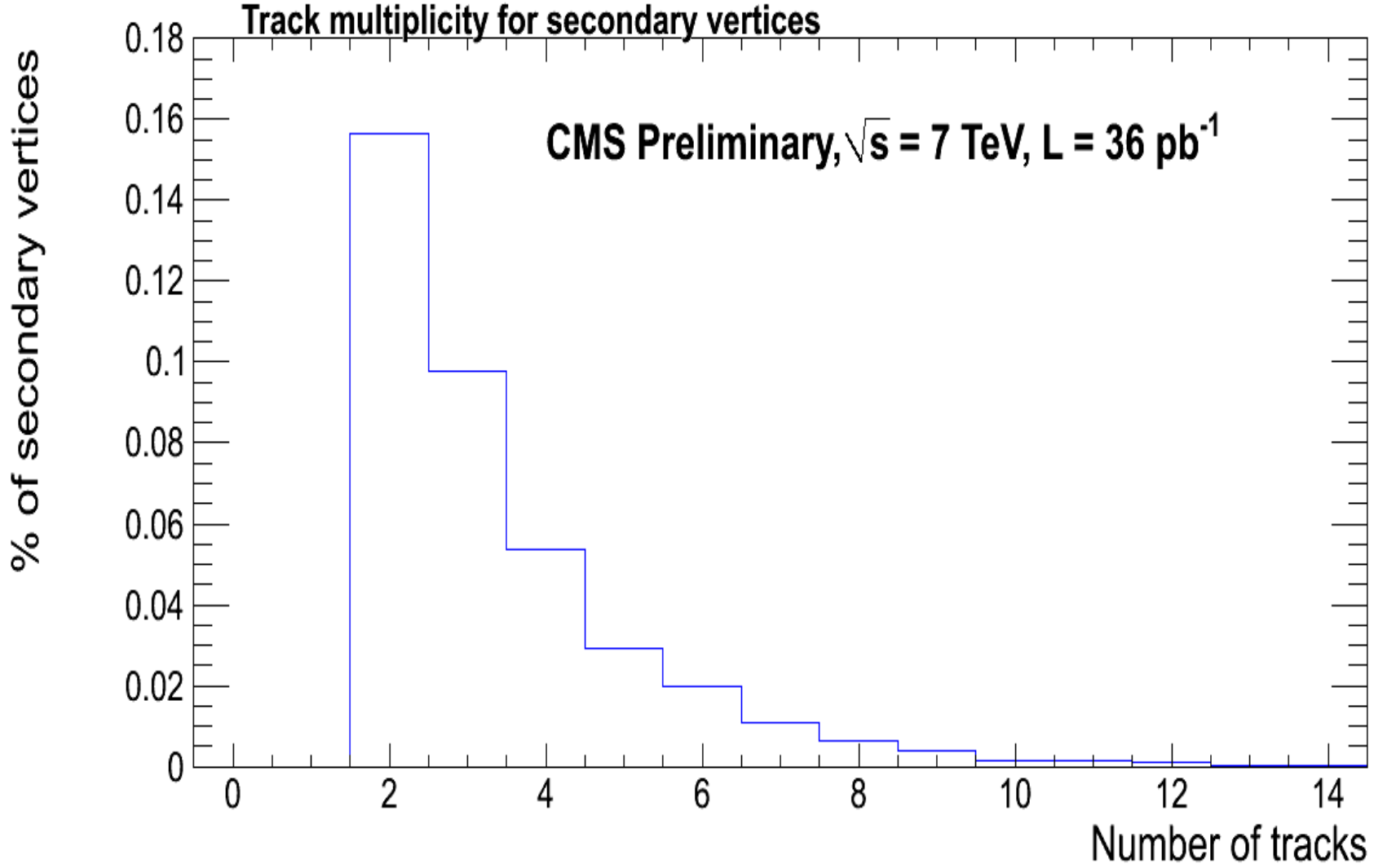
Number of vertices Vs Lumi



Vertex track Multiplicity in data



Fake Vertexes



CMS Simulation

$\sqrt{s}$ = 7 TeV, L = 36 pb^{-1}

- Predicted Visible/ True