A first look at Bose-Einstein effect in events at √s=7 TeV

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Data Samples

- The data samples used for Data and MC are the official D3PD's produced for the track-based MB analysis
- Collision data - 7 TeV:

data10_7TeV.00152166.physics_MinBias.merge.NTUP_MINBIAS.f239

- MC Sample

mc09_7TeV.105001.pythia_minbias.merge.NTUP_MINBIAS.e517_s764_s767_r1229

Total statistic data (290K), mc (455K)

- Analysis program based on PROOF: whole collision data sample processed in about 25 minutes on a 4core pc.

Events and tracks selection

Using selection for MinBias version 1.5:

https://twiki.cern.ch/twiki/bin/view/AtlasProtected/MinimumBiasEventsSelection#Event_and_Track_Selection_fo_AN1

- EVENT SELECTION:
  - L1_MBTS_1 trigger condition
  - Pile-up removal;
  - Vertex selection (at least one vtx with type==1 || 3)

After event selection: data 220k – MC 450k

- TRACK SELCTION:
  - P_t>500 MeV/c, η_{max} < 2.5, >=1 pixel hits, >= 6 SCT hits
  - Trans and Long Imp parameter w.r. to primary vtx < 1.5 mm (d0, z0)
  - Trans Imp parameter w.r. to beam spot < 4 mm

Selected tracks: data 2.1M (~9.6 tracks per event), mc 4.9M (~10.7 tracks per event).

What we study…

We study like-sign bosons (signal) produced in high energy collisions.

The hypothesis is that all tracks are pions.

We use the standard variable: $Q^2 = -(p_1-p_2)^2 = M^2 - 4m^2$

(M is the mass of the pair and m the mass of pions)

The analysis proceeds by comparing the measured distribution of Q to the one of a “reference sample” (to be discussed) where no BE effect is observed:

$$R(Q) = dN/dQ_{sig} / dN/dQ_{ref}$$

Finally in order to reduce the bias due to the construction of the reference sample the double ratio $\mathfrak{R}$ is defined:

$$\mathfrak{R} = R_{DATA}/R_{MC}$$

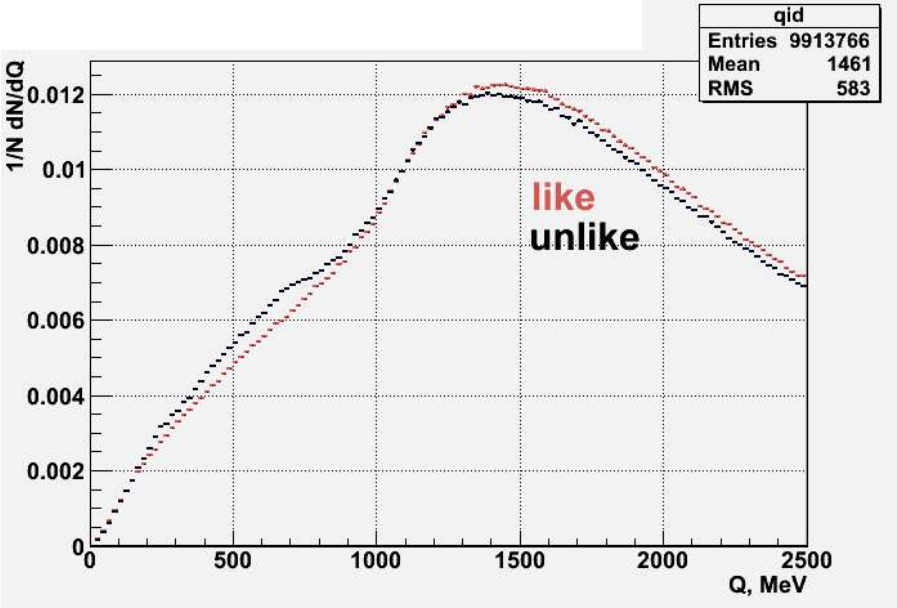
The reference sample

The reference sample should have the same distributions as the real sample but without Bose Einstein effect.

There are various possibility to define the reference sample (none is perfect…):

- **Opposite charge pairs (this is what we use in the present analysis);**
- Same charge pairs inverting p: (E,p) → (E,-p) for one track;
- Same charge pairs with p rotated in the transverse plane.

The possibility to mix tracks from different events is complicated by the fact that it is difficult to keep the correct event kinematics.

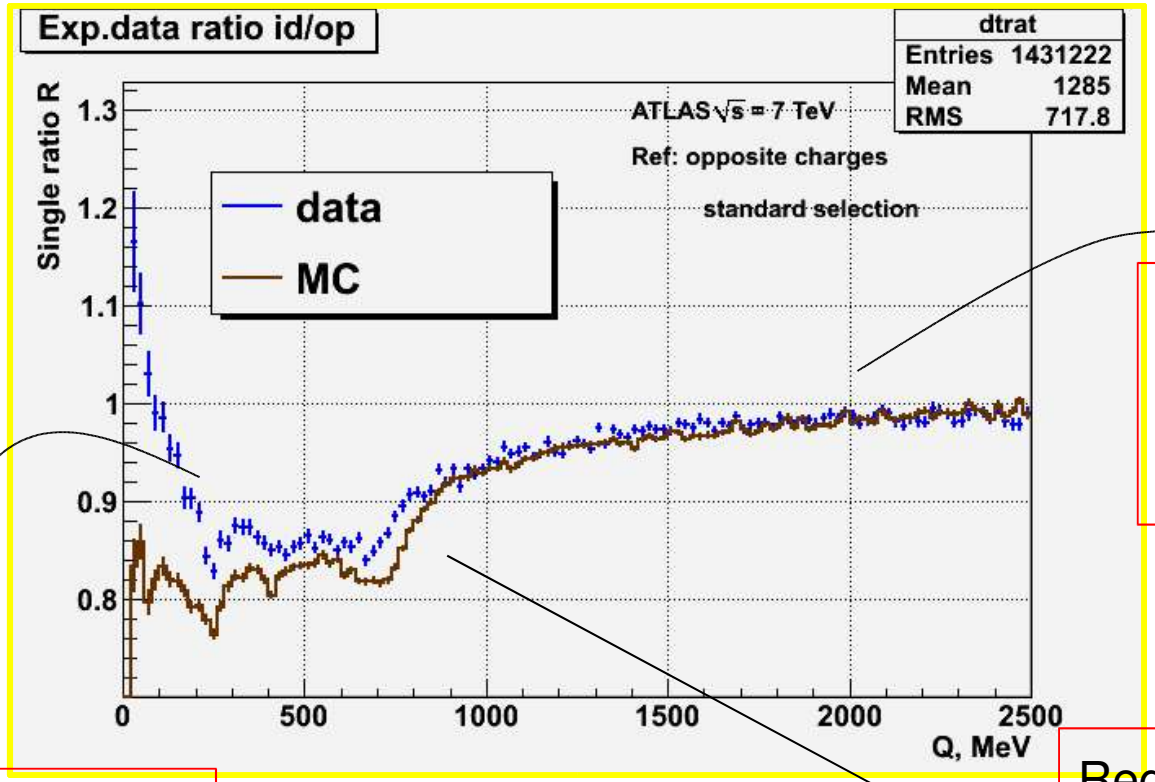


dN/dQ for unlike and like charge samples for collision data.
Distributions are normalized to 1
Enhancement at low Q is due to the correlation effect.

The inclusive single ratio R

$R(Q) = dN/dQ_{sig} / dN/dQ_{ref}$

Ref == opposite charge



High Q values correctly described by the MC.

Region where the correlation effects is observed.

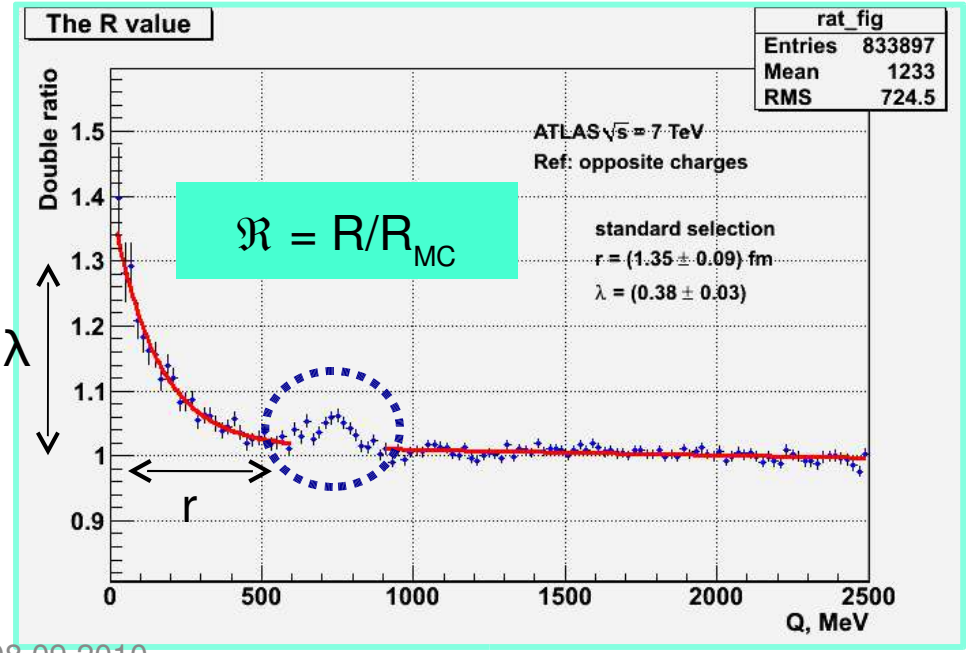
Region of light vector mesons production (ρ,η,ω). Incorrectly described by the MC (?)

The inclusive double ratio $\Re$

R is parametrized with the function:

$$R(Q) = C[1+\lambda\Omega(Qr)]\cdot(1+\delta Q)$$

$\Omega(Qr)$ represent the Fourier transfrom of the emission region of radius r and strength λ. The parameter δ allows for long range correlation.



$\Re$ is fit with the function f(Q) where
$\Omega(Qr)$ is a pure exponential:

$\Omega(Qr) = \exp(-Qr)$

as suggested by the data

The region Q=[600-900] MeV and the region Q < 20 MeV is excluded from the fit.

We do not correct for the Coulomb effect for this analysis.

RESULT:
R = (1.35 +/- 0.09) fm
λ = (0.38 +/- 0.03)

Comparison with CMS results

	r (fm)	λ
ATLAS 7 TeV	1.35+-0.09 +- ??	0.39+-0.03 +- ??
CMS 900 GeV	1.59+-0.05+-0.19	0.625+-0.021 +-0.046
CMS 2.36 TeV	1.99+-0.18+-0.24	0.663 +- 0.073 +- 0.048

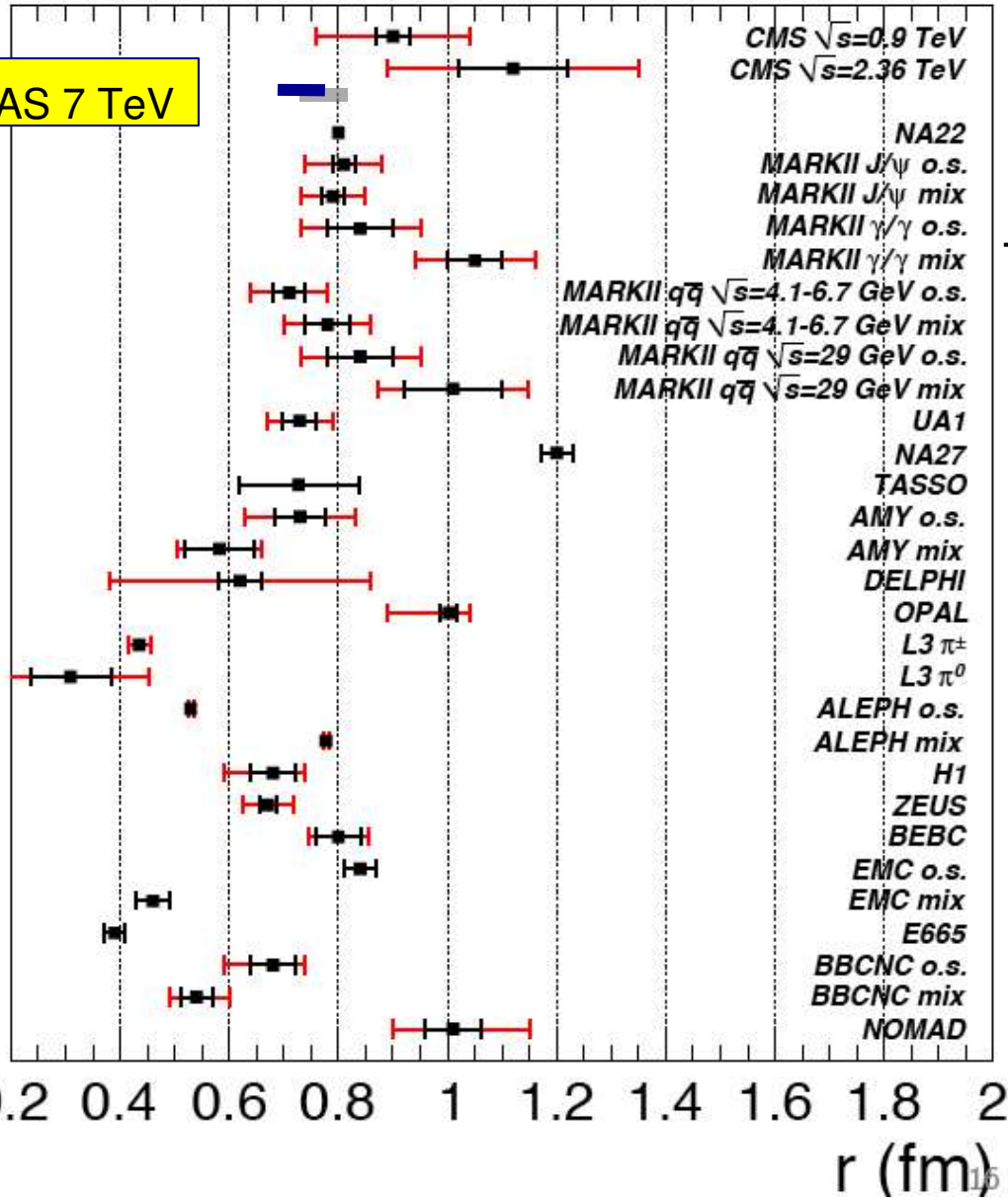
First error statistical, second one systematics.
R values are consistent while λ shows some discrepancy but CMS is @ different c.m. energy.

Size of stat. error: The data sample for CMS @ 900 GeV is 270K events ~3M tracks / ATLAS @ 7 TeV 220k events ~2M tracks … statistical error size is not consistent … it could be due to different MC sample size … to be checked.

Comparison with previous results

Indicative ATLAS 7 TeV

Previous experiment used a gaussian parametrization. In order to compare the first momentum of the distribution need to take care that
First momentum:
Gaussian $1/r\sqrt{\pi}$
Exponential $1/r$



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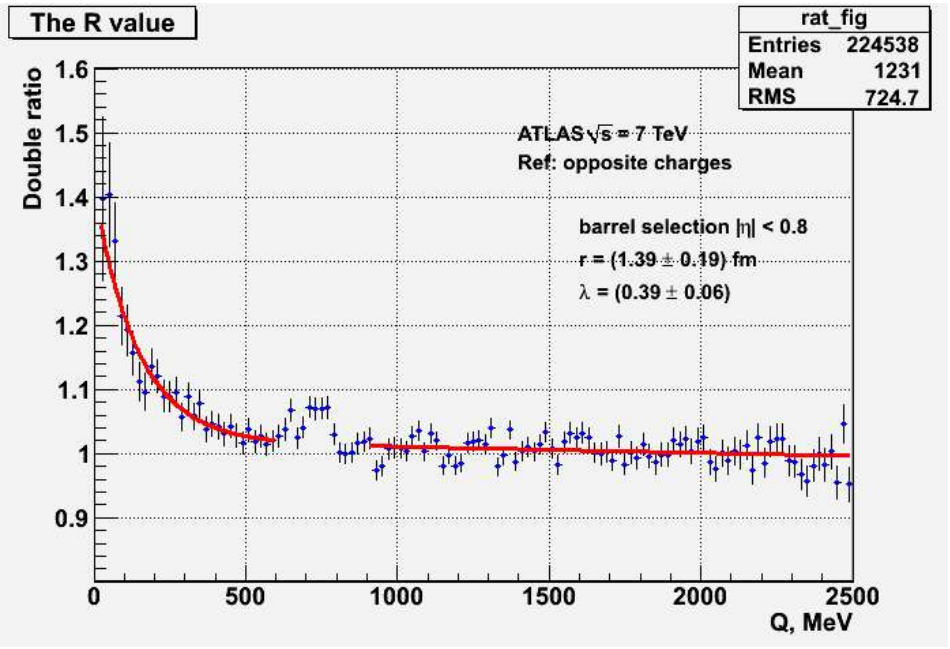
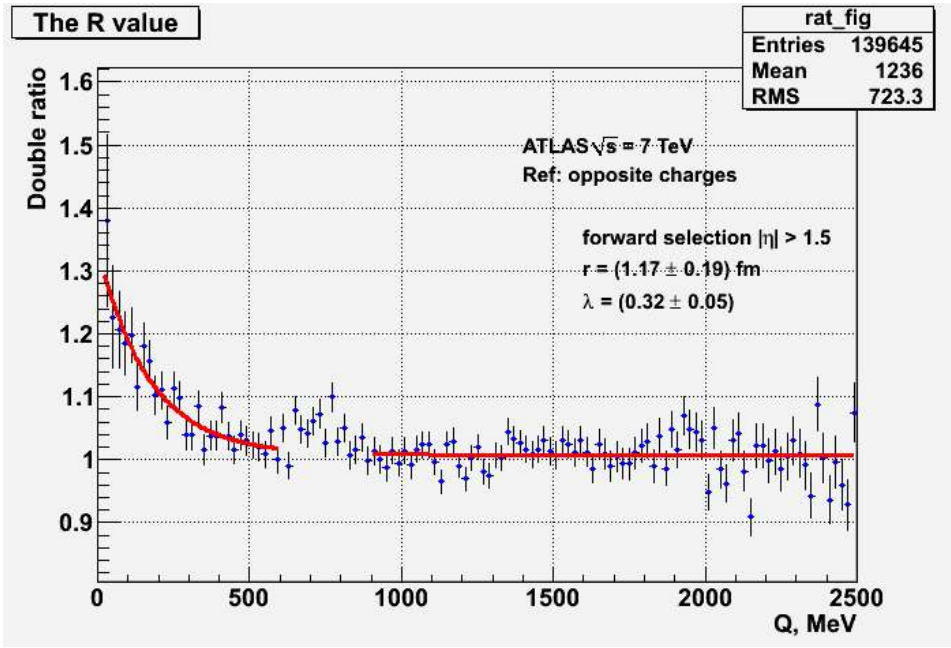
Dependence on η-region



Both tracks: |η|<0.8



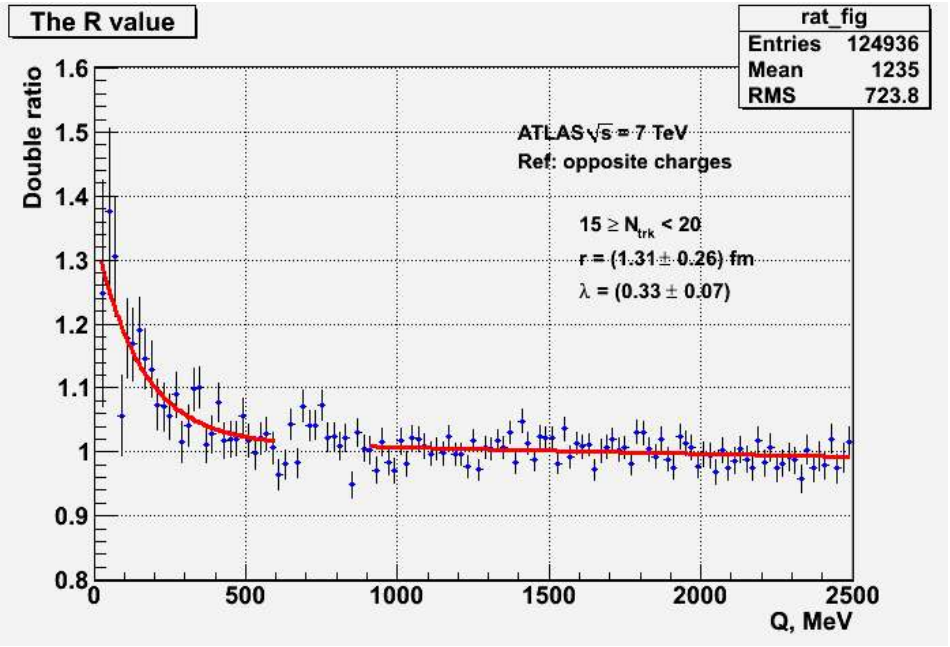
Both tracks: |η|>1.5 + same side (can be studied)

	r (fm)	λ
central	1.39+-0.19	0.39+-0.06
forward	1.17+-0.19	0.32+-0.05

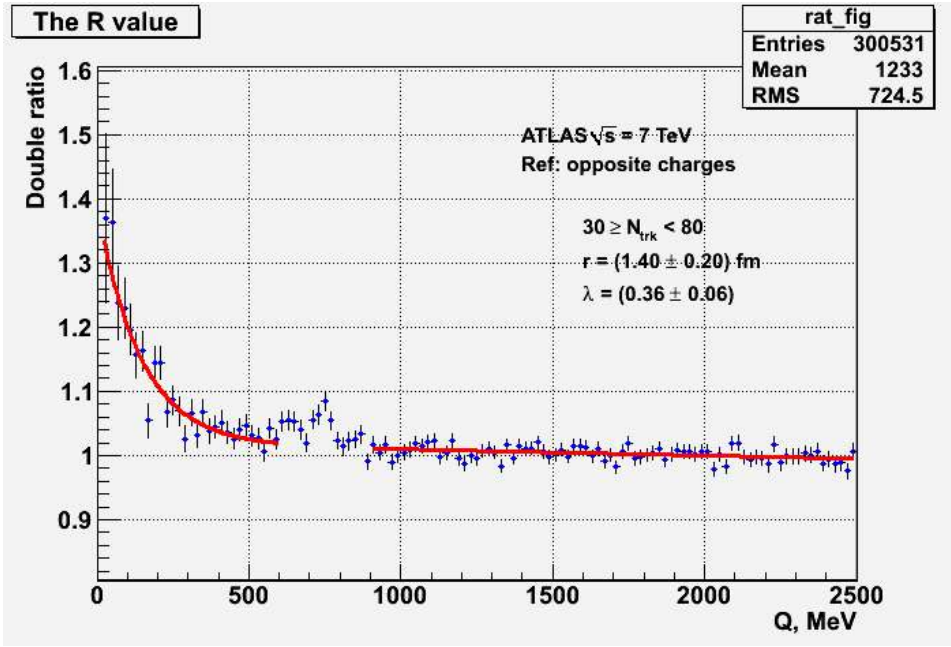
No dependence on eta is observed.

Dependence on event topology

The r and λ parameters may depend on event topology: vtx-track multiplicity, SumEt, AveragePt … We have started to study the dependence on vtx-track multiplicity.



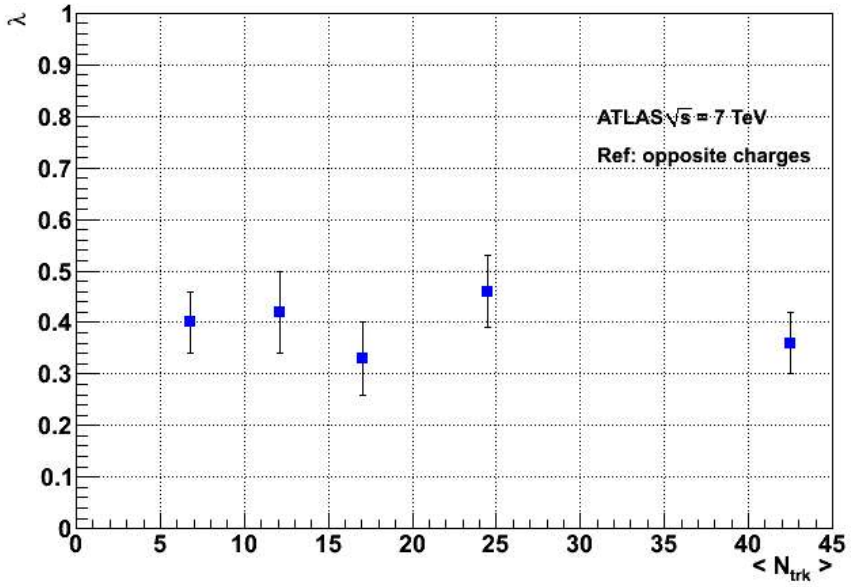
Q distribution for events with vtx multiplicity 15 ≤ Ntr < 20



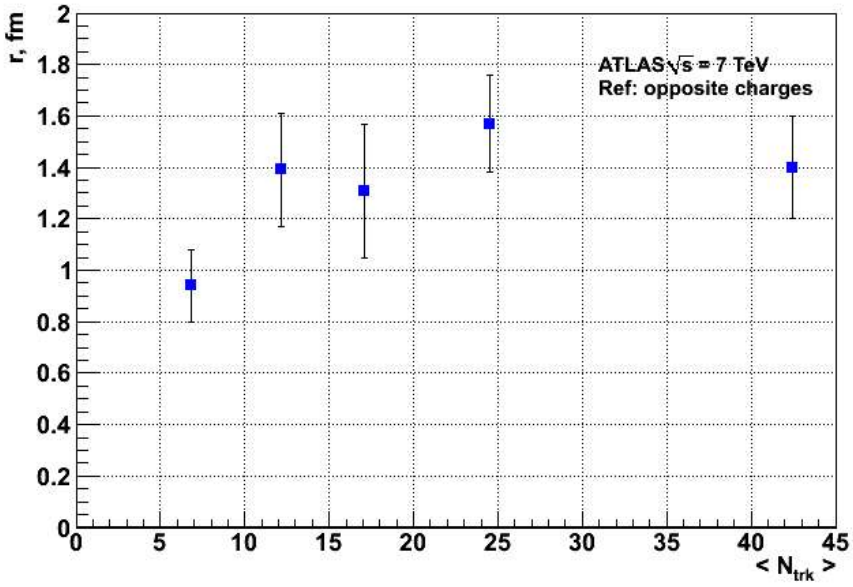
Q distribution for events with vtx multiplicity 30 ≤ Ntr < 80

Study of fit parameters dependence on multiplicity of tracks in vertex

Dependence on event topology



λ propogation vs N_{tr}



r propogation vs N_{tr}

r parameter: slight increase with N_{tr} (?)

λ parameter stable within statistical errors.

Future plans

- Coordinate the effort with other groups
- Systematics:
  - Selection cuts;
  - Reference sample definition.
- Increase statistics for 7 TeV and study 0.9 TeV sample
- Complete the study of paramter dependence on event topology: Ntrk, SumEt, AverageTrkPt, track opening angle
- Include Gamow factor evaluation

Back ups

Ideas

- Select well reconstructed tracks ?
- Add plot of multiplicity of tracks at primary vtx
- Split tracks could bias the signal sample if they are not correctly reproduced in MC. Is there a good way to get rid of split tracks ? CMS requires: cos(theta) <0.99998 & deltaPT_tracks>20MeV

Selection cuts efficiencies

- (*trk_pt)[iTrack] > 500.: 43.9% / 49.3%
- (*trk_seedFinder)[iTrack] == 0 : 98.7% / 98.8%
- fabs((*trk_eta)[iTrack]) < 2.5: 99.1% / 99.0%
- (*trk_nSCTHits)[iTrack] >= 6: 93.0% / 94.0%
- (*trk_nPixHits)[iTrack] >=1: 100.0% / 100.0%
- fabs((*trk_d0_wrtBS)[iTrack]) < 4.0: 99.9% / 99.9%
- fabs((*trk_d0_wrtPV)[iTrack]) < 1.5: 94.0% / 94.4%
- fabs((*trk_z0_wrtPV)[iTrack]*sin