

Cross section

Physics observable

$$\sigma = \frac{N}{fL}$$

Luminosity

$$L = f \cdot N_1 N_2 \cdot \text{Overlap}$$

LHC instrumentation<sup>2-6</sup>

Measured by experiments (van der Meer or beam-gas)<sup>1</sup>

$$\int \rho_1(x,y,z,t) \rho_2(x,y,z,t) dx dy dz dt$$

Single bunch density function of colliding bunch pair

For single Gaussian  $\rho_1, \rho_2$ :

$$O = \frac{1}{2\pi \sqrt{(\sigma_{x1}^2 + \sigma_{x2}^2)(\sigma_{y1}^2 + \sigma_{y2}^2)}}$$

Overlap integral: no crossing angle, head-on

$$\times \left( 1 + \frac{\sigma_{z1}^2 + \sigma_{z2}^2}{\sigma_{x1}^2 + \sigma_{x2}^2} \tan^2(\phi) + \frac{\sigma_{z1}^2 + \sigma_{z2}^2}{\sigma_{y1}^2 + \sigma_{y2}^2} \tan^2(\phi) \right)^{-1/2}$$

Correction for crossing angle  $\Phi$  ( $\approx 0.85$ )

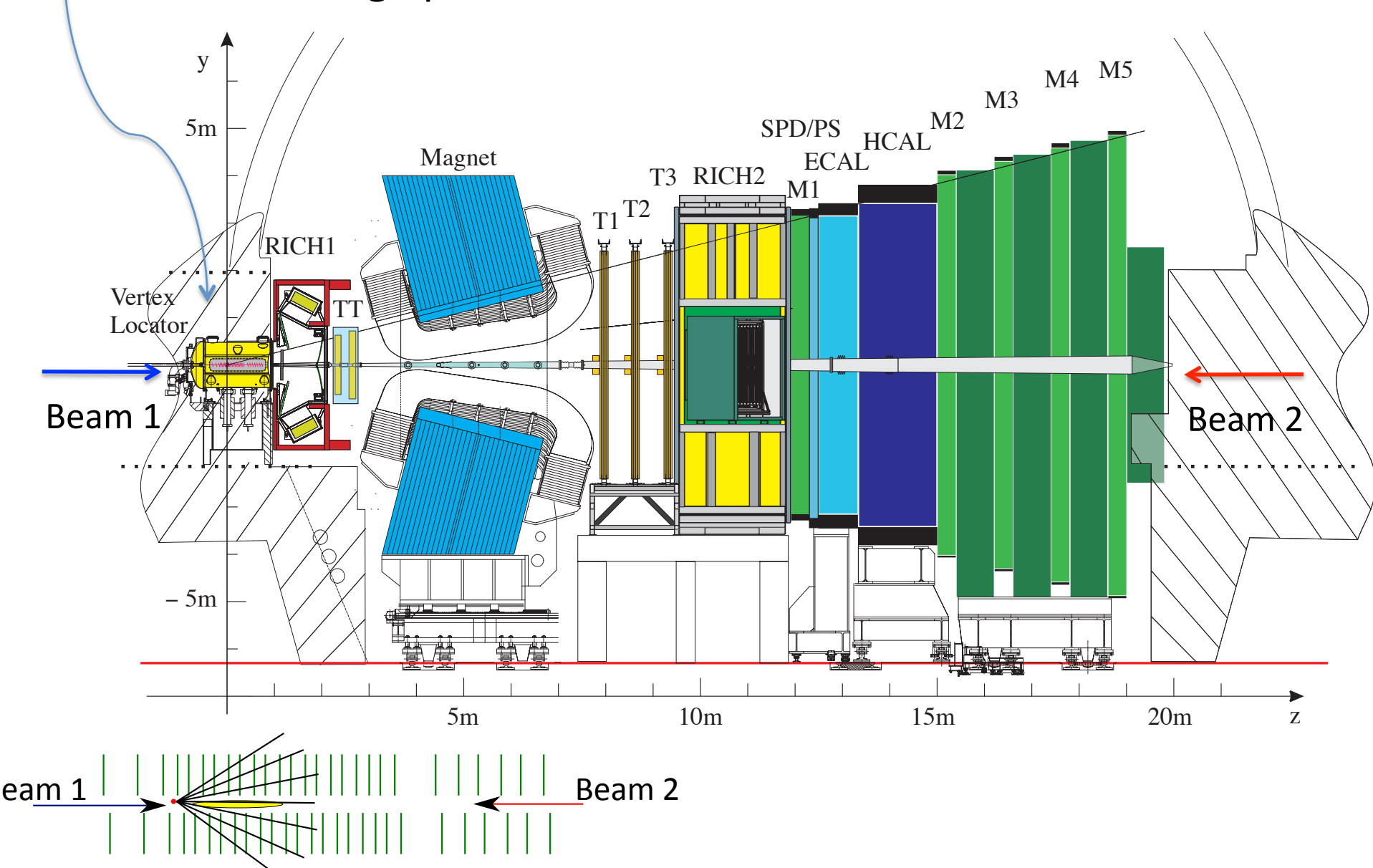
$$\times \exp\left(-\frac{\delta_x^2}{2(\sigma_{x1}^2 + \sigma_{x2}^2)} - \frac{\delta_y^2}{2(\sigma_{y1}^2 + \sigma_{y2}^2)}\right)$$

Correction for offset beams ( $\approx 1$  ideally)

$$\times \exp\left[S^2 \frac{\sigma_{z1}^2 + \sigma_{z2}^2}{2} \left( \frac{\delta_x \tan(\phi)}{\sigma_{x1}^2 + \sigma_{x2}^2} + \frac{\delta_y \tan(\phi)}{\sigma_{y1}^2 + \sigma_{y2}^2} \right)^2\right]$$

Cross term for angle with offset ( $\approx 1$  ideally)

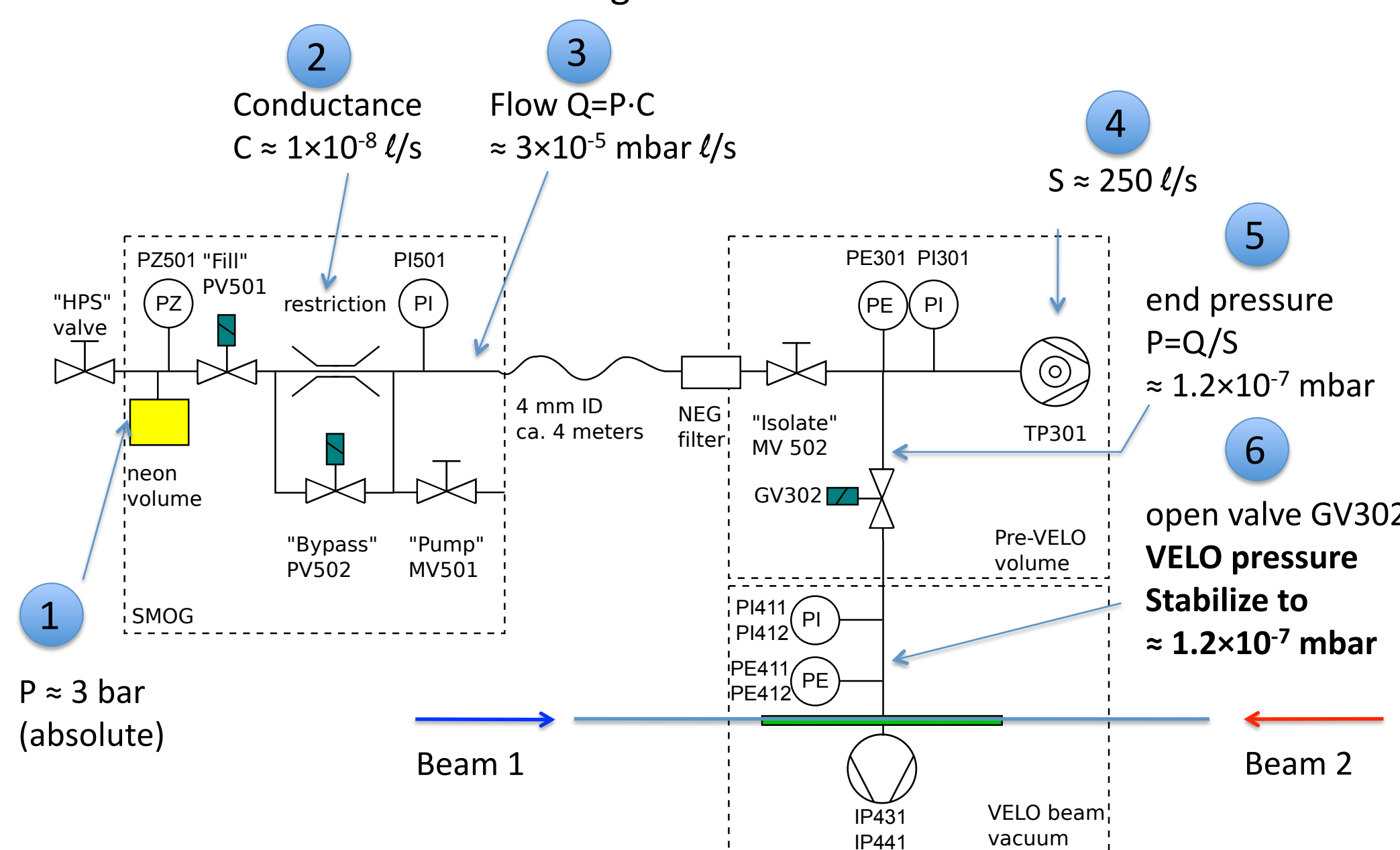
**VELO** geometry and beam proximity permits to detect beam-gas vertices over a large Z range With high precision



Beam parameters are measured using interactions between beam and residual gas

Needed:  $\leftarrow$  Vertex detector  $\rightarrow$  Gas  $\rightarrow$

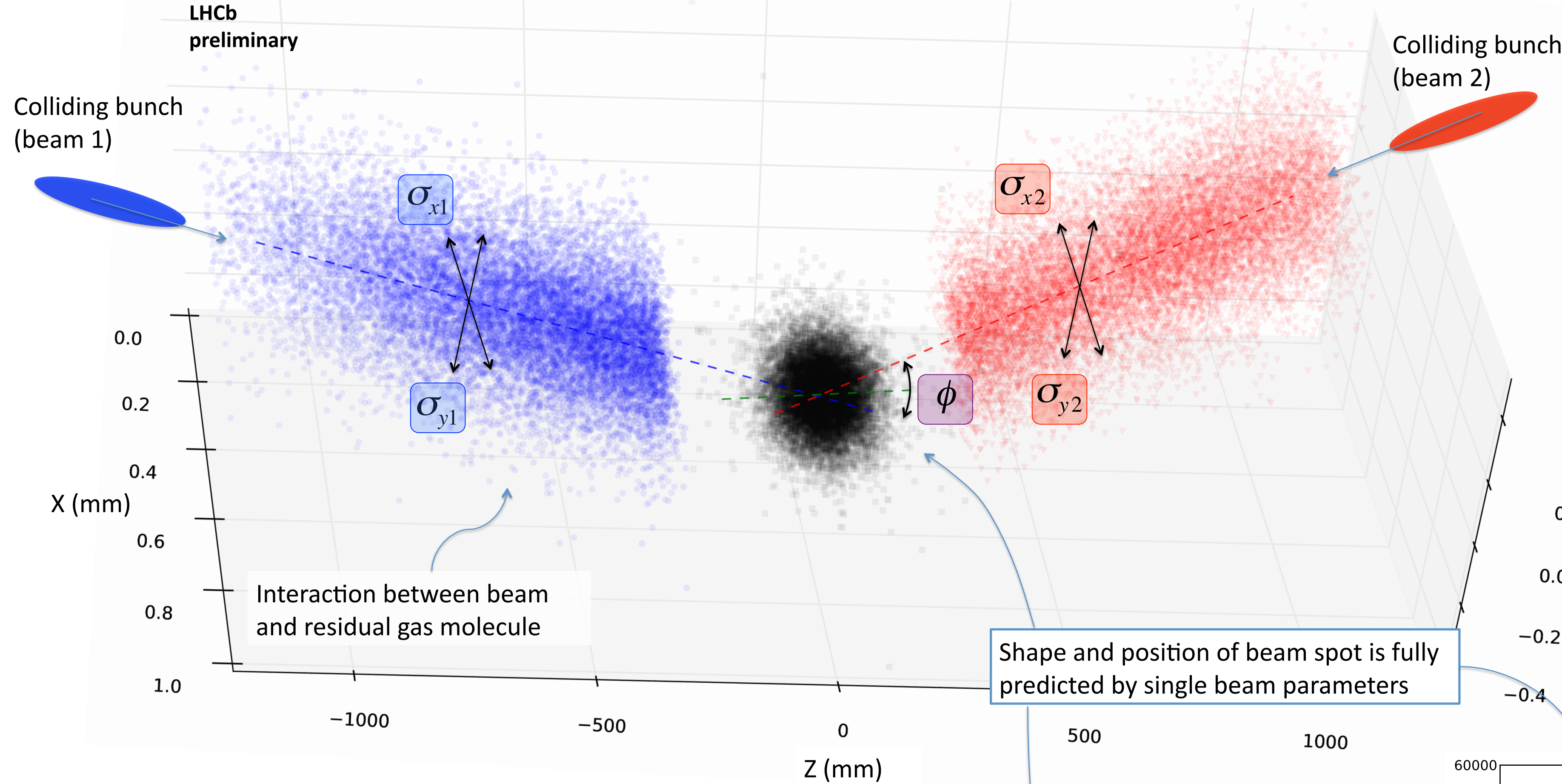
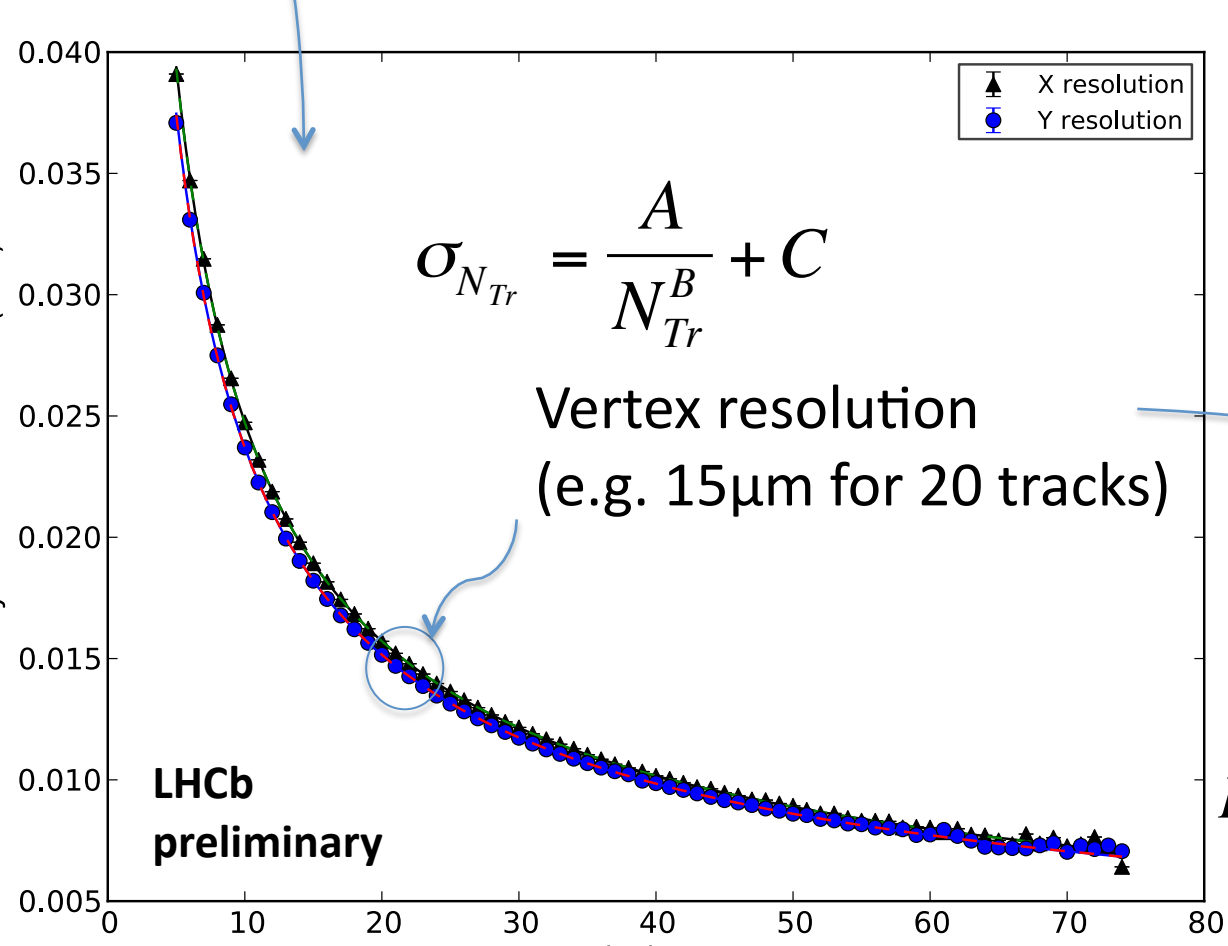
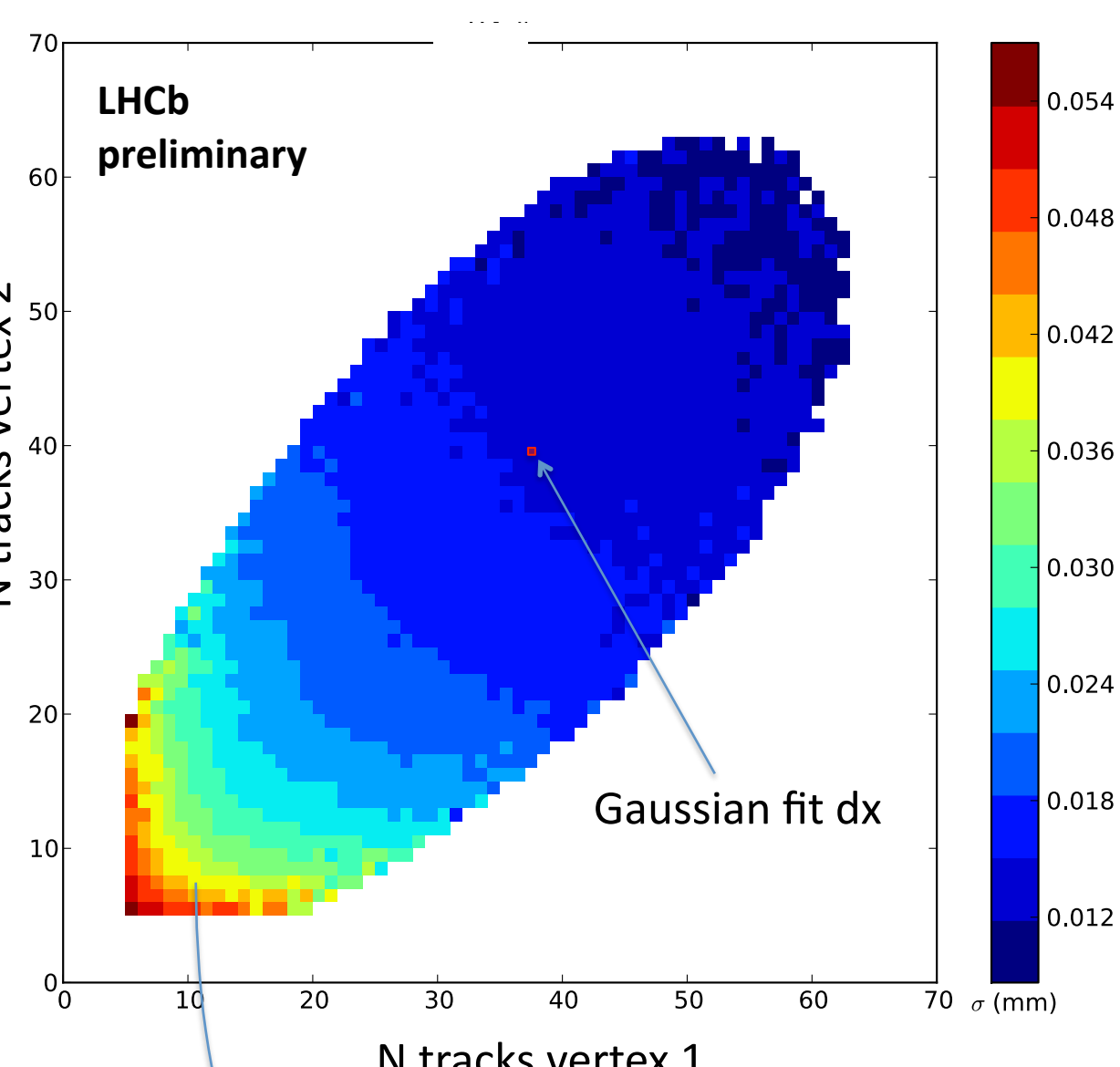
**SMOG** inject gas in beam vacuum vacuum is degraded: from  $\approx 10^{-9}$  mbar to  $\approx 10^{-7}$  mbar



## Resolution

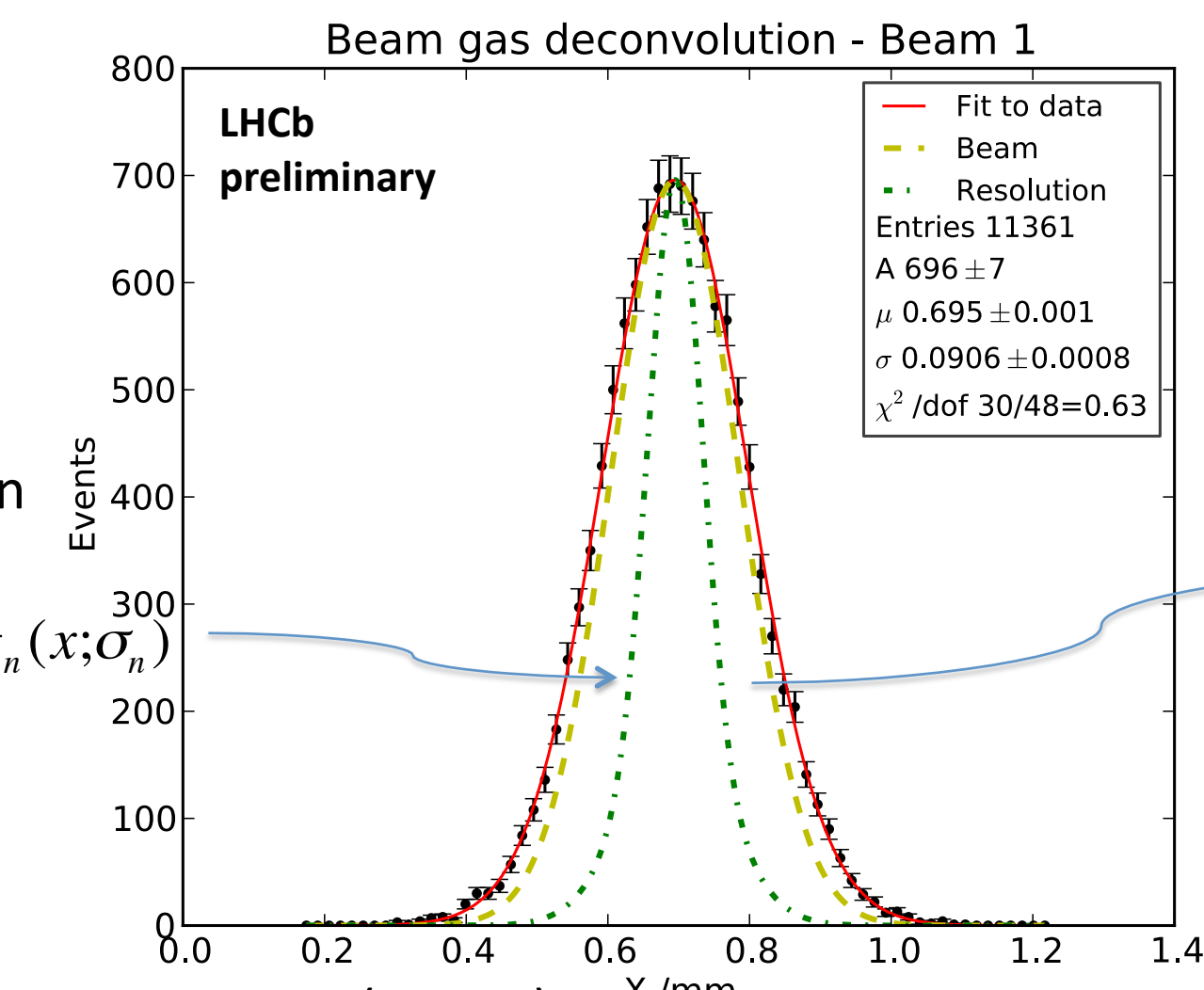
- depends on:
  - Z position of vertex
  - Number of tracks
  - Beam gas or beam beam events

Split vertex method  
 $dx = \sqrt{\sigma_{N_{Tr1}}^2 + \sigma_{N_{Tr2}}^2} = f(N_{Tr1}, N_{Tr2})$

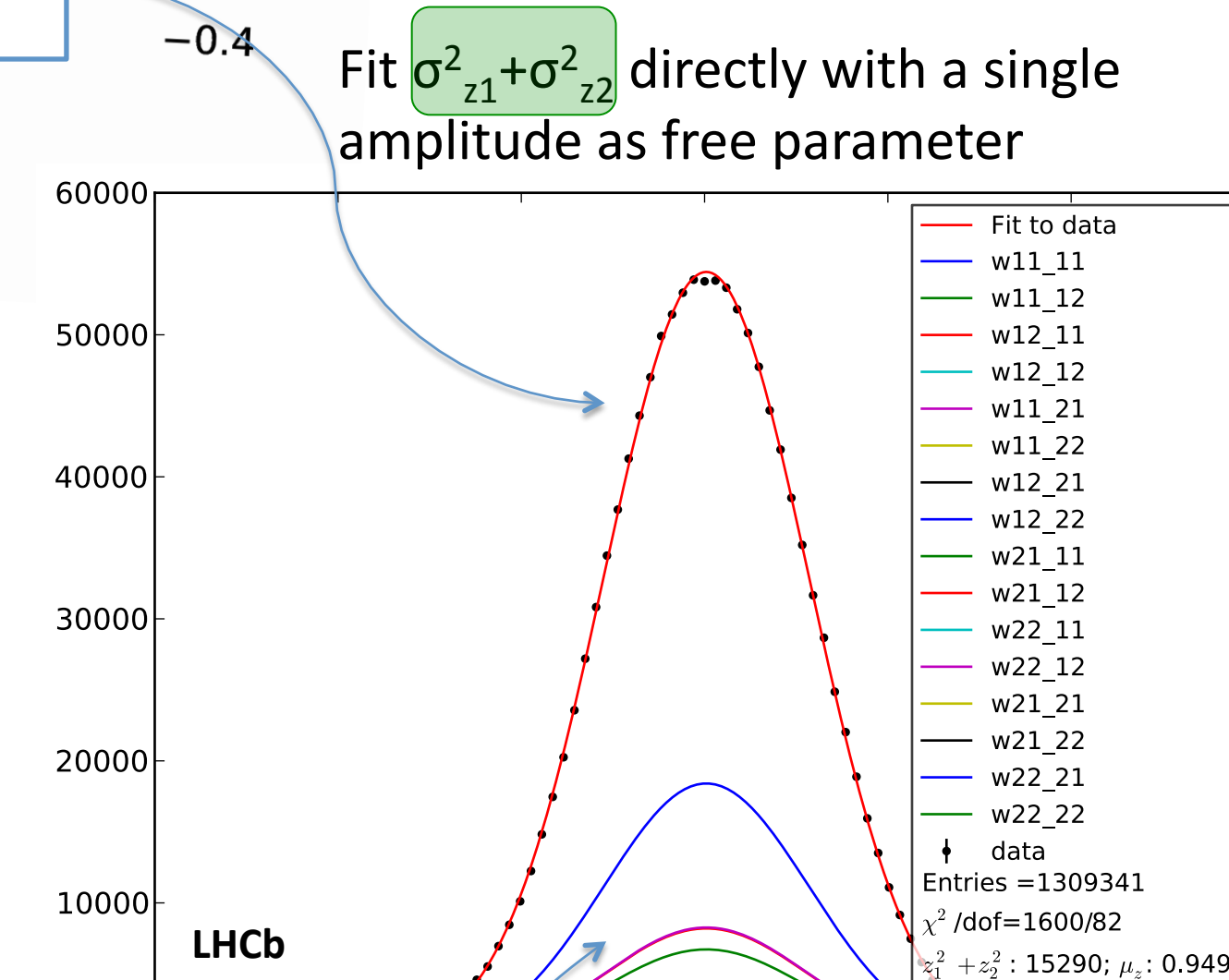
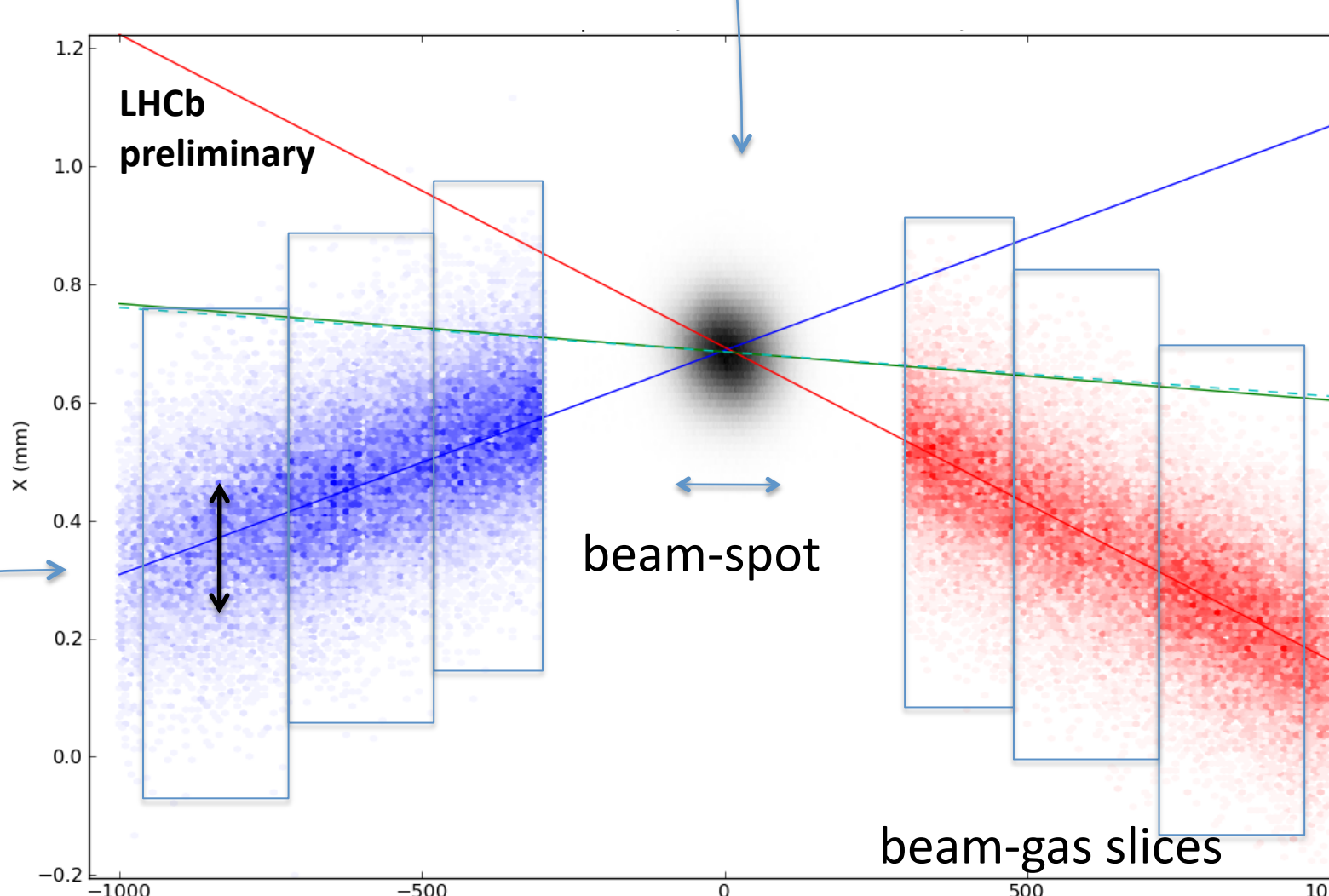


## Deconvolution

Extract true beam shape: measured beam width is a convolution of true beam widths with the resolution



## Global fit



## Conclusion

- High accuracy of beam gas method possible in 2012 with gas injections (SMOG)
- No gas injection in 2011 but beam gas method still possible with less accuracy
- Beam gas method has potential to equal or surpass classical van der Meer method

Additional beam gas measurements:

- Measure single bunch relative intensity in a statistical way (independent of LHC devices)
- Measure charges outside nominal filled LHC bunches (so-called "ghost charges", not seen by LHC instrument)
- Measure beam size evolution over time

## References

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- "LHC Bunch Current Normalisation for the April-May 2010 Luminosity Calibration Measurements" G. Anders et al. (BCNWG note1), CERN-ATS-Note-2011-004 PERF
- "LHC Bunch Current Normalisation for the October 2010 Luminosity Calibration Measurements" A. Alici et al. (BCNWG note2), CERN-ATS-Note-2011-016 PERF
- "Study of the Relative LHC Bunch Populations for Luminosity Calibration", G. Anders et al. (BCNWG note3), CERN-ATS-Note-2012-028 PERF
- "Study of the LHC Ghost Charge and Satellite Bunches for Luminosity Calibration", A. Alici et al. (BCNWG note4), CERN-ATS-Note-2012-029 PERF
- "Inclusive W and Z production in the forward region at  $\sqrt{s} = 7$  TeV, LHCb Collaboration", 2012, J. High Energy Phys. 06 (2012) 058, LHCb-PAPER-2012-008
- "Measurement of the cross-section for Z to ee- production in pp collisions at  $\sqrt{s} = 7$  TeV", LHCb Collaboration, 2012, LHCb-PAPER-2012-036