EbE Vertexing for Mixing

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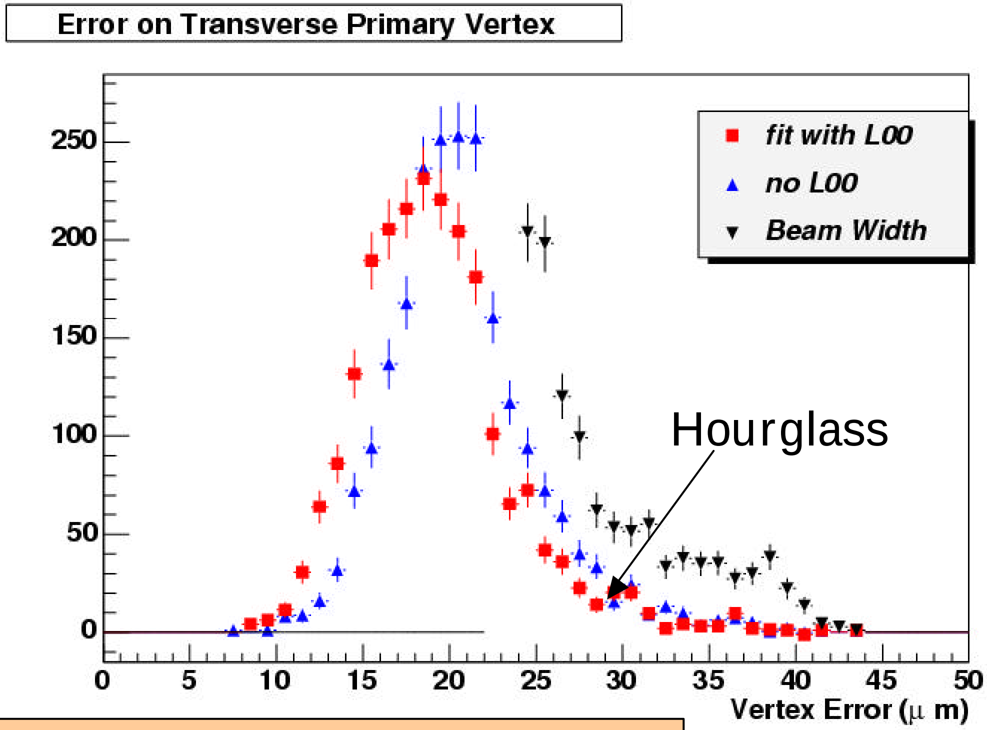
Current status

EbE: itearative track selection/pruning algorithm to provide an unbiased estimate of the PV position on an Event-by-Event basis

- Hadronic analyses used a flat ~25um beamline!
- Possible improvements:
  - Move to “hourglass”
  - Move to EbE
  - EbE + Hourglass
    - One of the ½leptonic analyses used this

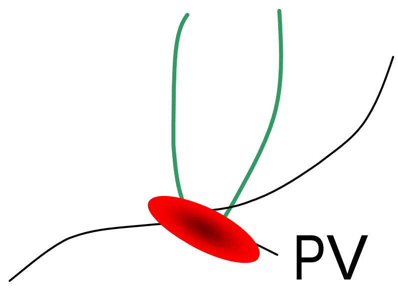


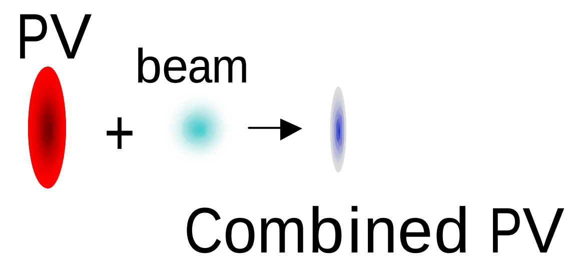
No matter what you choose, you need to understand your errors (pulls)

Decay L_{xy} Determination with EbE

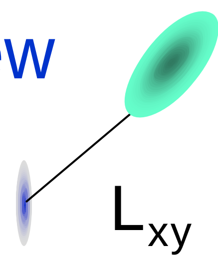
A 3 step process:

1. Determine vertex from tracks in the event (~25μm-ish)
2. Apply beamline constraint (~25μm-ish)
3. Compute secondary vertex position

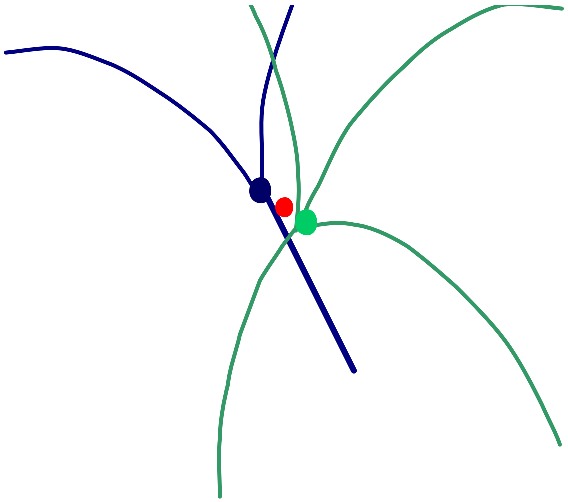




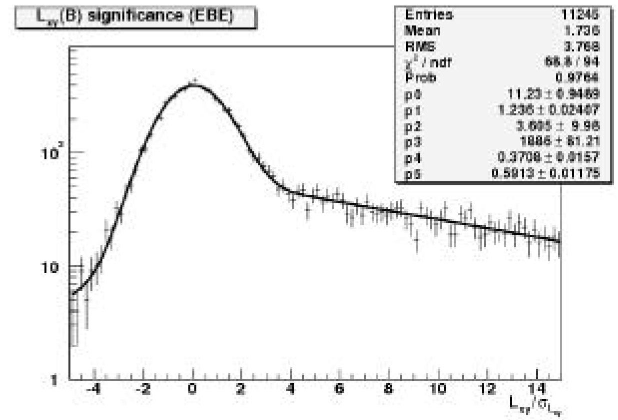
At each step, pulls of the new ingredient must be 1!!!



The tools to check the Pulls!



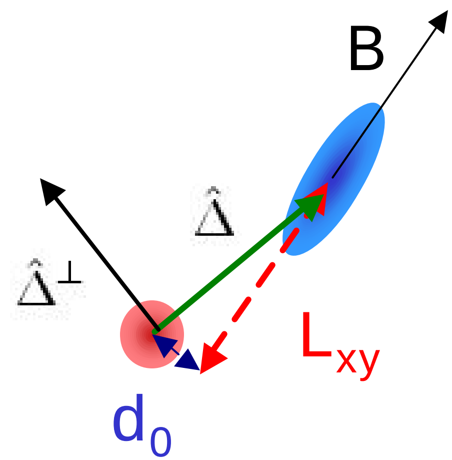
- Prompt peak
- V-truth
- V1-V2
- d_0/σ



$$L_{xy} := \vec{\Delta} \cdot \hat{P}_B$$

$$d_0^B := \left| \vec{\Delta} - \frac{P_B^2}{\vec{P}_B \cdot \vec{\Delta}} \vec{P}_B \right| \approx \vec{\Delta}^\perp \cdot \hat{P}_B$$

$$\boxed{\begin{aligned} \sigma_{L_{xy}} &= {}^t\hat{\Delta}\Sigma_V^2\hat{\Delta} \\ \sigma_{d_0^B} &= {}^t\hat{\Delta}^\perp\Sigma_V^2\hat{\Delta}^\perp \end{aligned}}$$

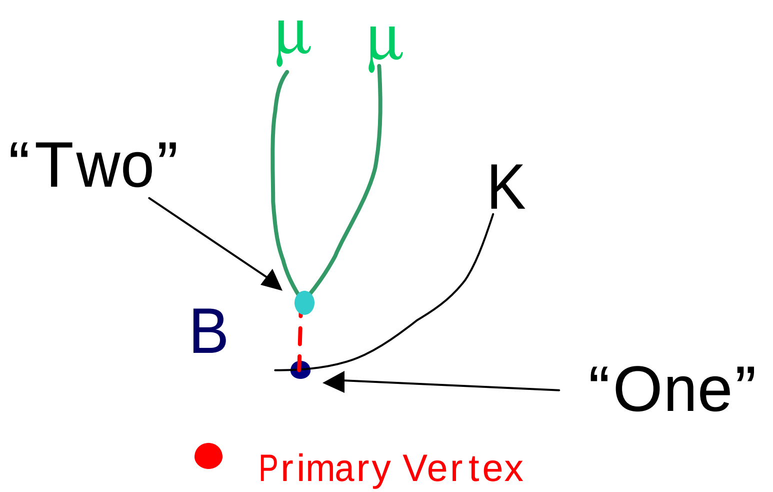


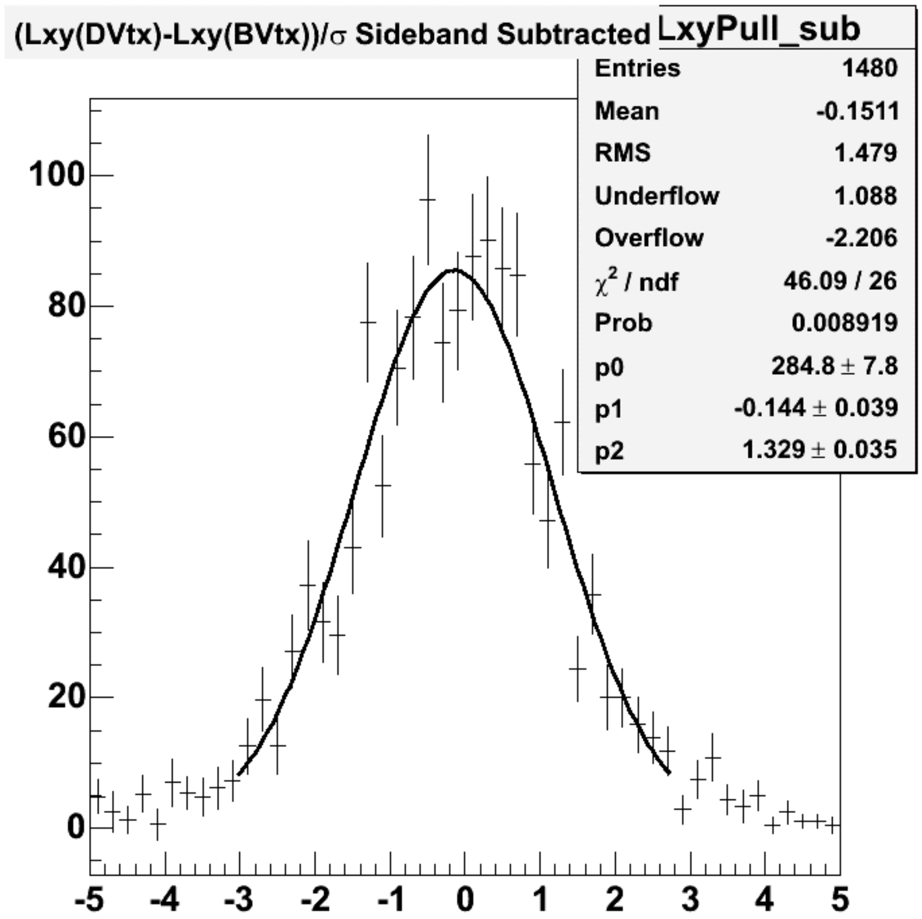
$$\hat{\Delta} = (x, y) \Rightarrow \hat{\Delta}^\perp = (y, -x)$$

One more tool for the SV

Example: $B \to \psi K^+$

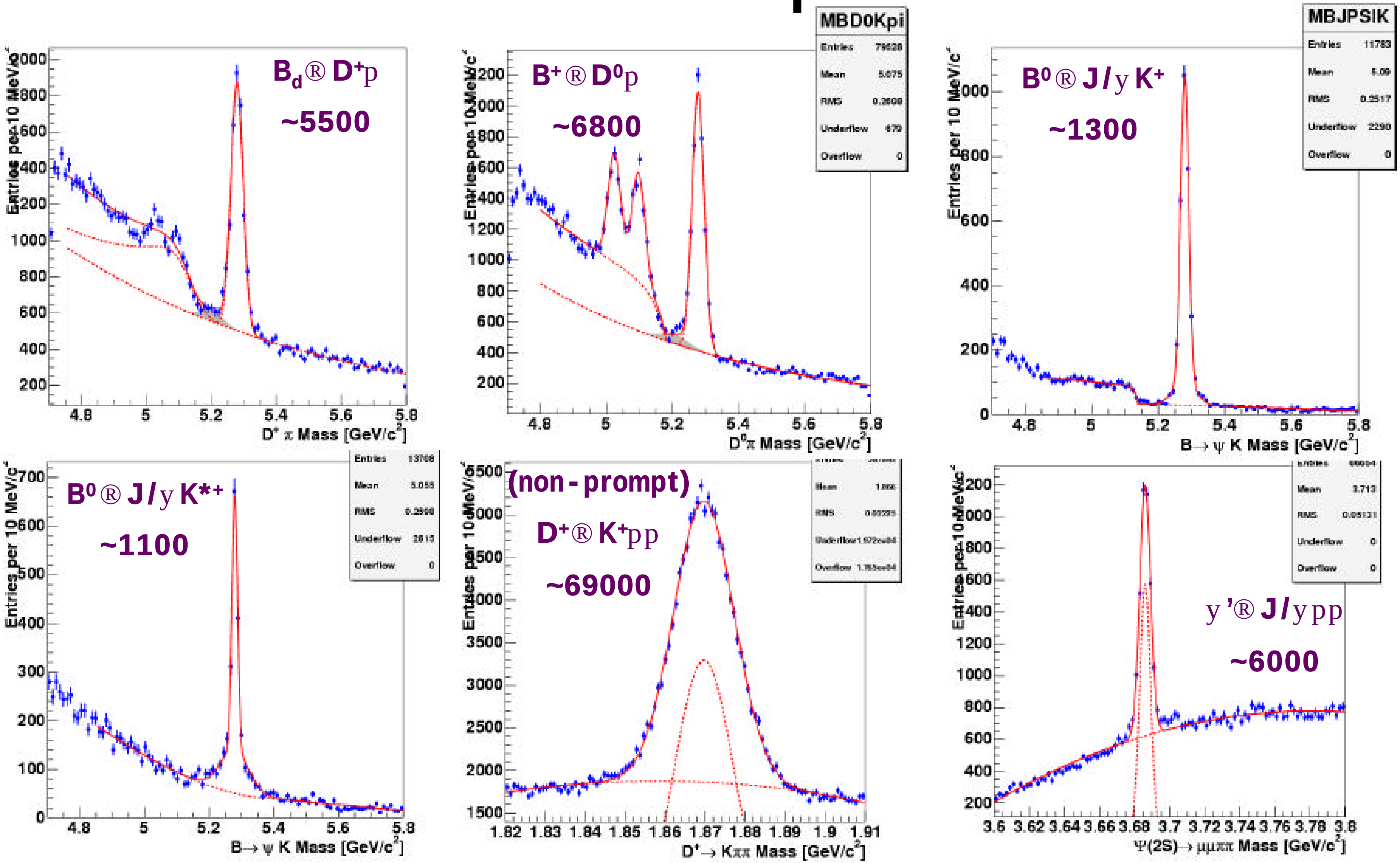
- Fit ψ to a single vertex
- "point" ψ back to K
- Measure L_{xy} wrt B vertex
- Pull is a proxy for a "seconday vertex" pull!





Tracks' d_0 can be used as cross-check

The samples



~15000 fully reco'd B, ~69000 Fully reco'd D+, ~6000 fully reco'd ψ' (re-running)

Montecarlo: mostly BGEN (basically all of the above+B_s), using Pythia if possible

Technicalities (contd.)

Reconstruction:

- Based on the ~350pb^{-1} dataset/ 5.x production
- 6.1.0 CharmMods with CTVMFT "fix" (does not really affect results though)
- Standard tracking requirements (COT+3Si)
- Tight selection cuts to improve S/B

Montecarlo:

- Using the standard BMC tools plus:
- Stephanie's L00 reweighting
- Kludge (CharmMods/DCalcPrimVertModule) to generate PV based on data histograms for BGEN

Plan

Primary Vertex

Measure PV scale factor from V_1-V_2 → Data / MC → Consistency → PV scale factor from V_1-V_2 on data

Beamline

Measure d_0(B):

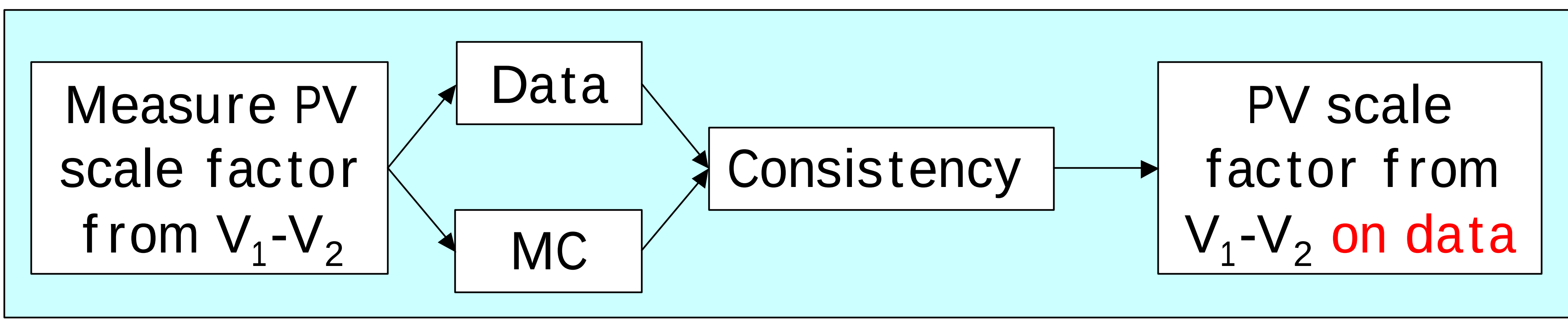
Beam, TrackbasedEbE, BeamconstrainedEbE

→ Relevance of beam resolution on L_{xy} → Beam σ scale factor not necessary

Secondary Vertex

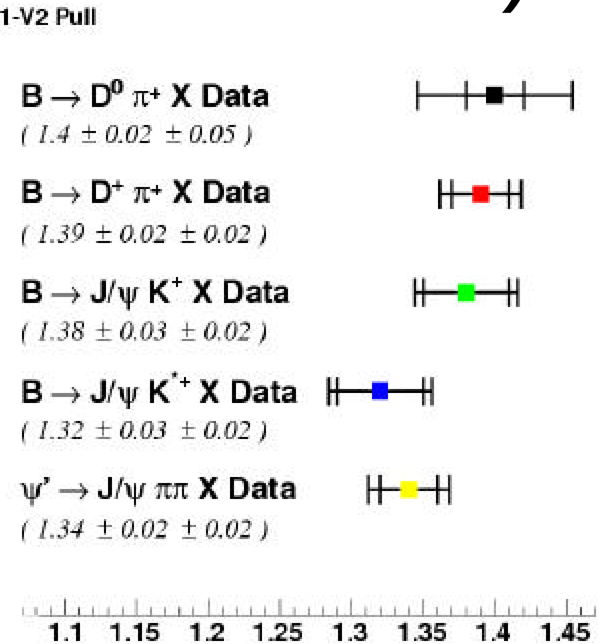
Measure "N-1" L_{xy} and d_0 → Data / MC → Consistency, Validate MC → PV scale factor from V-truth on Monte Carlo

Primary Vertex



PV Scale Factor (no beam constr.)

- Can be probed directly on data using V_1-V_2
- Consistent picture in data: O(1.38)
- Monte Carlo after L00 re-weighting shows similar numbers (bottom right)
- Measured systematics from fit model and across samples [effect is O(5%)]



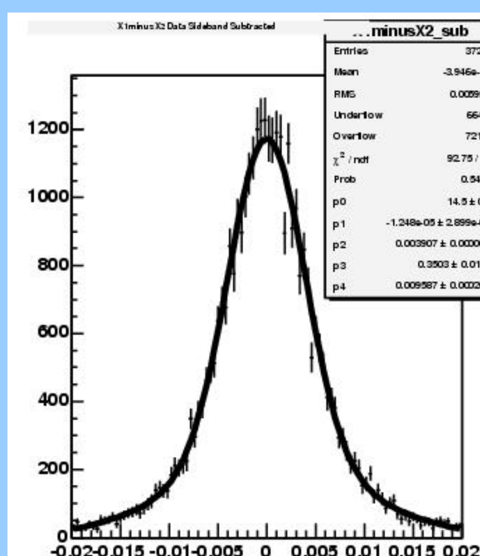
Pull fit:

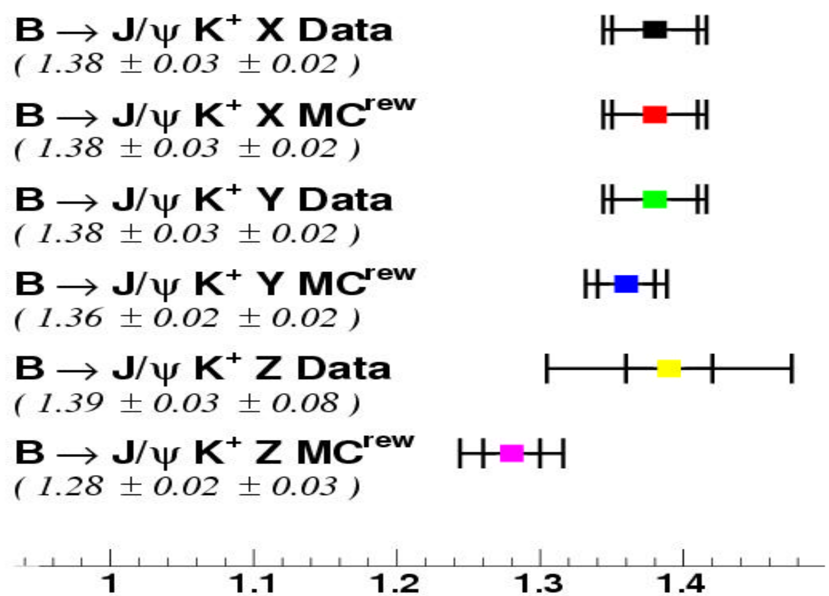
Reference:

- Gauss (±2σ)

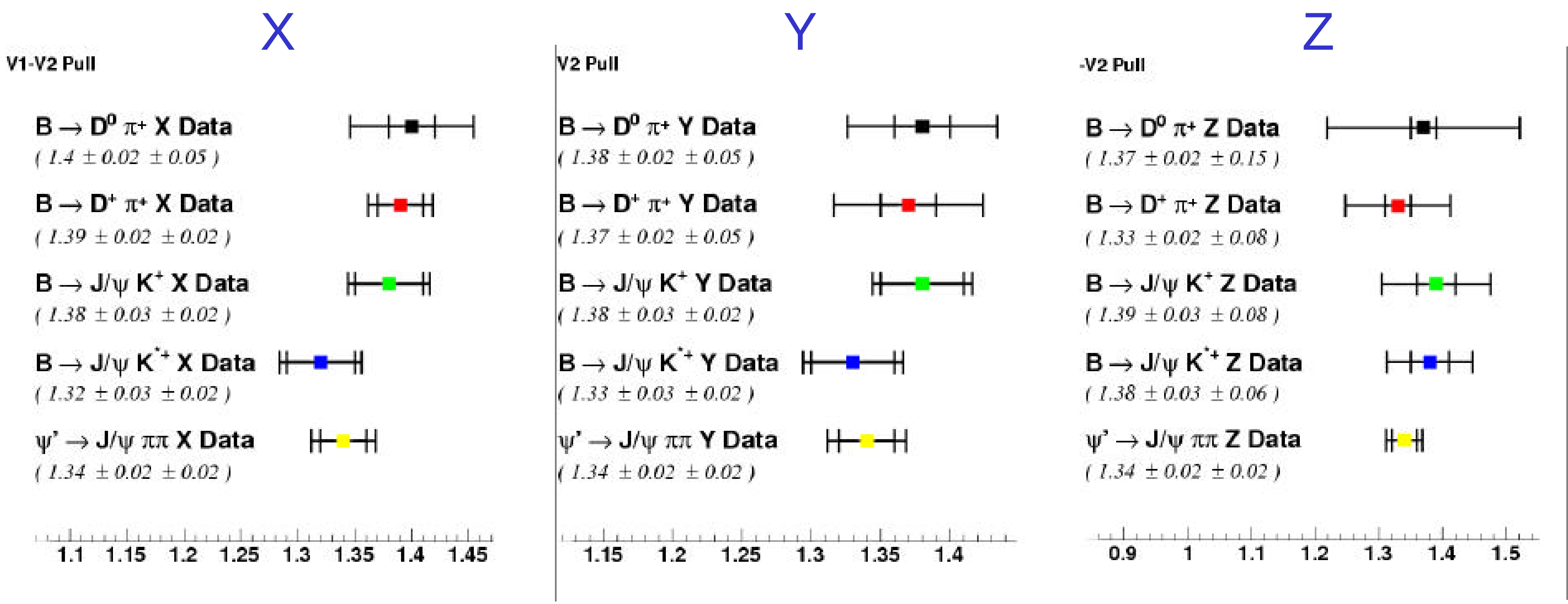
Model Syst.:

- Bigauss
- GaussExp





PV scale factor: other plots (X,Y,Z)

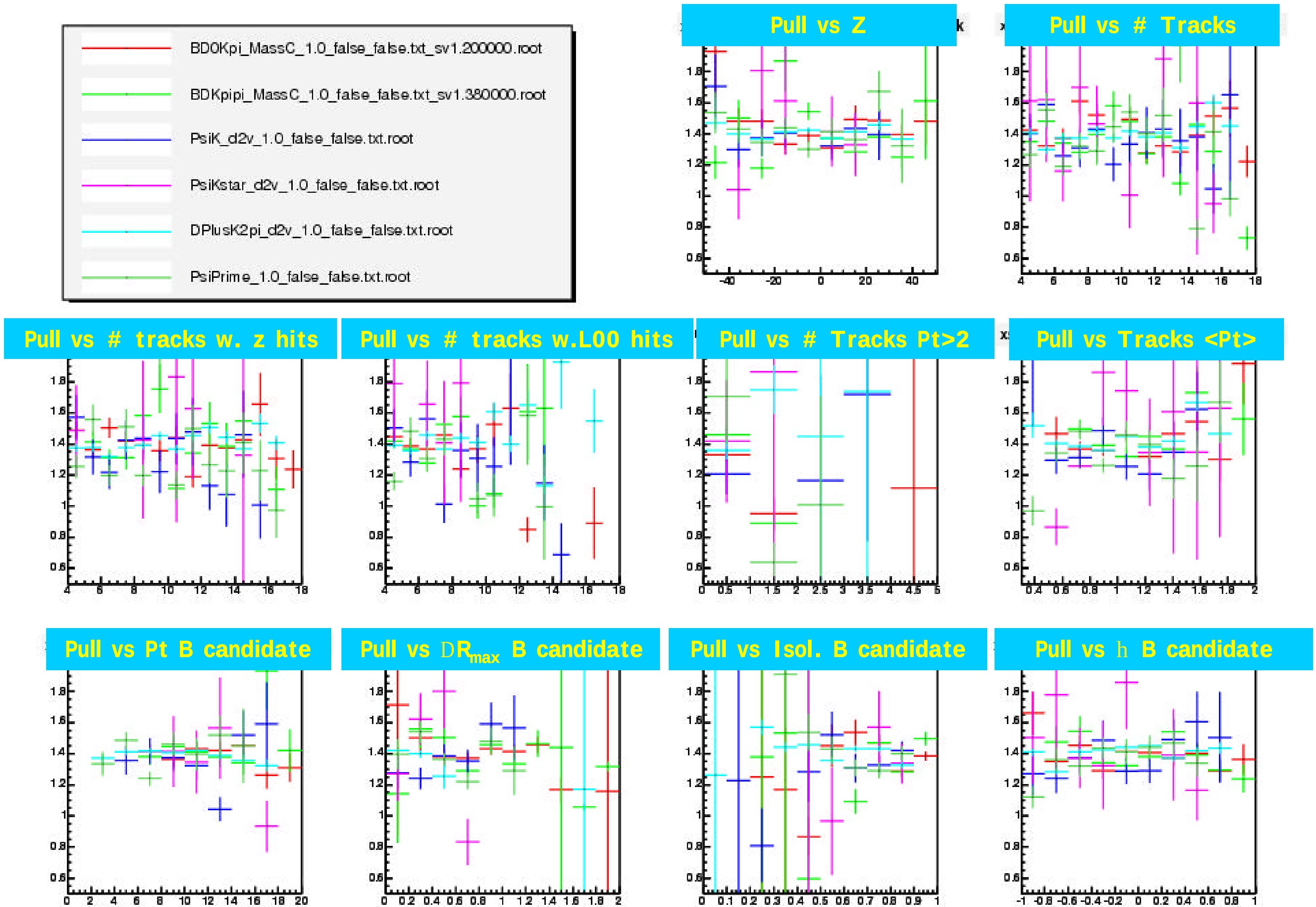


Pull uncertainty is dominated by:

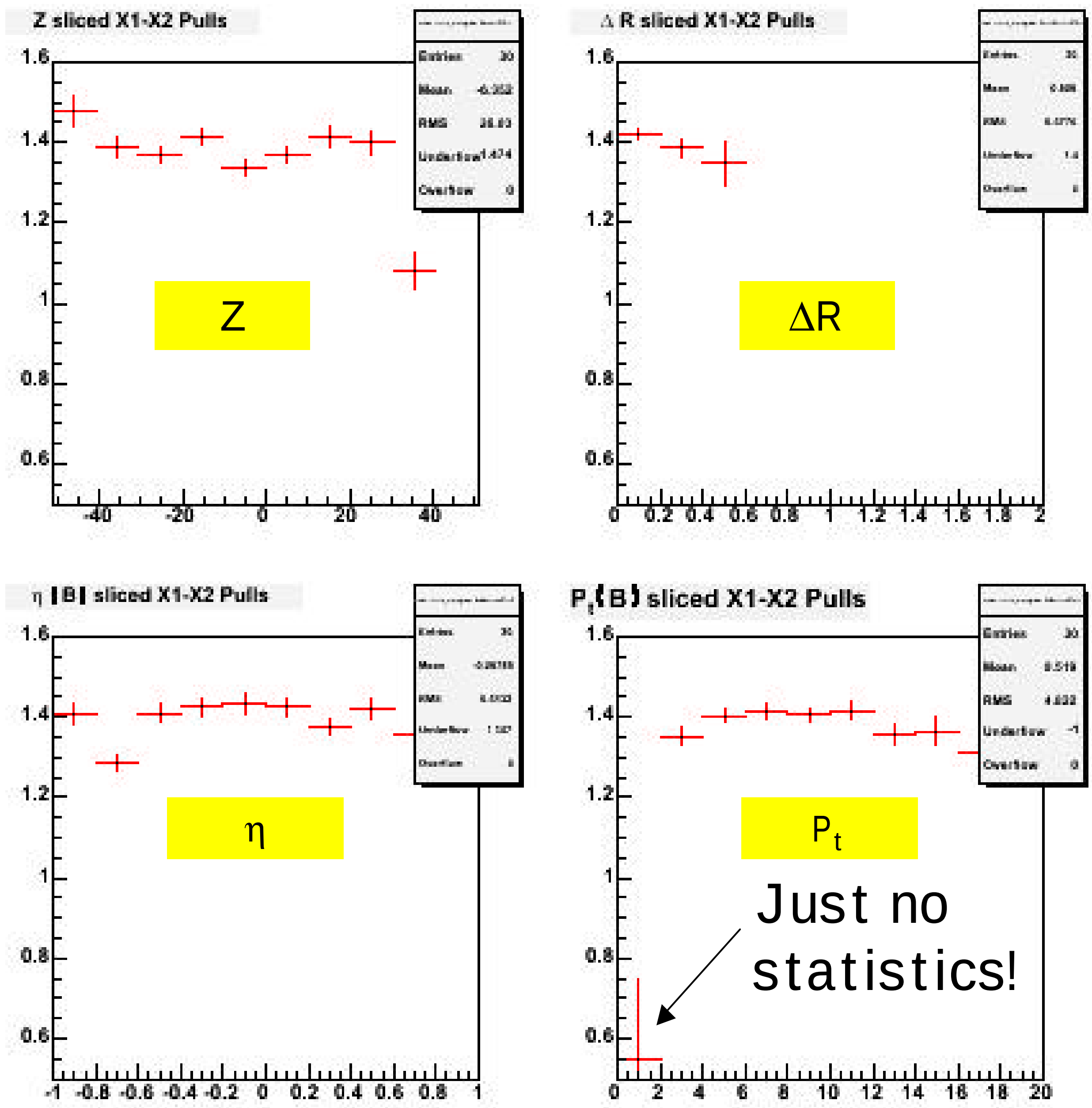
- Variability among samples
- Systematic uncertainty from fit model

5% Uncertainty

PV scale factor dependencies (X)



PV scale factor: details (à la CDF7500)

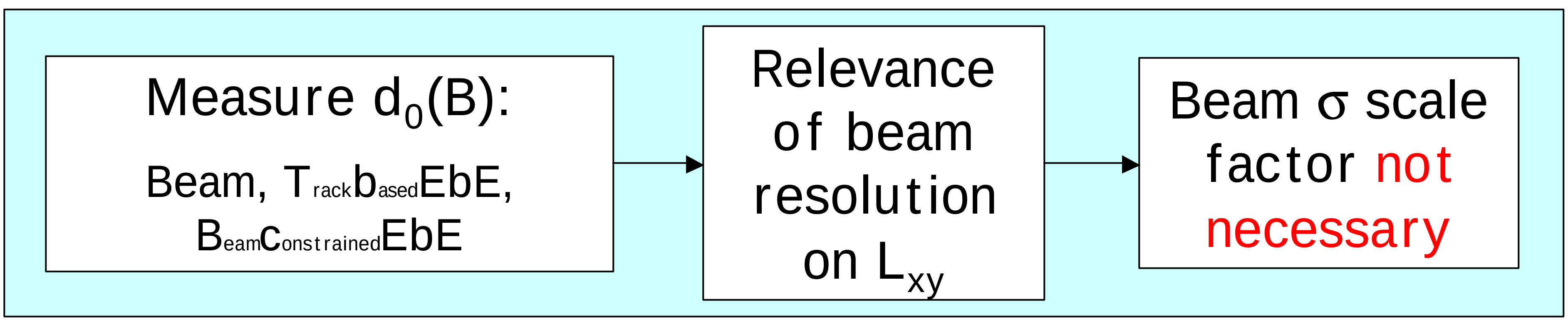


Non-statistical fluctuations dominated by fit model!

Conclusions on PV

- Scale factor measured on data
- Stable (within 5%):
  - Among samples
  - No evidence of dependencies
- We can move to the next step!

Beamline



Measure d_0(B):
Beam, TrackbasedEbE,
BeamConstrainedEbE
Relevance of beam resolution on L_{xy}
Beam σ scale factor not necessary

d_0(B): properties and limitations

Three possible ways of measuring PV:

1) Beamline
2) Track based Primary Vertex (TBPV)
3) TBPV constrained to beamline ("EbE")

What enters in $\sigma(d_0)$:

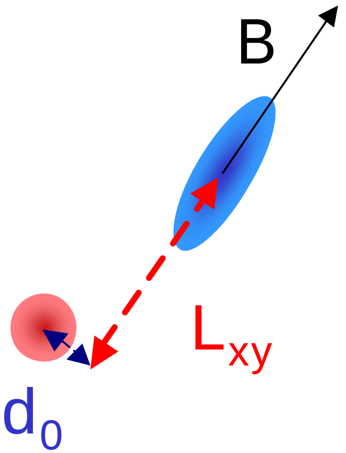
a) Beam (1,3)
b) Secondary vertex (1,2,3)
c) TBPV (2,3)

☹None of (1,2,3) probes only one piece!

☹Regime (relative contribution of a,b,c) differs between (1,2,3) but also between L_{xy} and d_0!

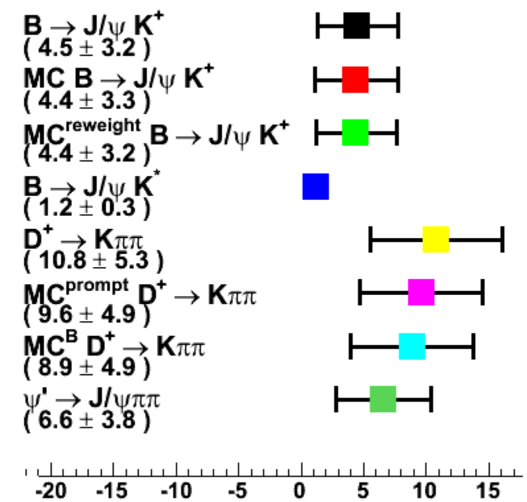
Let's see what happens in a real case...

Limit to the d_0 / L_{xy} analogy

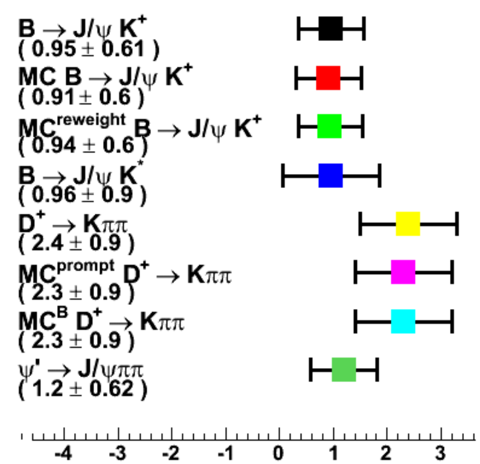


SV resolution ellipsoid is elongated and "seen from" different angles by d_0 and L_{xy} !

'D' Vertex error ellipsoid anisotropy (mean±RMS)



'D' Vertex error scale [in 100µm units] (mean±RMS)

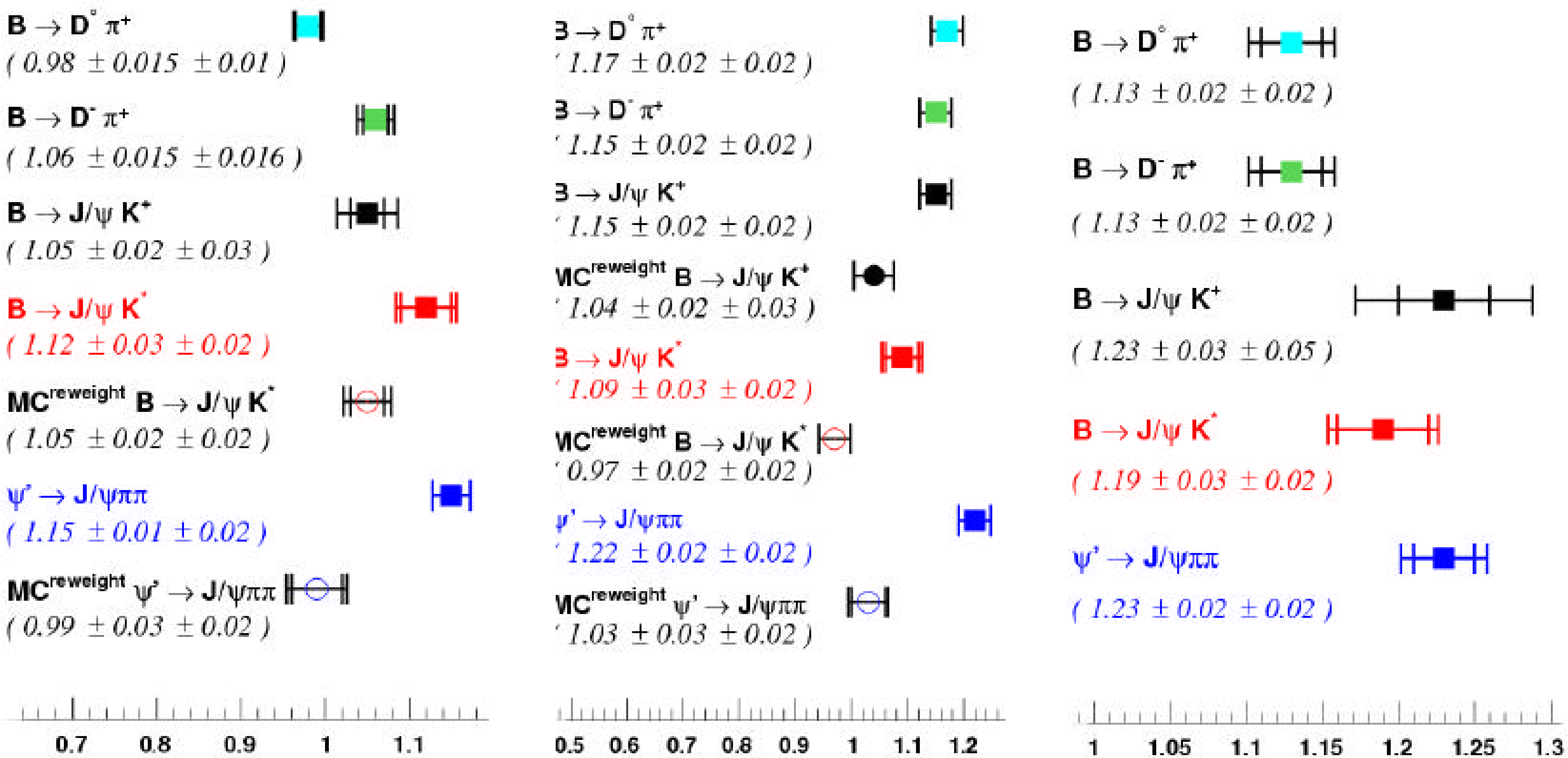


	Not Beam Constrained		Beam Constrained	
	σ_{d0}	σ_{Lxy}	σ_{d0}	σ_{Lxy}
PV	23	27	17	17
SV	12	36	12	36
Sum	27	45	21	43

d_0 and L_{xy} probe different regimes of σ_{PV}/σ_{SV}: d_0 dominated by PV, L_{xy} dominated by SV

Back to d_0: Comparison among samples and with MC

Track based EbE | Beamline | EbE (with beam constr.)



SV | Beamline and SV | Beamline and SV

Source of deviations from 1

Evidences of underestimate of beamline and SV errors!

Why blow-up on the beamline does not concern L_{xy}

Why 30%?

- Back-of-the-envelope calculations:
    - Typical 'long run'
    - Initial and final luminosities
    - On-line (SVT) beam width measurement confirms estimate
    - Tested on single run

Why it is of marginal relevance:

- Using 'average beam width' attenuates the effect: 30%→20%:

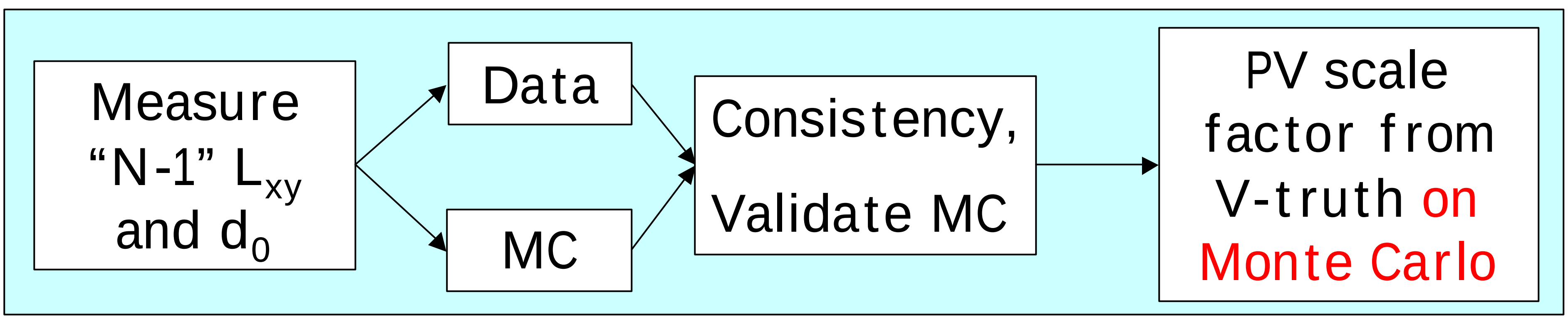
	σ [μm]	Pull [%]
L_{xy}	+0.5	+2%
d_0	+2	+6%

Other sources not investigated, however: not much of a concern for L_{xy}, relevant for d_0

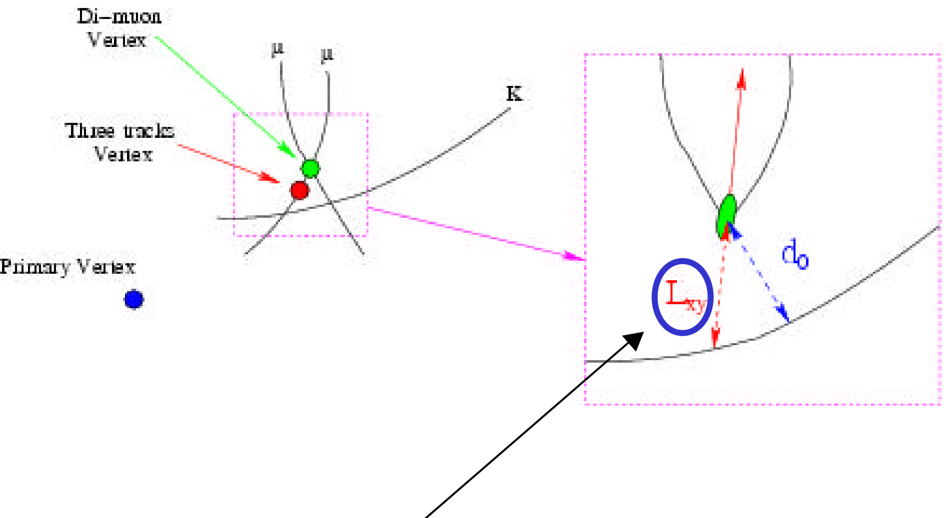
Bottom line

- d_0 pulls show effect of non unitarity of:
  - Beamline pulls
  - Secondary vertex pulls
- Restoring beamline pulls' unitarity is of marginal (2%) relevance for Lxy
- Let's move on to the secondary vertex!

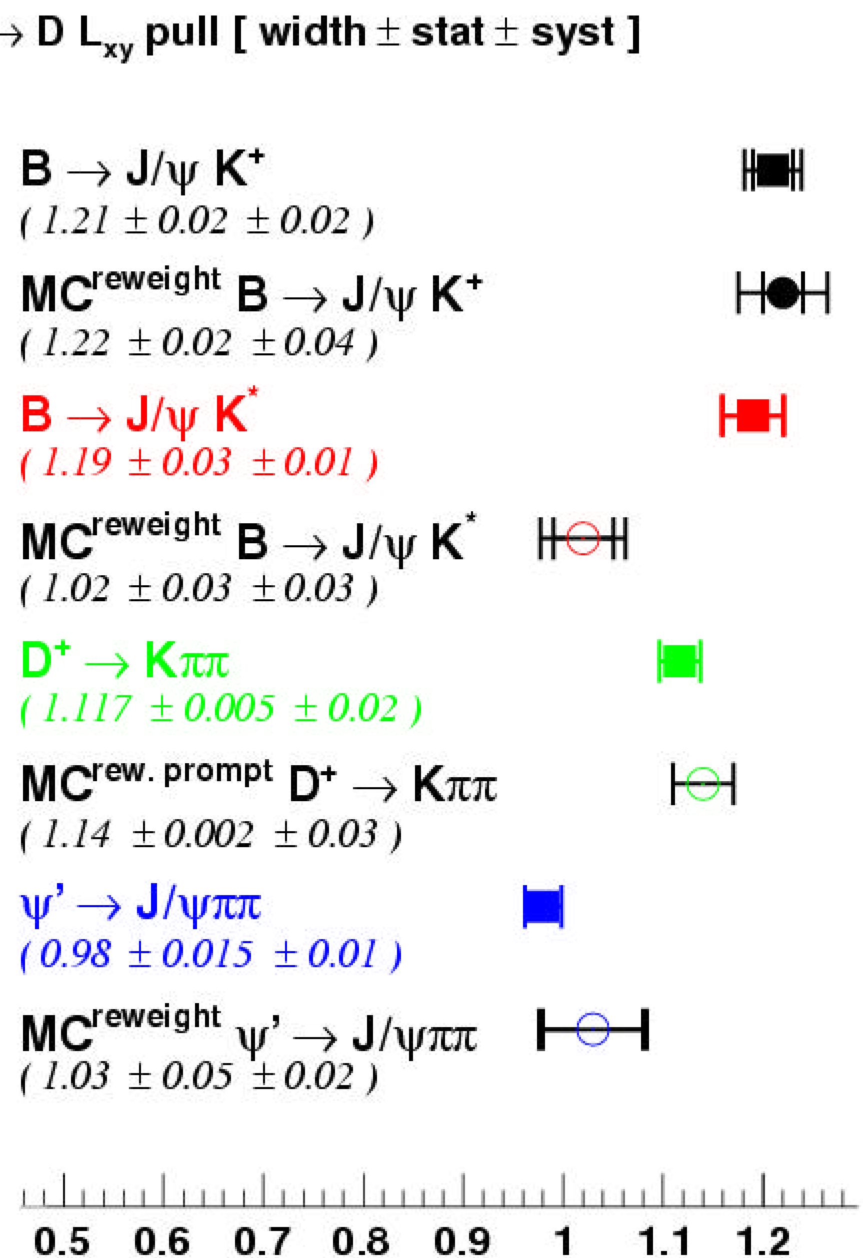
Secondary Vertex



“N-1” L_{xy}: data and MC



- Computed L_{xy} pulls for the various samples
- Compared to MC evaluation
- Pretty good agreement!
- MC seems to account for (possible) inter-sample variations and absolute scale of pulls!



Dependencies

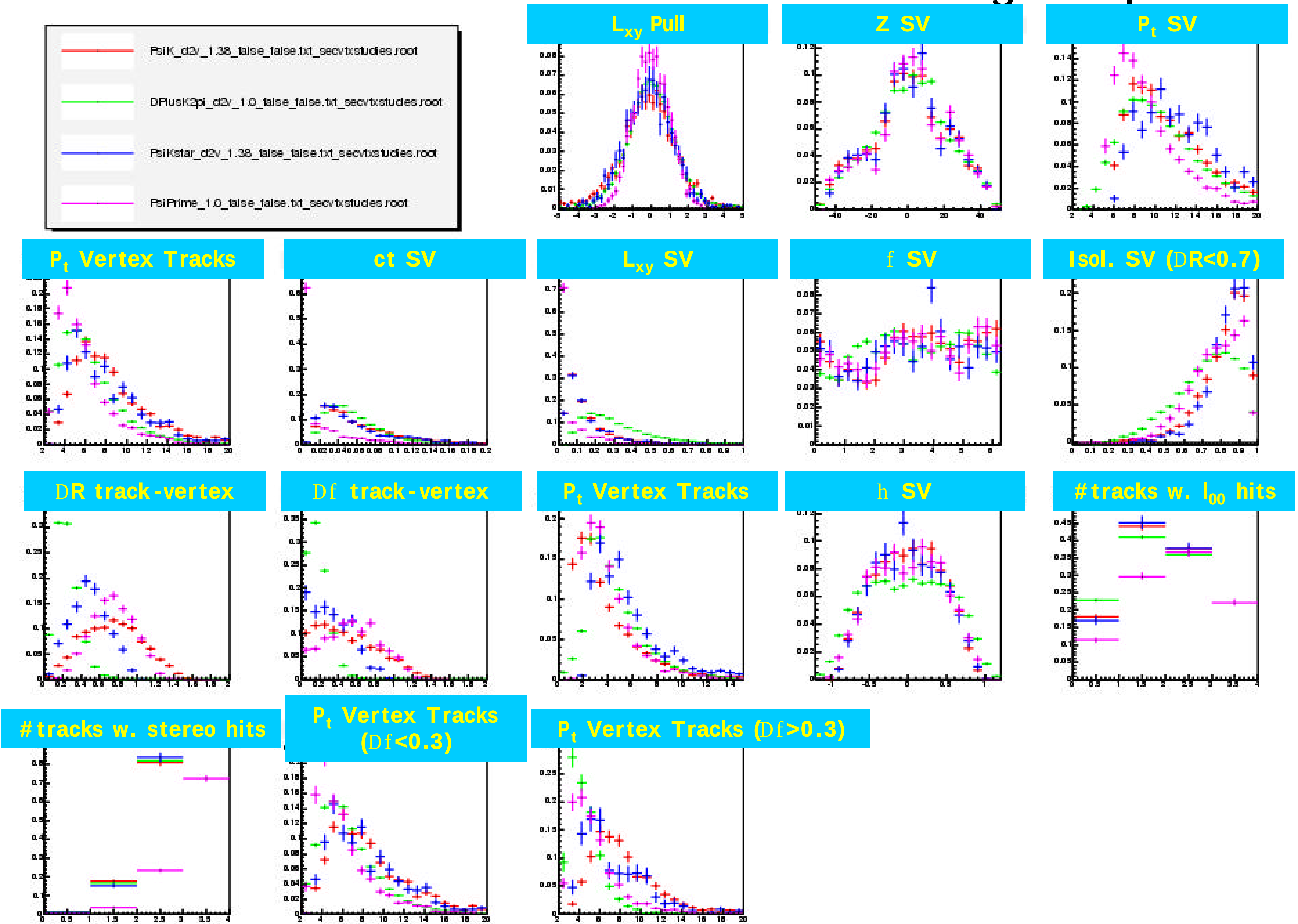
Look for evidence of dependencies on geometry, kinematics etc:

- Pick a suitable set of variables:

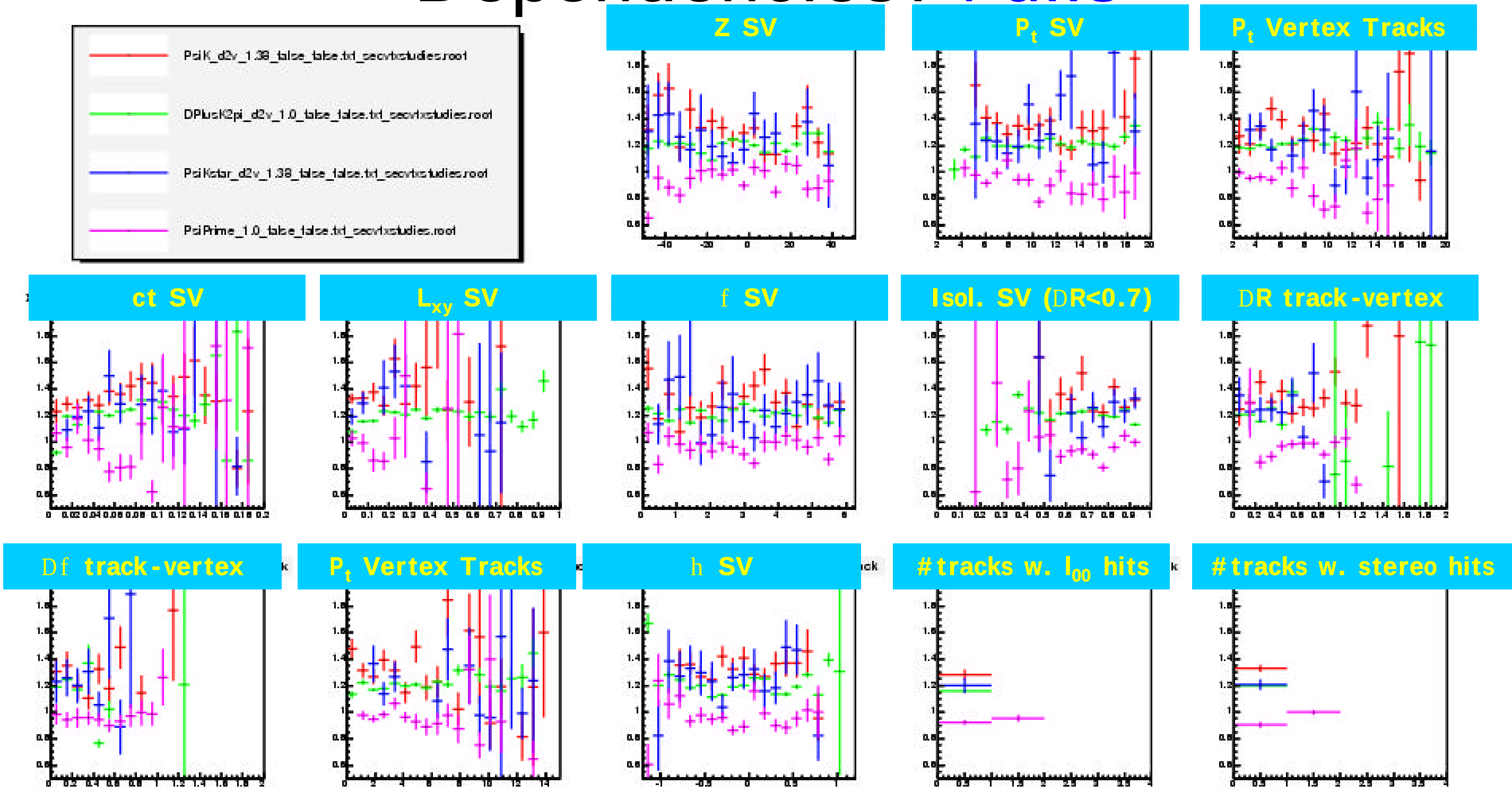
Z of SV	$\Delta\phi$ single track-rest of vertex
Pt of SV	Pt of single track
Combined Pt of tracks in SV	η of SV
Ct of SV	# tracks with L_{00} hits in SV
L_{xy} of SV	# tracks with stereo hits in SV
ϕ of SV	Combined Pt of tracks in SV ($\Delta\phi$<0.3)
Isolation of candidate B (ΔR<0.7)	Combined Pt of tracks in SV ($\Delta\phi$>0.3)
ΔR single track-rest of vertex	

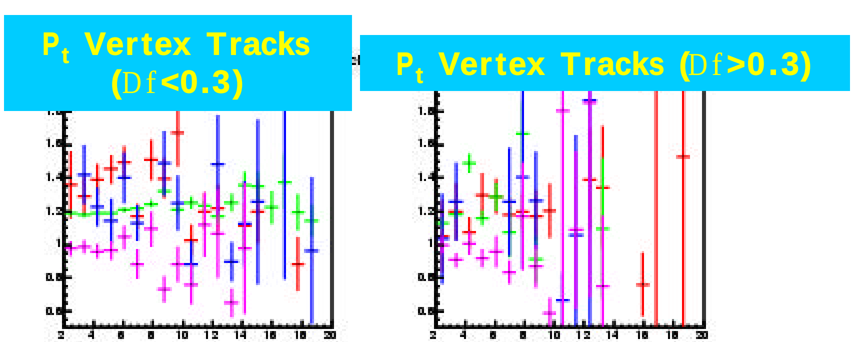
- Compare how various samples probe them
- Check pull vs variables

How different are distributions among samples?



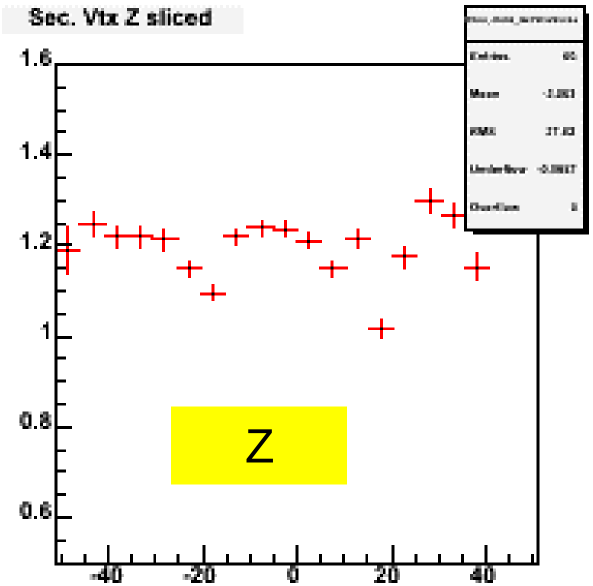
Dependencies? Pulls

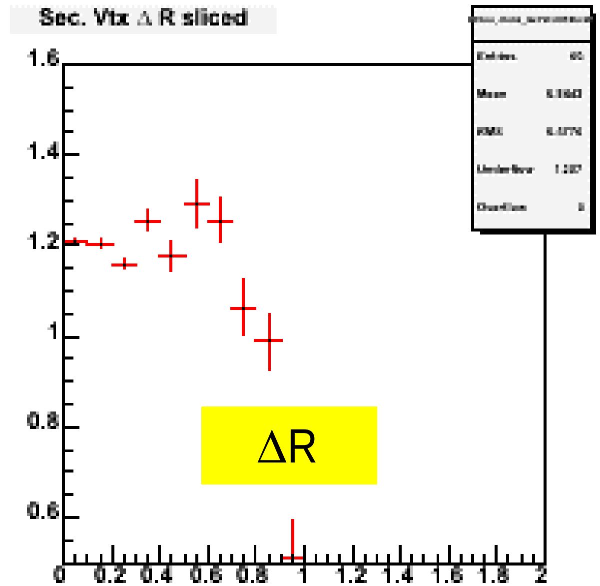


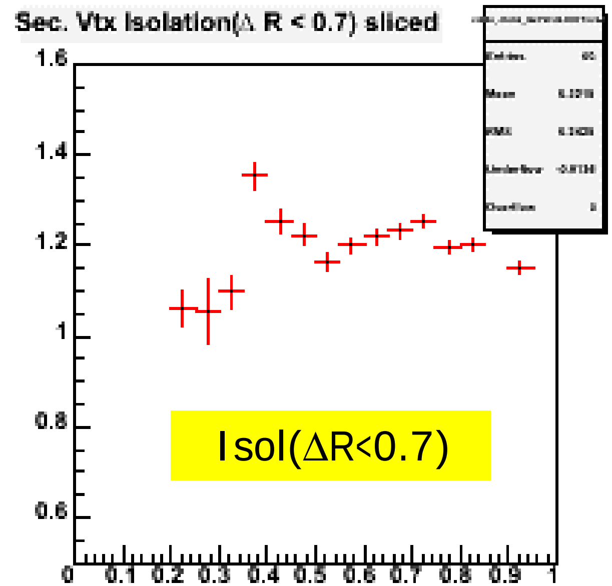


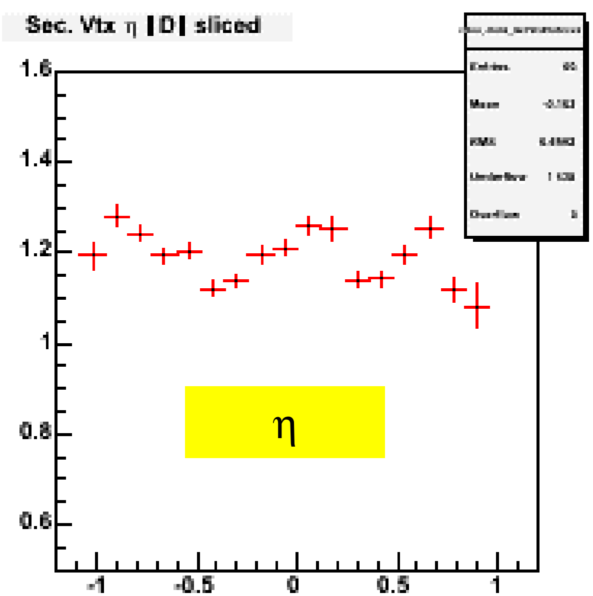
Just an overview: most interesting repeated next...

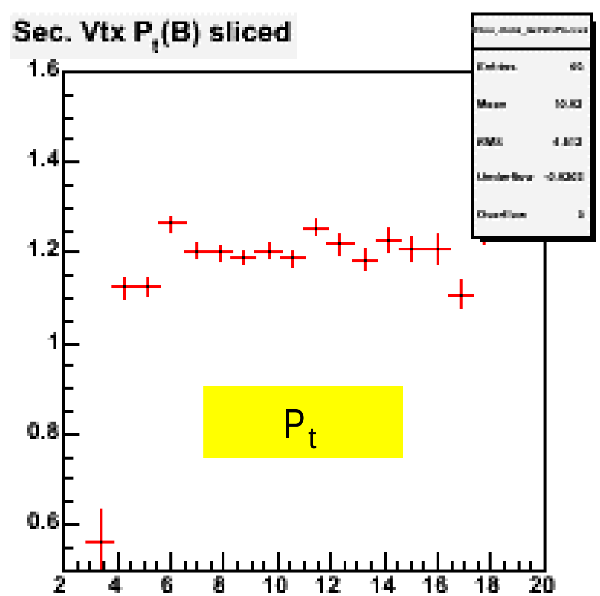
SV scale factor: details (à la CDF7500)







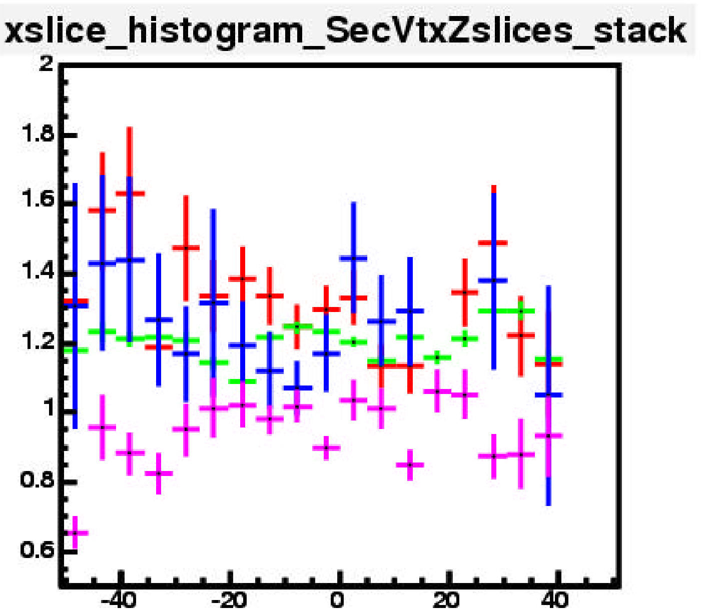


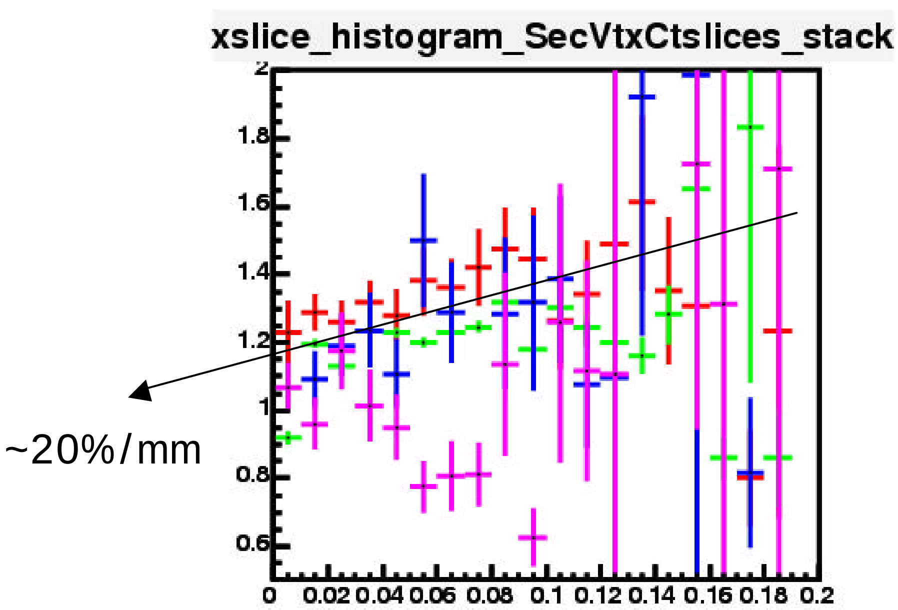


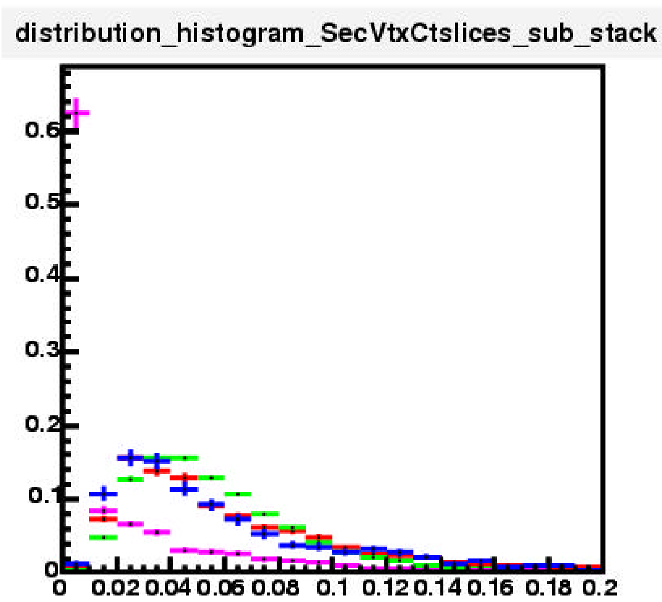
Non-statistical fluctuations dominated by fit model!

Selected Plots

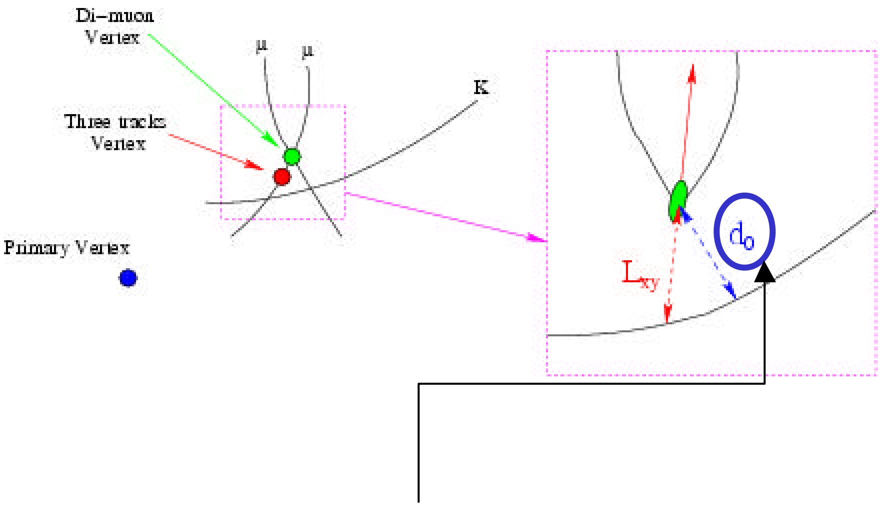
- We expect some variation as a function of Z (for instance, because of detector structure)
- Ct dependence?
- All variations well within ±10% when integrated over kinematics



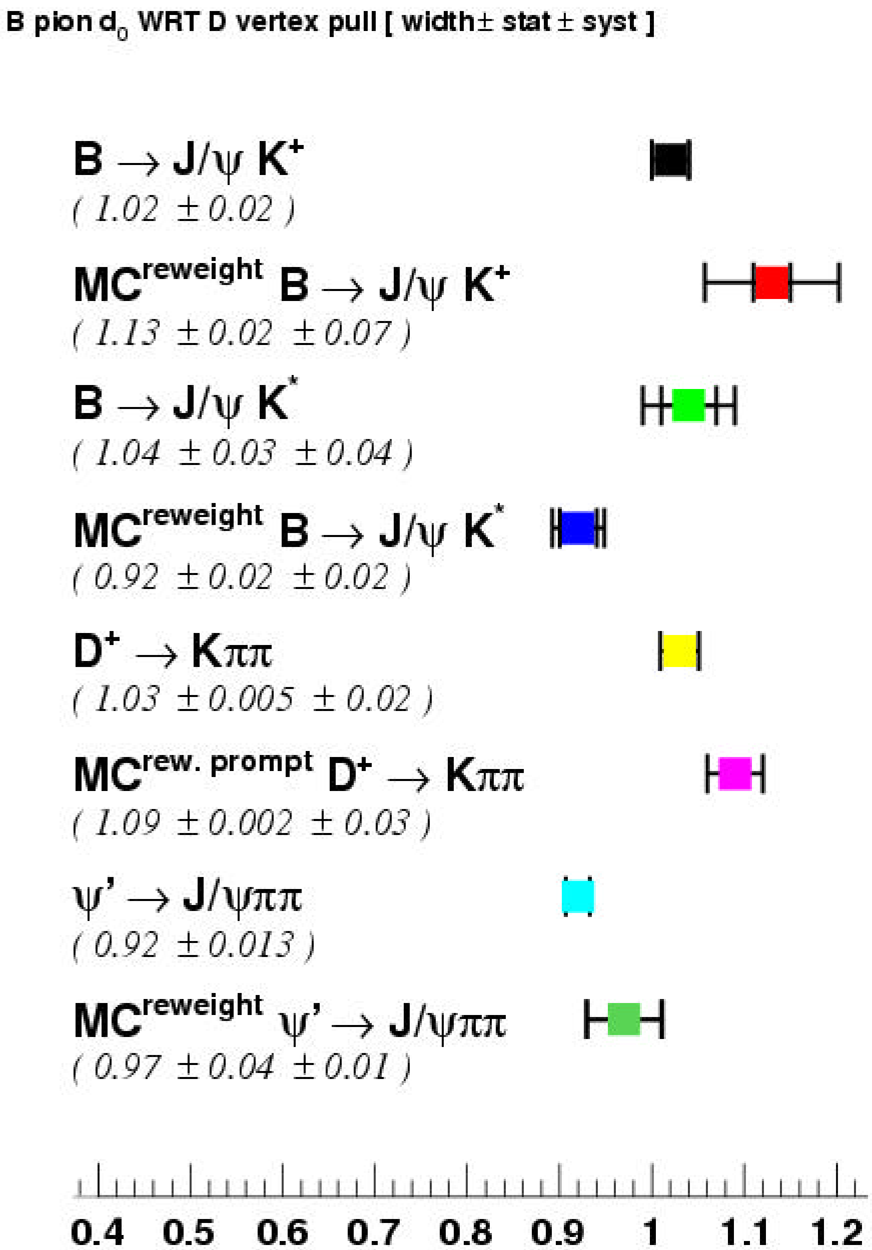




"N-1" d_0: a cross check!



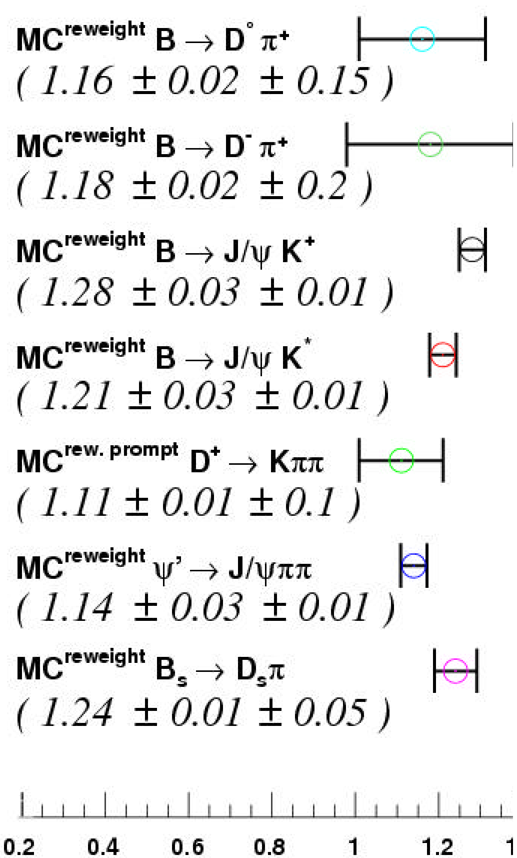
- Compute also d_0 pulls for the various samples
- Compare to MC evaluation
- Pretty good agreement here as well!
- Good job with the realistic simulation+reweighting!



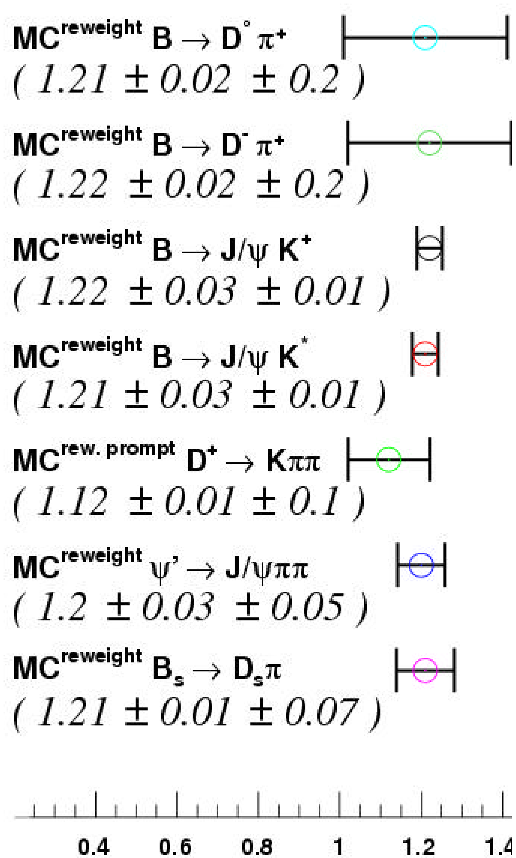
SV scale factor from MC

Now that we know to what extent we can rely on MC, let's look at reconstructed-truth!

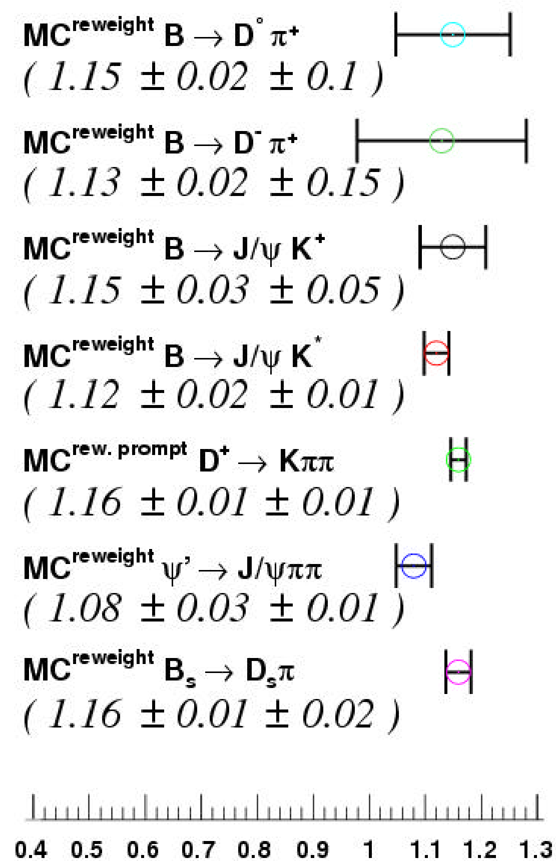
SV_{reco}-Sv_{truth}: X



SV_{reco}-Sv_{truth}: Y



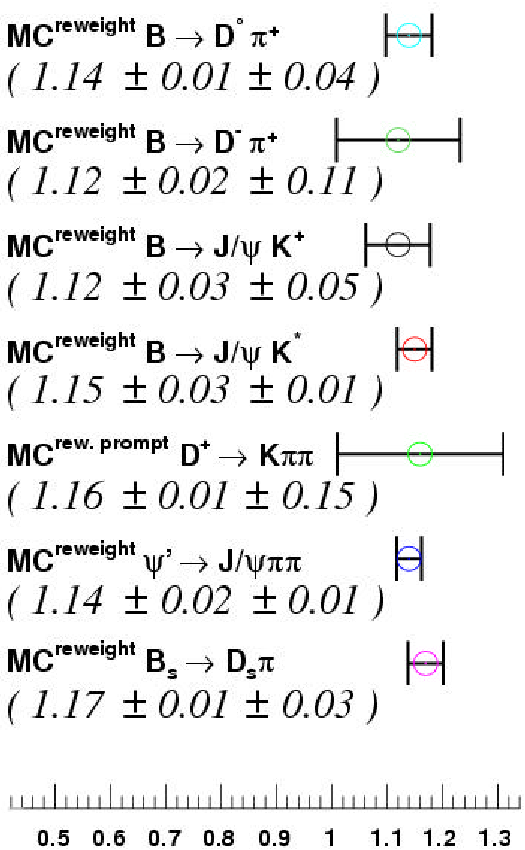
SV_{reco}-Sv_{truth}: Z



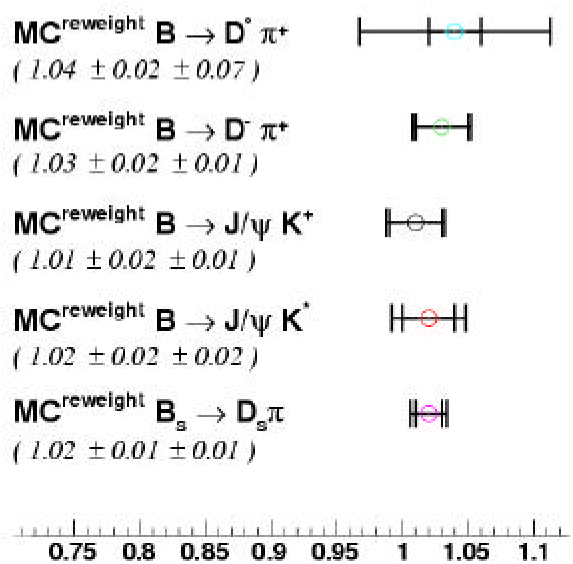
SV scale factor from MC

...projected along P_t, and broken down into PV and SV contribution:

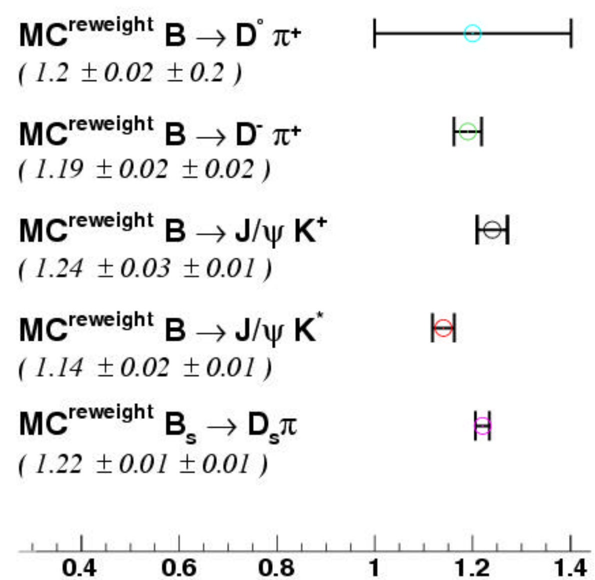
L_{xy}^{reco}-L_{xy}^{truth}



L_{xy}^{reco}-L_{xy}^{truth}: PV



L_{xy}^{reco}-L_{xy}^{truth}: SV



- Amazingly stable and consistent with X, Y and Z!
- Variations well within 10%

SV Pull Strategy

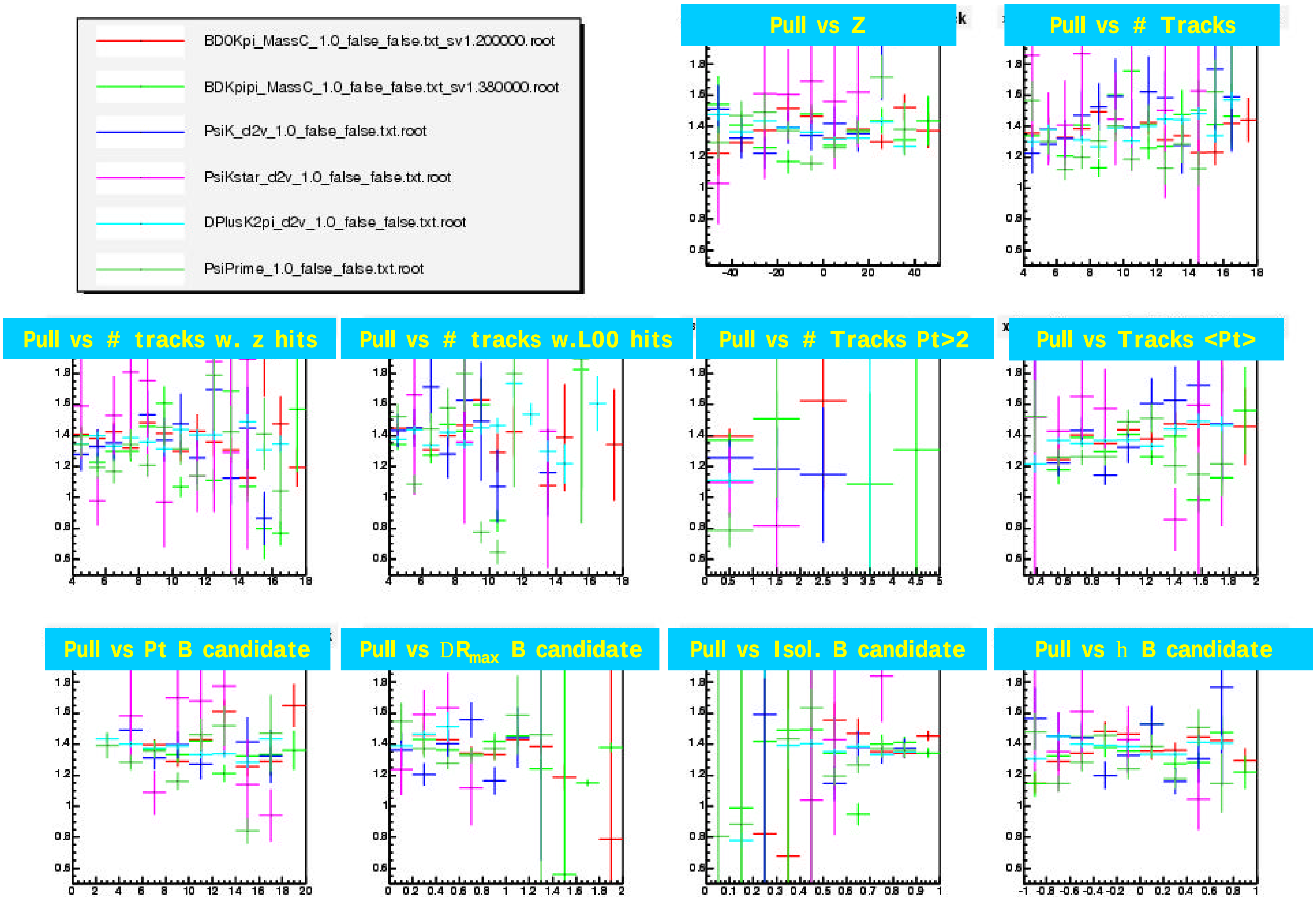
- “N-1” d_0 and L_{xy} validate montecarlo
- Dependencies studied in “N-1” d_0/L_{xy} are mostly due to choice of variables (to be confirmed by last bullet!)
- MC predicts a SV scale factor of 1.2±10%
- Before blessing: dependencies of MC scale factor

Conclusions

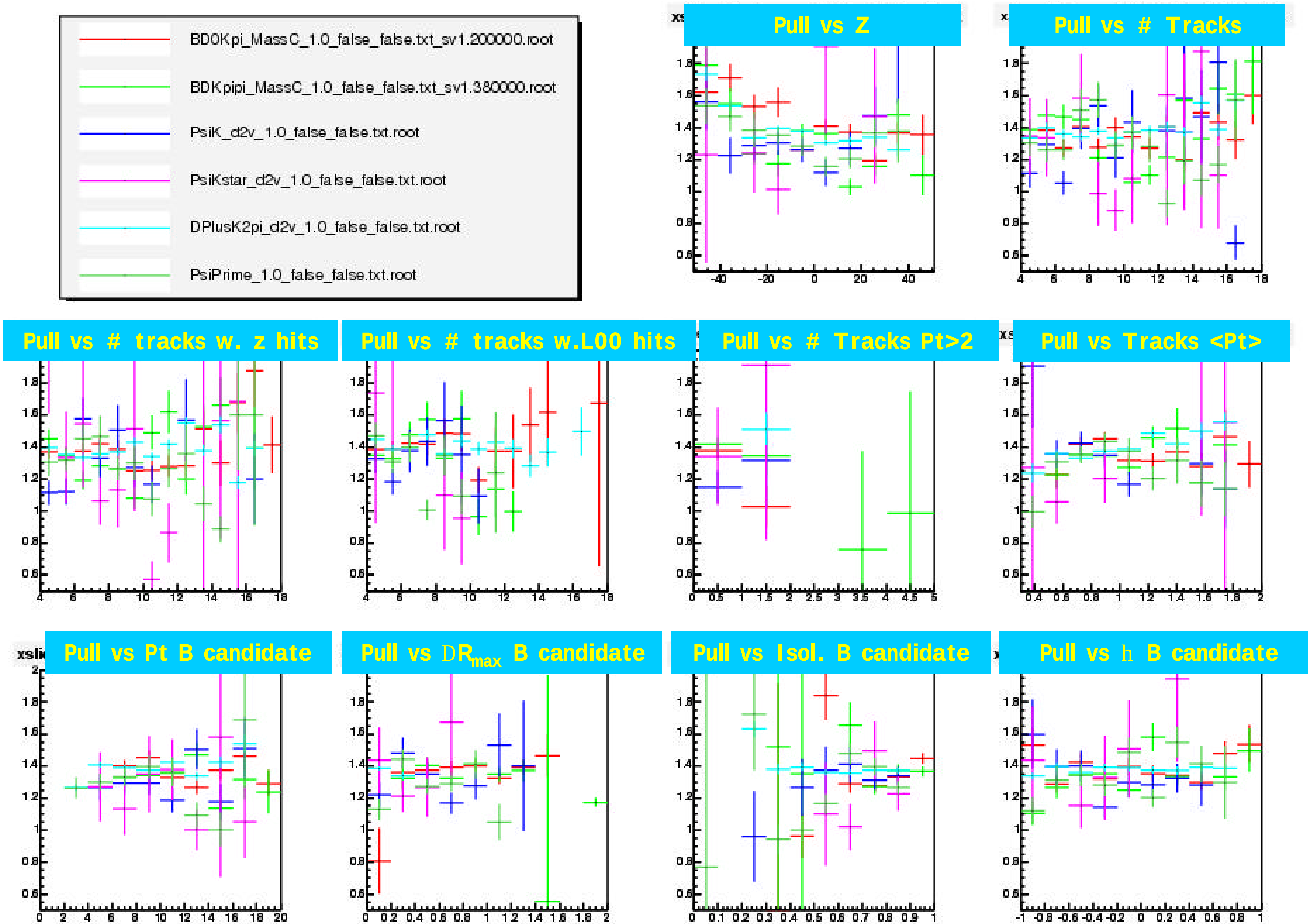
- Identified a procedure to determine all the relevant scale factors
- Three scale factors:
  - PV: 1.38±5% (based solely on data!)
  - Beamline: 1.0 (not really, but not relevant for L_{xy})
  - SV: 1.2 ±10% (from MC, after validation)
- Systematics mostly from inter-sample variation/neglected dependancies
- Re-running through all the samples to finalize numbers, stabilize statistics etc.

Backup

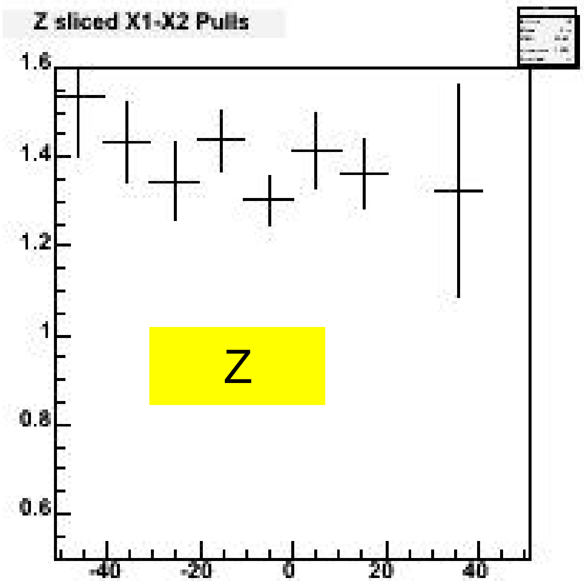
PV scale factor dependencies (Y)

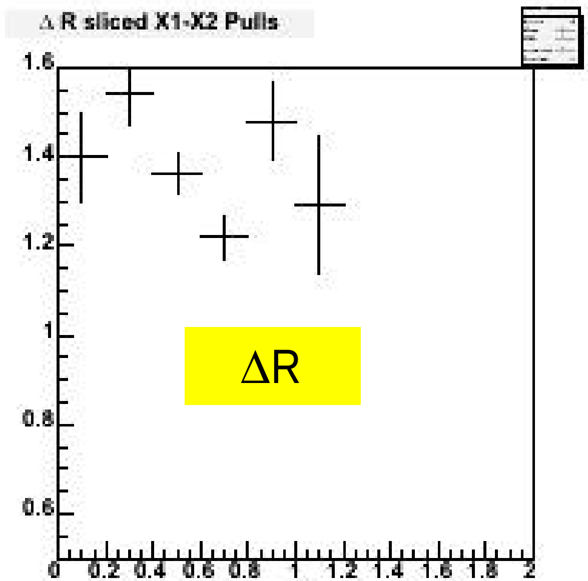


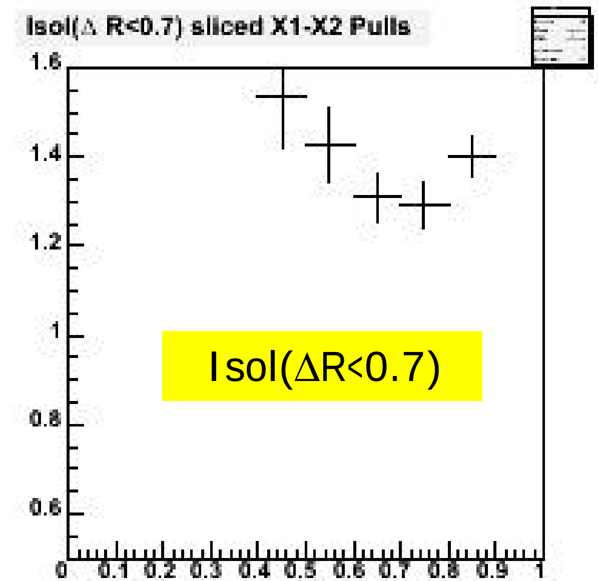
PV scale factor dependencies (Z)

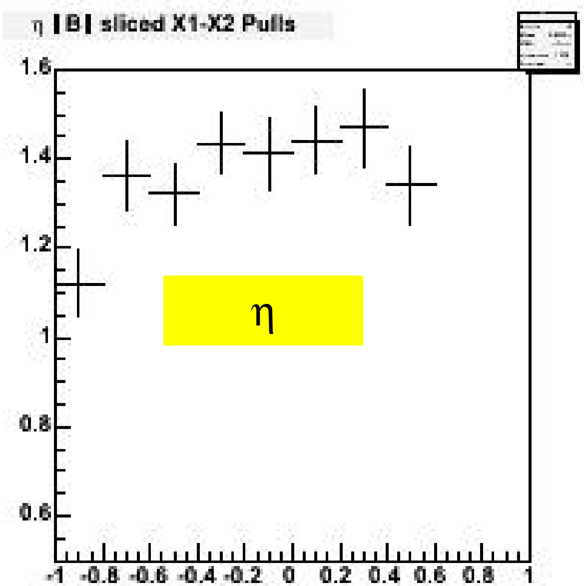


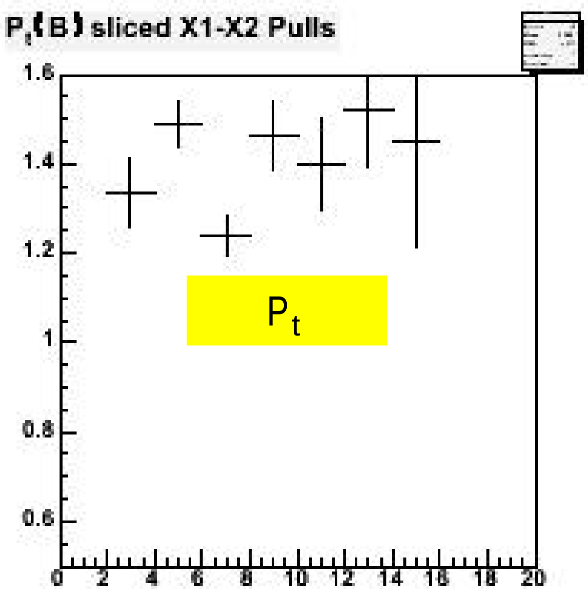
PV scale factor for ψ': details (à la CDF7500)





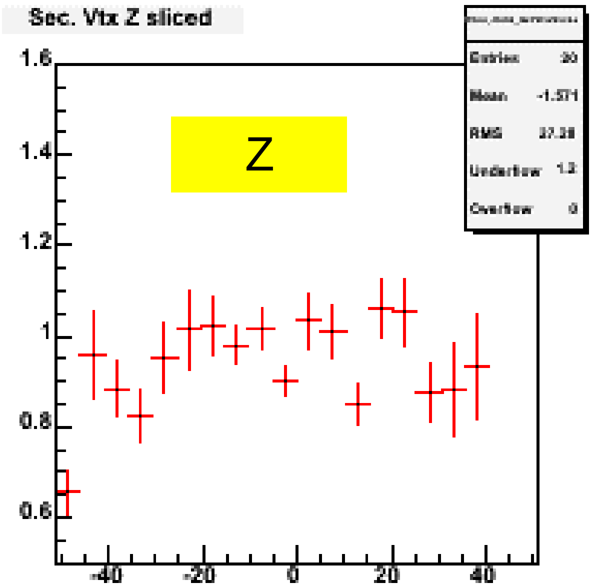


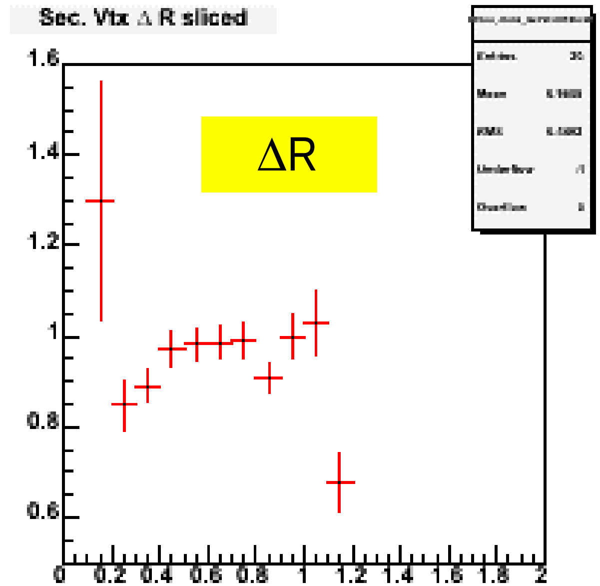


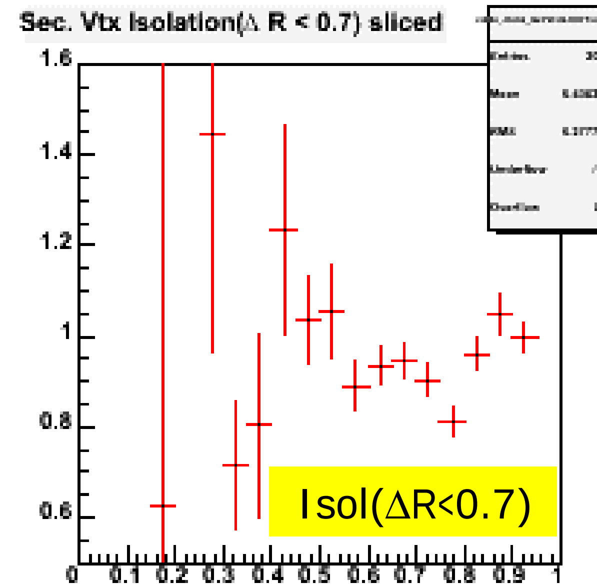


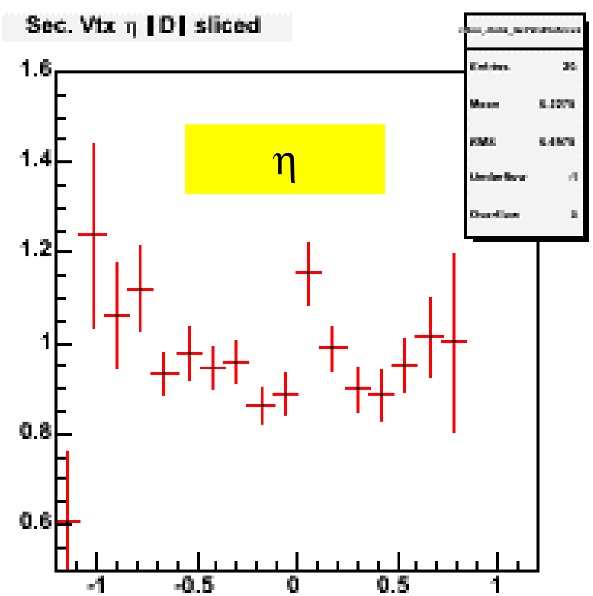
Non-statistical fluctuations dominated by fit model!

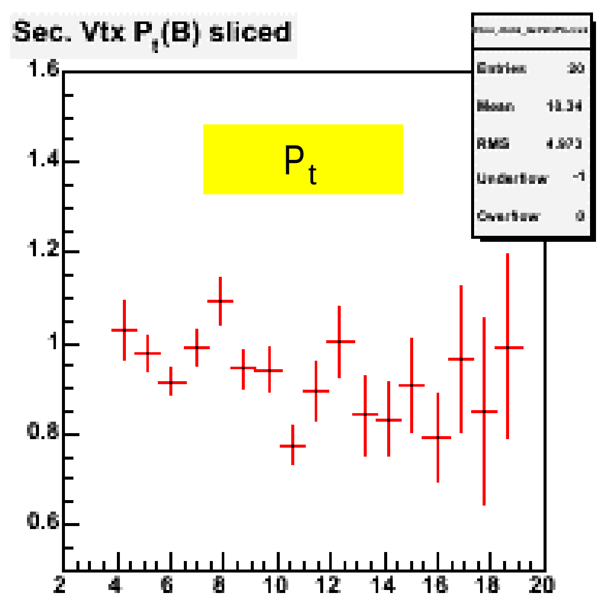
SV scale factor for ψ’: details (à la CDF7500)









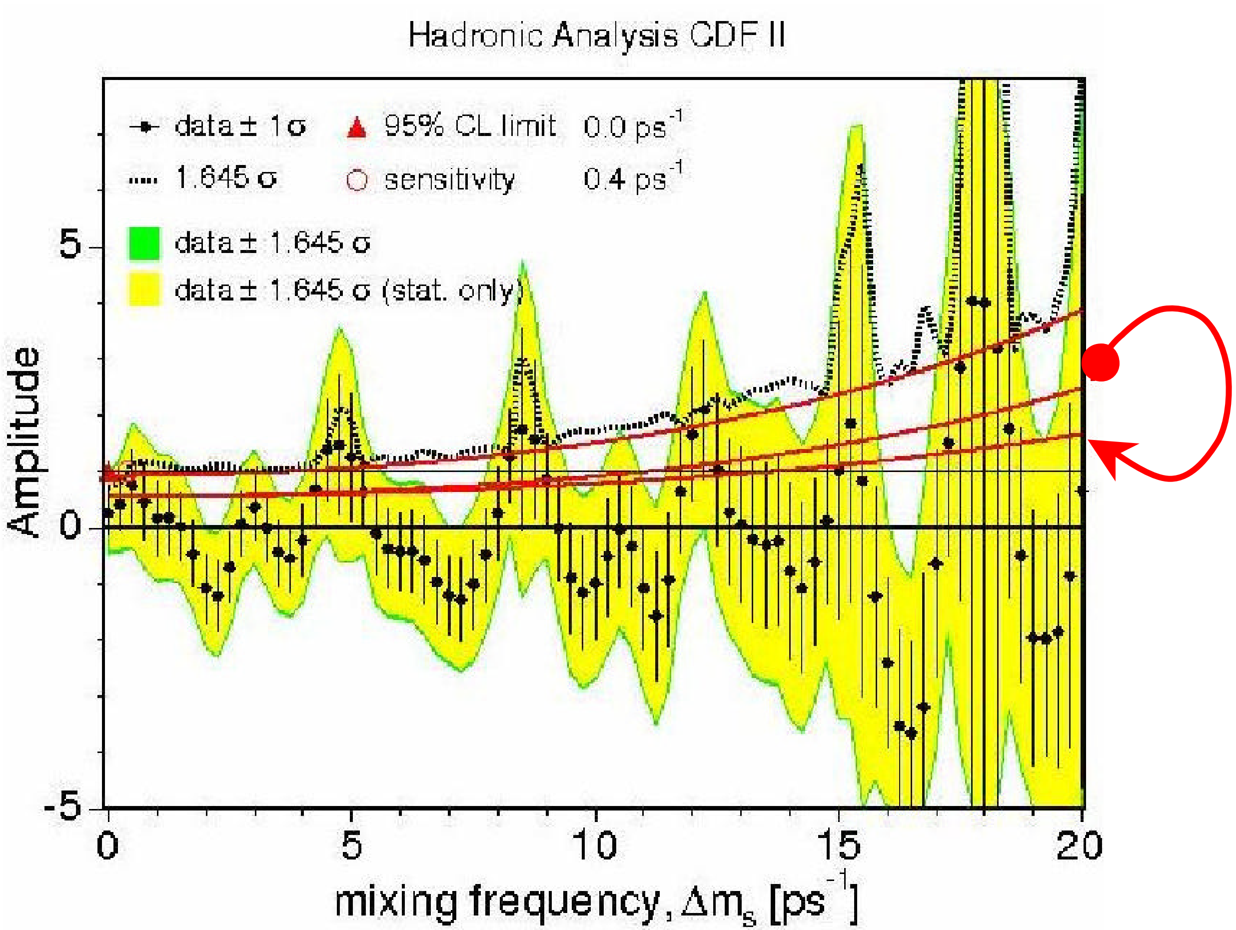


Non-statistical fluctuations dominated by fit model!

What do we gain?

Euphemism

1. 15-20% In vertex resolution!
2. Better control of systematics (hard to evaluate)
3. Correct EbE resolution (it is not clear that it is correct now)



- Red arrow is the effect of 1. Only
- Point 2. Affects mostly the green area (tiny ?)
- Point 3. Has an effect qualitatively similar to 1., but hard to evaluate

Hadronic analysis systematics

source	selected Δm_s scan points				
	0.0	5.0	10.0	15.0	20.0
$B_s \to D_s K$ level	0.019	0.024	0.030	0.037	0.047
dilution scale factors	0.143	0.168	0.205	0.254	0.314
dilution templates	0.119	0.147	0.178	0.211	0.246
fraction of Λ_b	0.014	0.009	0.009	0.011	0.012
Punzi term for σ_{ct}	0.009	0.008	0.022	0.033	0.030
dilution of $B \to DX$	0.025	0.001	0.000	0.000	0.001
σ_{ct} scale factor	0.000	0.024	0.061	0.090	0.144
usage of L00 in bias curve	0.001	0.001	0.001	0.001	0.001
Bs lifetime uncertainty	0.001	0.001	0.001	0.001	0.001
reweighted p_t spectrum	0.001	0.001	0.001	0.001	0.001
non-Gaussian tails in ct resol.	0.001	0.027	0.052	0.078	0.104
neglect B^0 in fit	0.039	0.036	0.033	0.031	0.028
effect of $\Delta\Gamma/\Gamma = 0.2$	0.028	0.028	0.028	0.028	0.028
Total systematic	0.195	0.232	0.289	0.357	0.443
Statistical	0.393	1.129	1.010	2.652	5.281