



A New StEvent Based Vertex Fitter

Thomas Ullrich, ITTF Meeting, March 6-7

- Robust Fitting
- Strategy and Algorithm
- The Right Weights
- SCAN for seeds
- Results
- CPU-Time
- Outlook

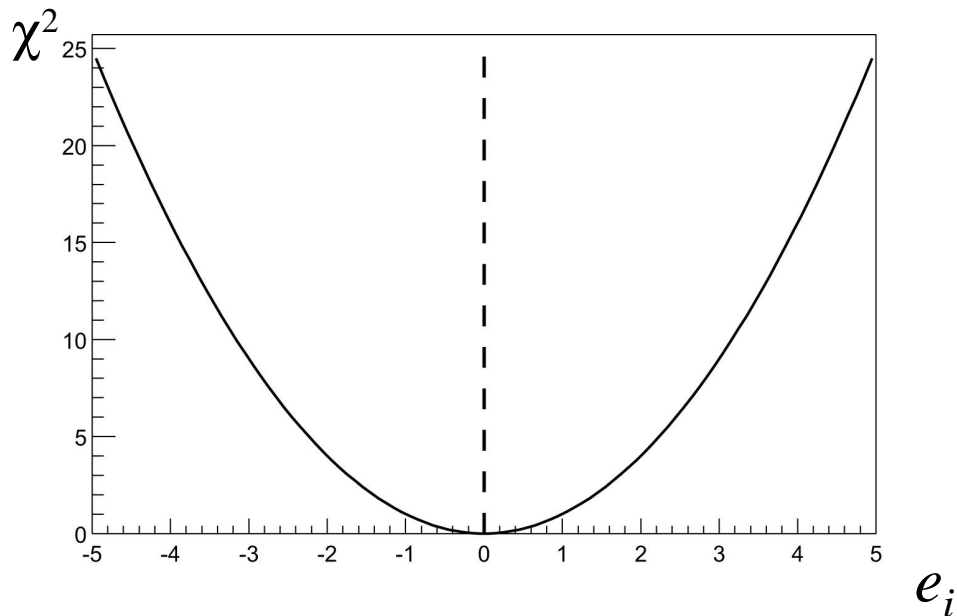
Robust Fitting

- In case of a background free set of points the best estimator can be obtained by minimizing the χ^2 function (LSM):

$$L = \frac{1}{N} \sum_{i=0}^N w_i e_i^2 \quad \text{where usually } w_i = \frac{1}{\mathbf{s}_i^2}$$

- This fails (more or less badly) if the sample is not background free

Outliers are heavily weighted and distort the χ^2 . The fitter will always try to minimize the background but is not sensitive to the actual data points any more.



Robust Fitting (continued)

- A common way out is outlier removal
 - Dangerous for simple sharp cuts since “N” varies (because points with $e > e_{cut}$ is not counted)
 - Fitting algorithm cannot deal with discontinuities in the derivatives
 - Usually: loss of precision and unreliable results
 - e_{cut} often arbitrary and depends on background level
 - The best approach is to modify L such that outliers are removed smoothly, i.e. they get lower weights dependent on their distance.
 - Gross-error model from J.W.Tukey (Tukey weights) but weights depend on background level (S/B) which has to be known in advance
 - Much simpler and almost as effective is:

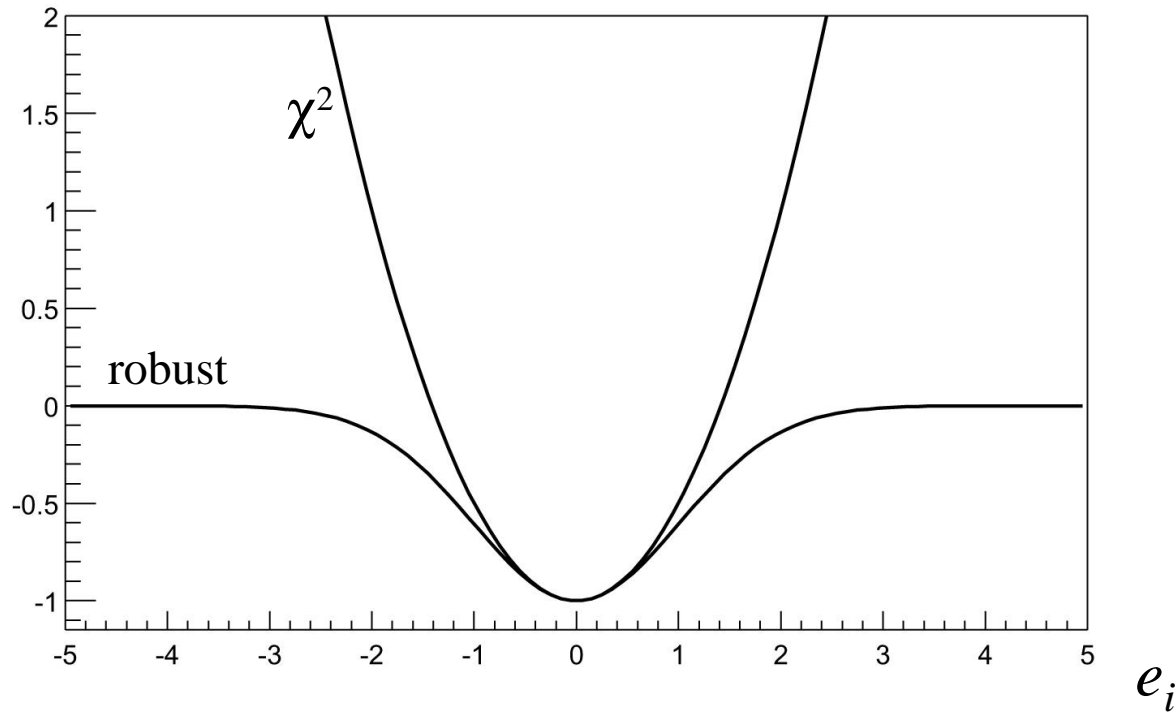
$$L = -\sum_i \exp(-e_i^2 / 2\mathbf{s}_i) = -N + \sum e_i^2 / 2\mathbf{s}_i - \frac{1}{2} \sum e_i^4 / 4\mathbf{s}_i^4 + \dots$$

- First term again the LSM term with $w_i = (2\mathbf{s}^2)^{-1}$



Robust Fitting (continued)

- Experiences are that the ‘Gaussian’ L is rather insensitive to the errors chosen (\mathbf{s}_i) \Rightarrow **robust fit**



$$L = -\sum_i \exp(-e_i^2 / 2\mathbf{s}_i) = -N + \sum e_i^2 / 2\mathbf{s}_i - \frac{1}{2} \sum e_i^4 / 4\mathbf{s}_i^4 + \dots$$

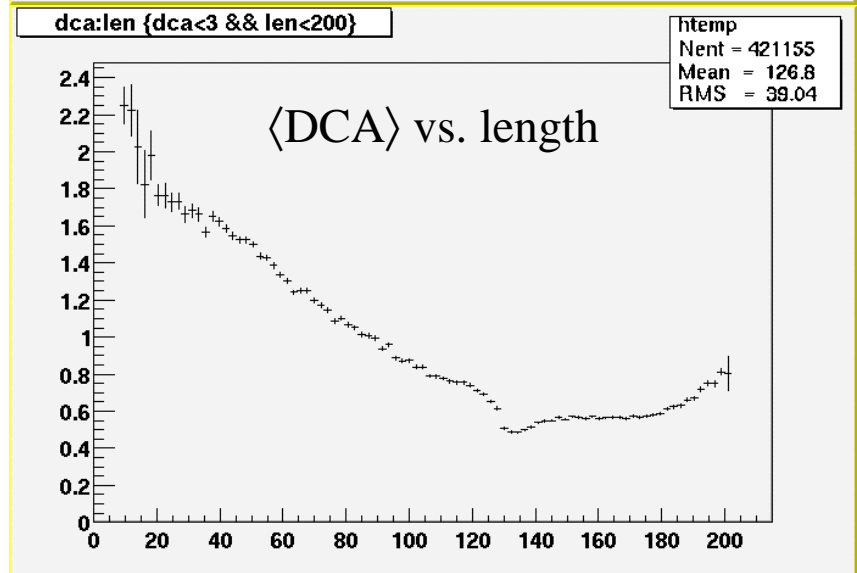
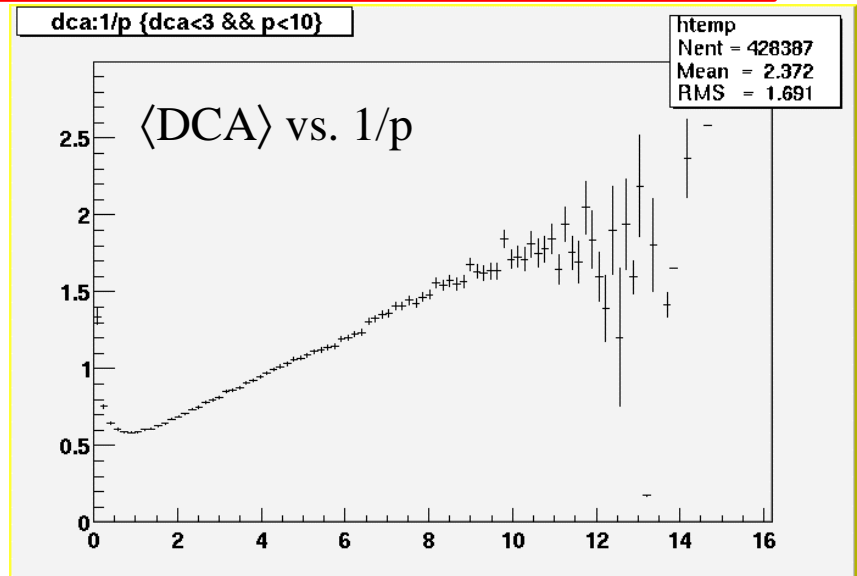
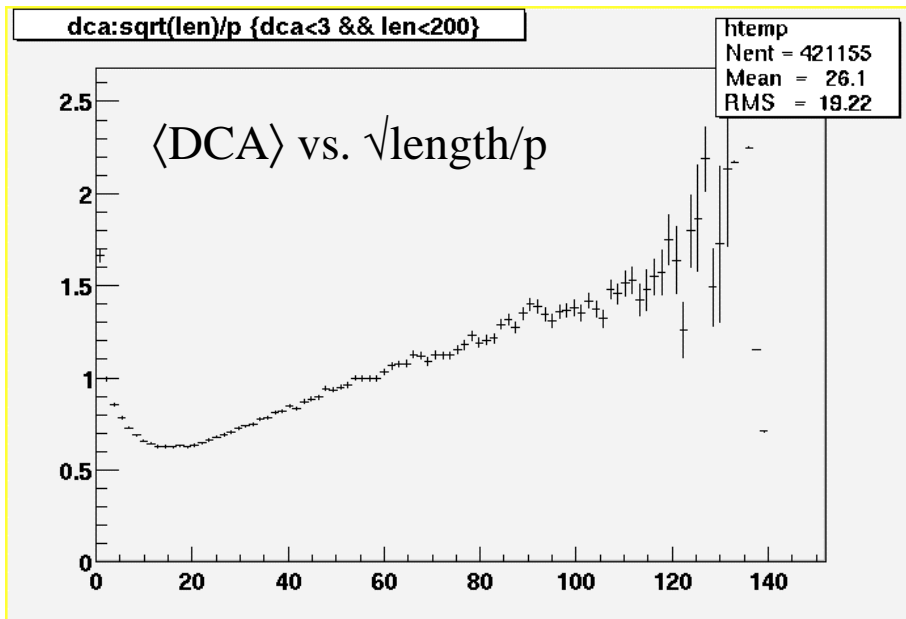
Strategy and Algorithm

- Use existing minimization package => MINUIT (TMinuit)
- Robust potential allows loose cuts on track quality
- Basic idea:
 - Store vector of helices of good tracks (fit OK && $n_{\text{fit}} > 9$)
 - Seed finding
 - Use Minuit SCAN command to find best seed for z ($x=y=0$)
 - Use slightly larger potential width ($3x$)
 - SCAN steps along z from $-2m$ to $2m$ and find smallest L
 - or
 - Use external seed (BBC, ZDC, whatever)
 - In any case same SCAN again in $z_{\text{seed}} \pm 5$ cm (width = 1)
 - resolution of ZDC or BBC isn't better than that
 - Run Minuits MIGRAD to find vertex (x, y, z)
 - User function `f cn` calculates L



The Right Weights – Hijing + TRS

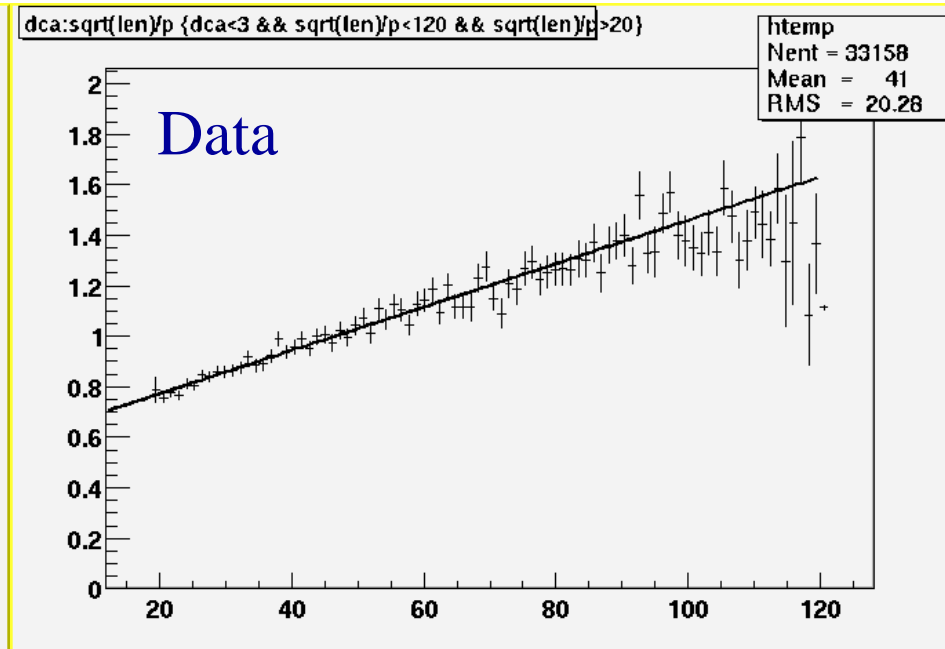
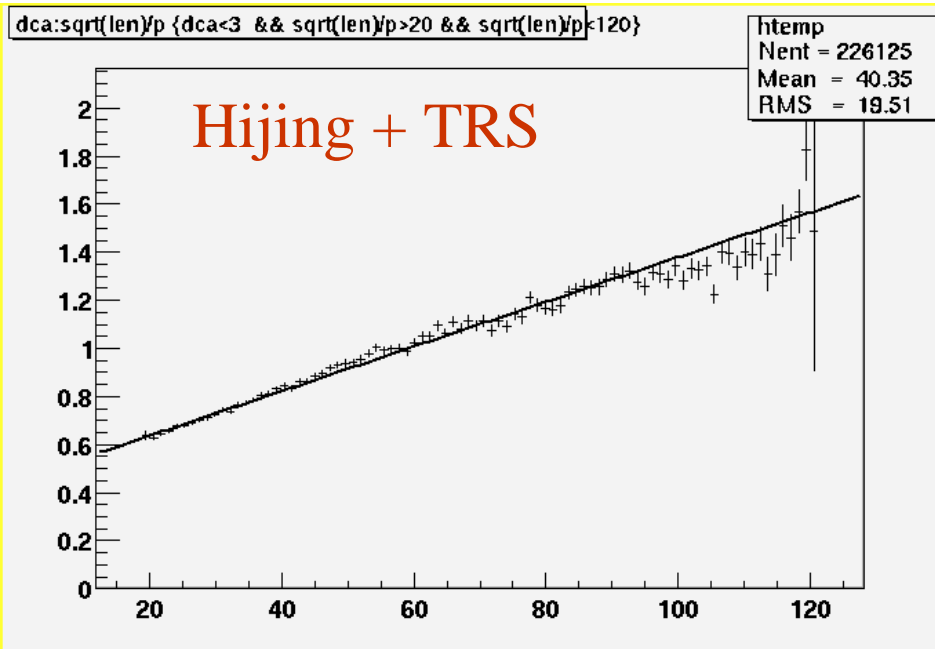
- Weighting with
 - Momentum p
 - Track length (1st to last point)
 - Both
 - or constant



Theory: $\langle \text{DCA} \rangle = \text{const} \cdot \sqrt{\text{len}}/p$



The Right Weights: Hijing + TRS vs. Data 2001



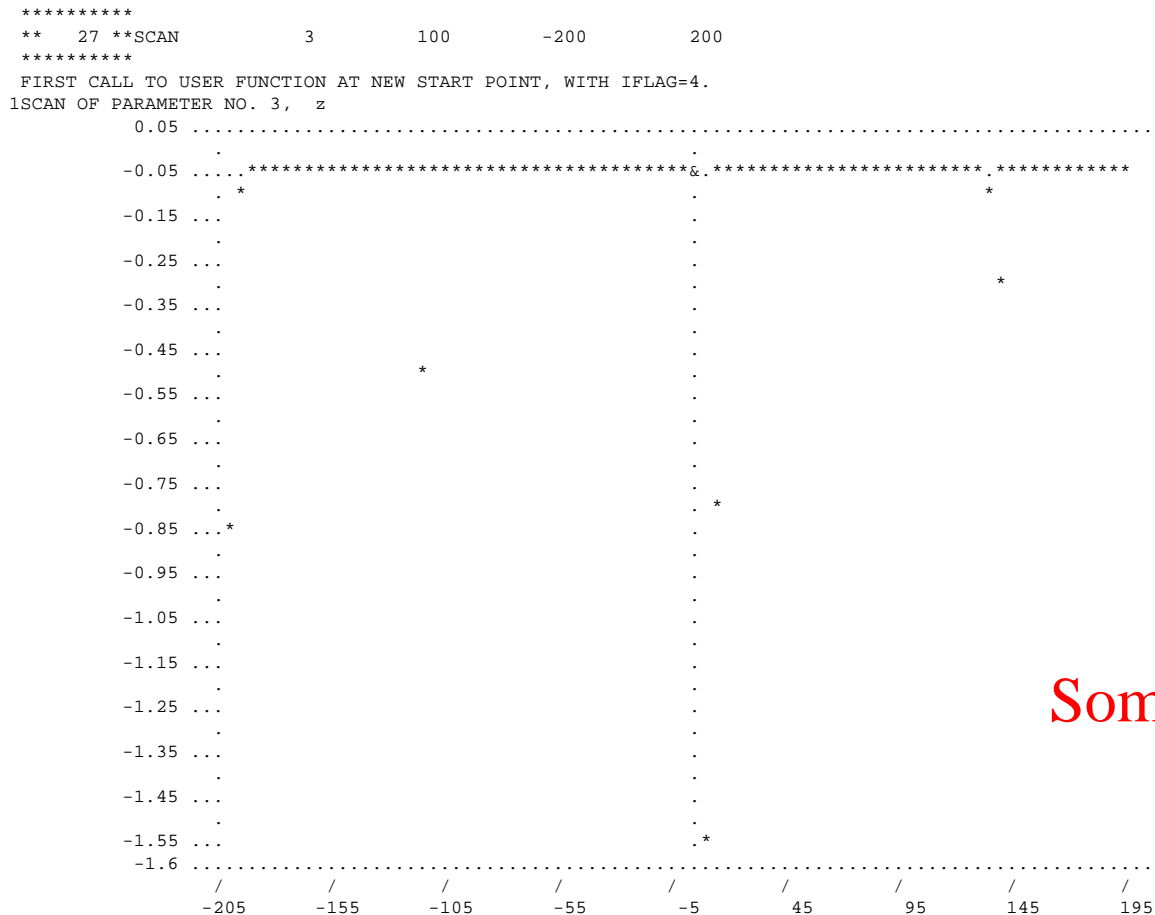
Final error: $\sigma_{DCA} = 0.45 + 0.0093 \sqrt{\text{length}/p}$ (Hijing + TRS)
 $\sigma_{DCA} = 0.60 + 0.0086 \sqrt{\text{length}/p}$ (data 2001)

Ignore the strange behavior at low and high values of $\sqrt{\text{length}/p}$

Note: all tracks with $p > 10$ have VERY bad DCA resolution (not real anyhow)



SCAN to find z_{seed} (MC continued)



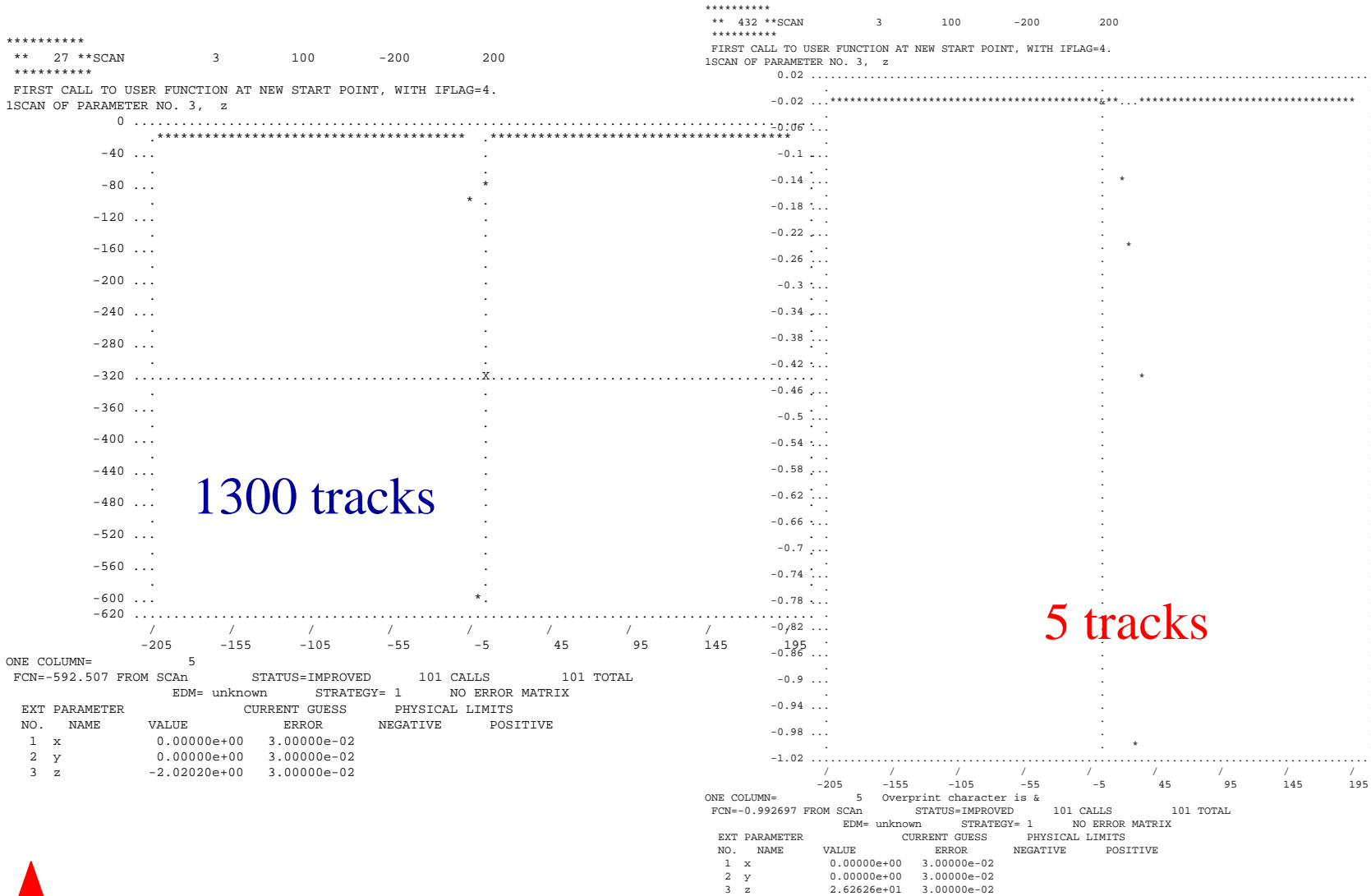
Some local minima

```

5 Overprint character is &
FCN=-1.54097 FROM SCAN      STATUS=IMPROVED      101 CALLS      101 TOTAL
      EDM= unknown      STRATEGY= 1      NO ERROR MATRIX
EXT PARAMETER      CURRENT GUESS      PHYSICAL LIMITS
NO.  NAME      VALUE      ERROR      NEGATIVE      POSITIVE
  1  x      0.00000e+00      3.00000e-02
  2  y      0.00000e+00      3.00000e-02
  3  z      6.06061e+00      3.00000e-02
  
```



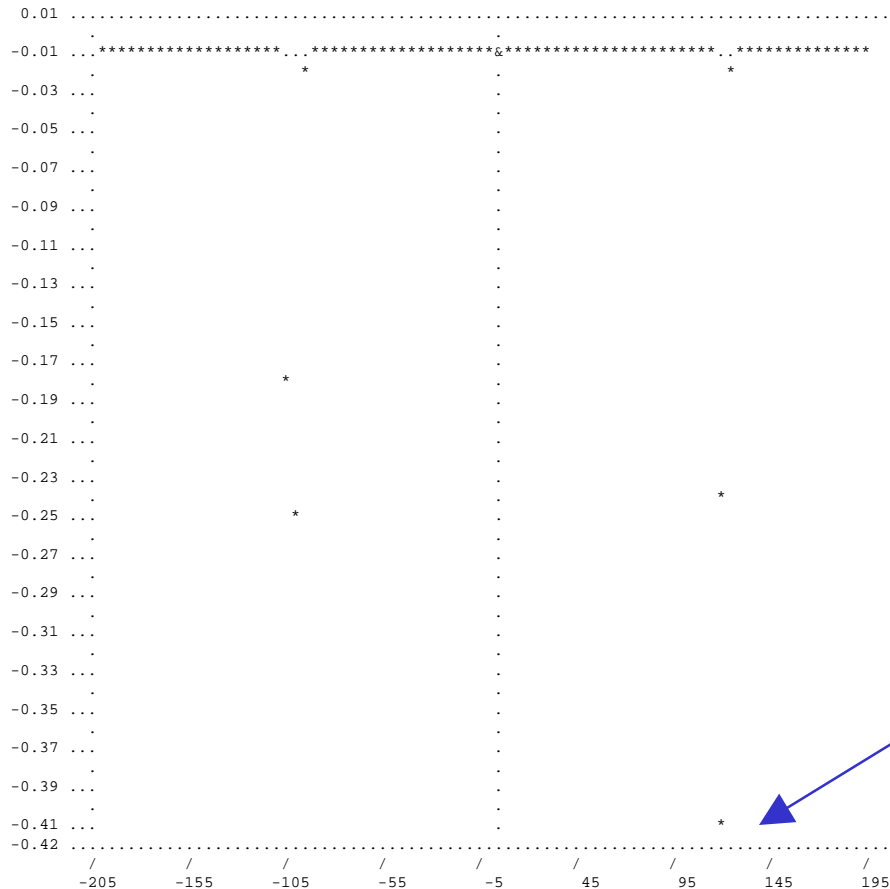
SCAN to find z_{seed} (Data 2001 continued)



SCAN to find z_{seed} (Data 2001 continued)

```
*****
** 472 **SCAN      3      100      -200      200
*****
```

```
FIRST CALL TO USER FUNCTION AT NEW START POINT, WITH IFLAG=4.
1SCAN OF PARAMETER NO. 3, z
```



22 tracks – pileup ?

On DST: no vertex found

this finder

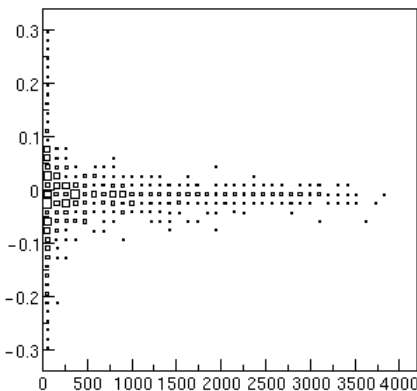
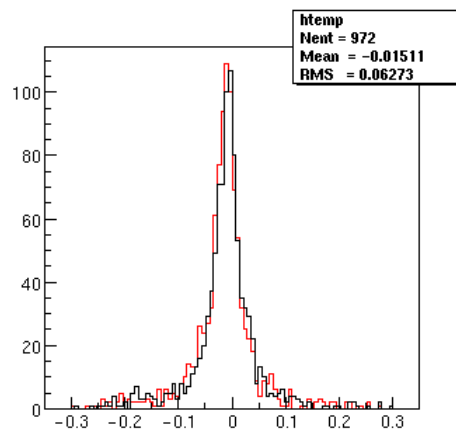
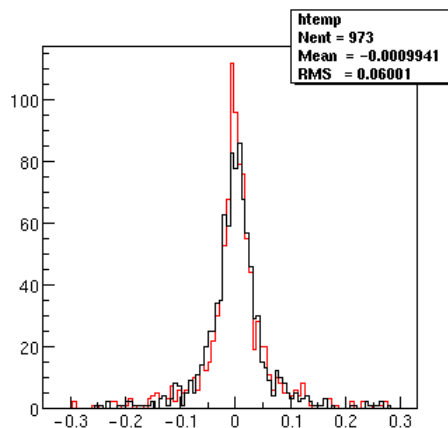
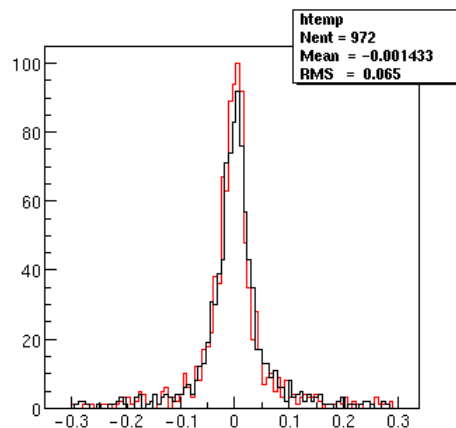
ONE COLUMN= 5 Overprint character is &

```
FCN=-0.400839 FROM SCAN STATUS=IMPROVED 101 CALLS 101 TOTAL
EDM= unknown STRATEGY= 1 NO ERROR MATRIX
```

EXT PARAMETER NO.	NAME	VALUE	CURRENT GUESS		PHYSICAL LIMITS	
			ERROR	NEGATIVE	POSITIVE	
1	x	0.00000e+00	3.00000e-02			
2	y	0.00000e+00	3.00000e-02			
3	z	1.19192e+02	3.00000e-02			



Results (MC)



HIJING + TRS min bias

- EVR+LMV as stored in DST
- new vertex refitted with StVertexFitter
 - ◆ without seed (own seed finder)
 - ◆ 1000 events only
 - ◆ not optimized for speed yet
- Brief summary:
 - ◆ efficiency similar to EVR
 - ◆ higher than LMV
 - ◆ slightly higher resolution



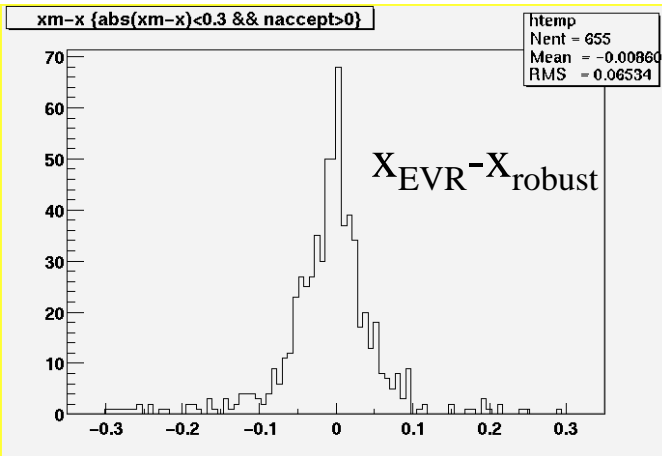
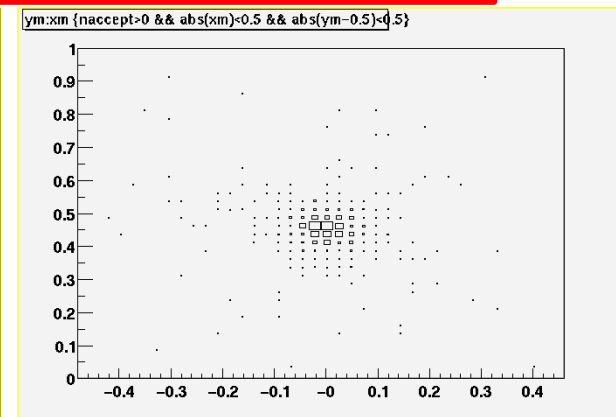
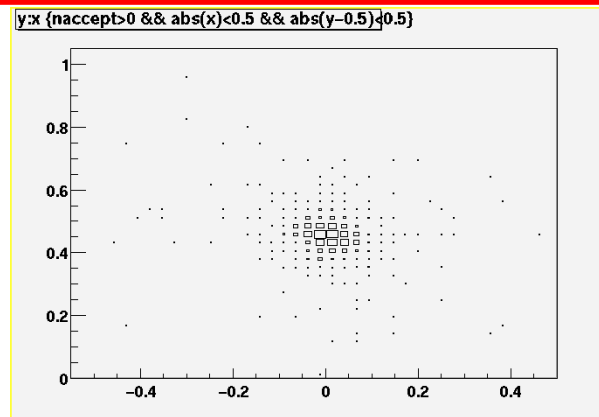
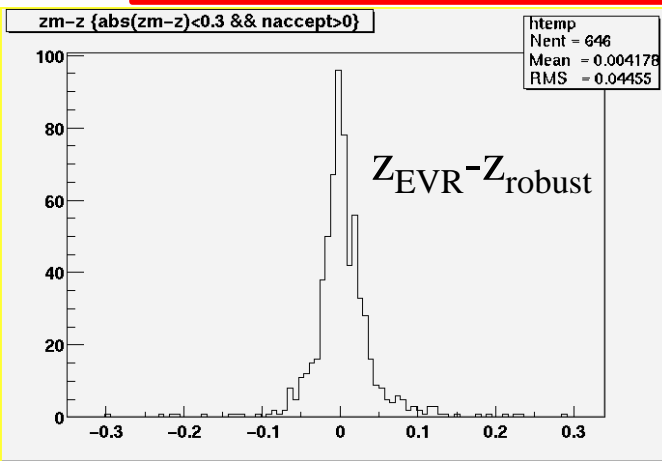
Results in Detail (MC)

# globals (no cuts)	Robust Minuit Fit		EVR + LMV	
	e(%)	s _z (cm)	e(%)	s _z (cm)
<10	32	0.169	18	0.164
10-20	60	0.124	38	0.128
21-30	87	0.086	77	0.098
31-50	90	0.092	73	0.100
51-100	98	0.093	95	0.092
101-200	100	0.060	100	0.069
201-500	100	0.035	100	0.040
501-1000	100	0.027	100	0.032
>1000	100	0.017	100	0.019
>2000	100	0.015	100	0.016
>3000	100	0.013	100	0.014
All (>0)	94	0.055	91	0.056

Counted as found if $|x-x_{MC}| \ \&\& \ |y-y_{MC}| \ \&\& \ |z-z_{MC}| < 3\text{mm}$



Results Data



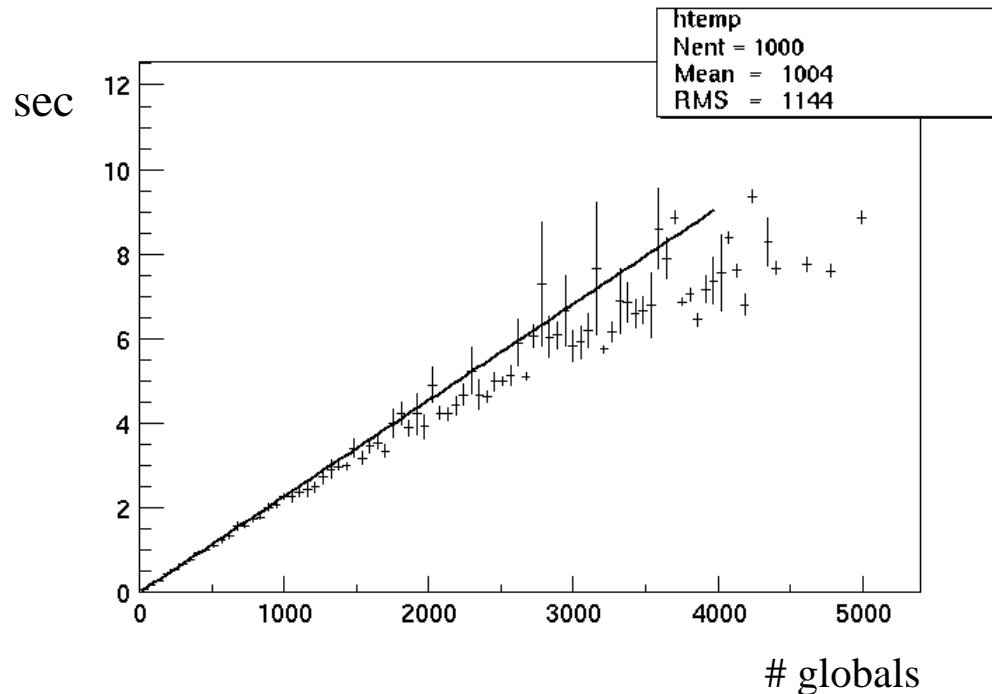
Au+Au minBiasVertex (Oct 2001)

Vertex counted as found if $|z| < 50$ cm and $|x (y)| < 1$ cm

- All events #tracks_{usable} > 0:
 - Minuit-Robust: 92%
 - EVR+LMV: 87%
- >500 tracks:
 - Minuit-Robust: 100%
 - EVR+LMV: 100%
- 1-100 tracks:
 - Minuit-Robust: 76%
 - EVR+LMV: 57%
- 1-30 tracks:
 - Minuit-Robust: 66%
 - EVR+LMV: 38%



CPU Time



Typical RCAS Linux box
Note: T_{CPU} less than linear
since fit converges faster

So far no efforts to improve on time

- Where does the time go?
 - ◆ Typical 1000 track event
 - 110 scan:
 - 110 * 1000 DCAs
 - MIGRAD
 - 20-40 * 1000 DCAs
 - Time in StHelix:distance(point) cannot be improved (?!)
 - External seed: 100 scans less
 - And even with scan: 100 tracks are enough for seed
 - Also lots of tracks carry no weight
- ⇒ Lots of ways to improve



Outlook

- ◆ New vertex finder based on Minuit and a robust fit function
- ◆ Works on StEvent
- ◆ surprisingly good so far
 - Equals EVR at high multiplicity
 - Exceeds efficiency of LMV
- ◆ Very compact code (< 200 lines including comments and empty lines)
 - Easy to maintain
 - Pileup removal easy to adapt
- ◆ Needs someone other than author with more experience in vertex finding to check thoroughly (Lenny, Jan)
- ◆ Future not clear ?!
 - Use when ITTF comes? Replace EVR, LMV, ppLMV?
 - Drop efforts?
 - Use as additional tool only?

