

Deterministic annealing filters for robust vertexing in BELLE

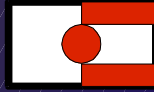
Vienna institute of high energy physics
(HEPHY)

dept. for algorithms and software development
(ASE)

Gerald Richter
Johannes Rindhauser

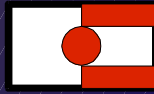
Rudi Frühwirth, Winfried Mitaroff, Meinhard Regler, Wolfgang
Waltenberger

BGM March '04, Tsukuba/Japan: 22.-24. Mar 2004



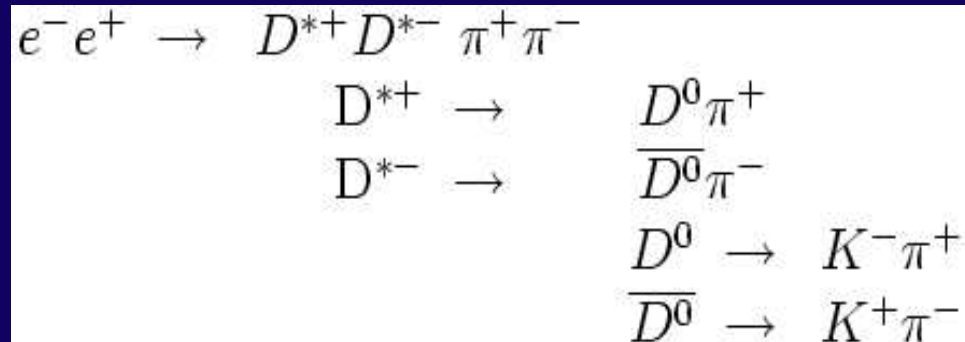
Some terminology

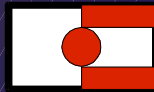
- Annealing: gradual decrease of a parameter corresponding to a temperature
- Robustification: in a statistical sense, making a filter algorithm less susceptible to the inclusion of bad measurements
- DAF: deterministic annealing filter (novel approach)
- KVF: Kalman vertex fitter (currently used vertexing algorithm)



Previous investigations of HEPHY::ASE for BELLE

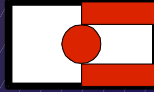
- **Diploma thesis** (Johannes Rindhauser) concerned with development of adaptive fitter for vertexing
- **Diploma thesis** (Gerald Richter) concerned with development of DAF for tracking
- **Extended research** for the vertexing task, implementation of DAF
 - examined topology





Using a measurement for a vertex fitting hypothesis

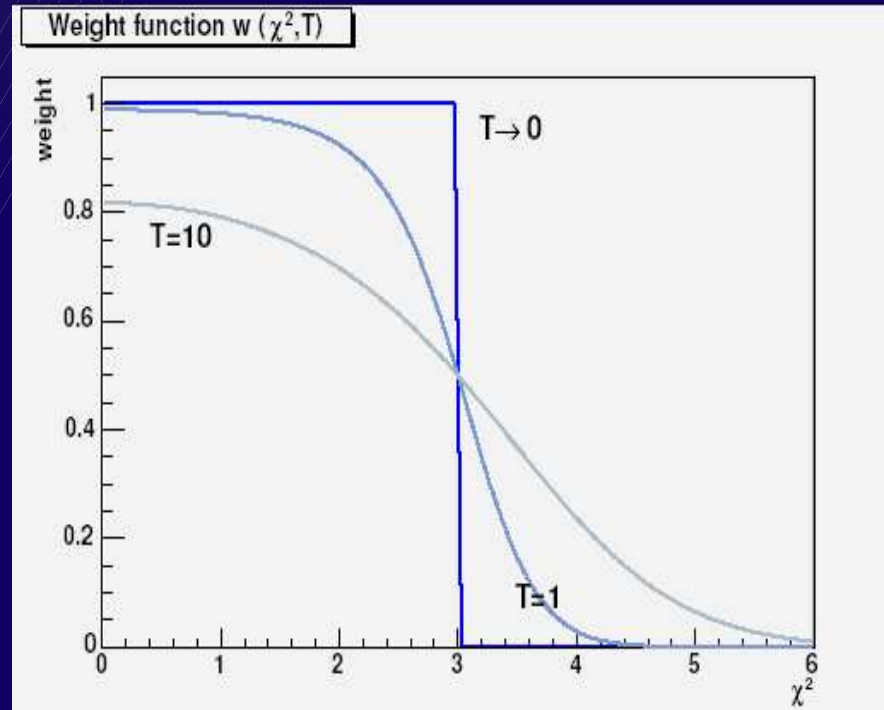
- **Measurements** used are **tracks**
- **Improvement and robustification** can only be achieved by implementing a **non-linear estimator**
- **Hard assignment:** binary decision to include measurement or not
 - Resembles classical fitting approach
- **Soft assignment:** using association probability, which results in a weighted inclusion of the measurement
 - Adaptive approach



Annealing temperature and weights

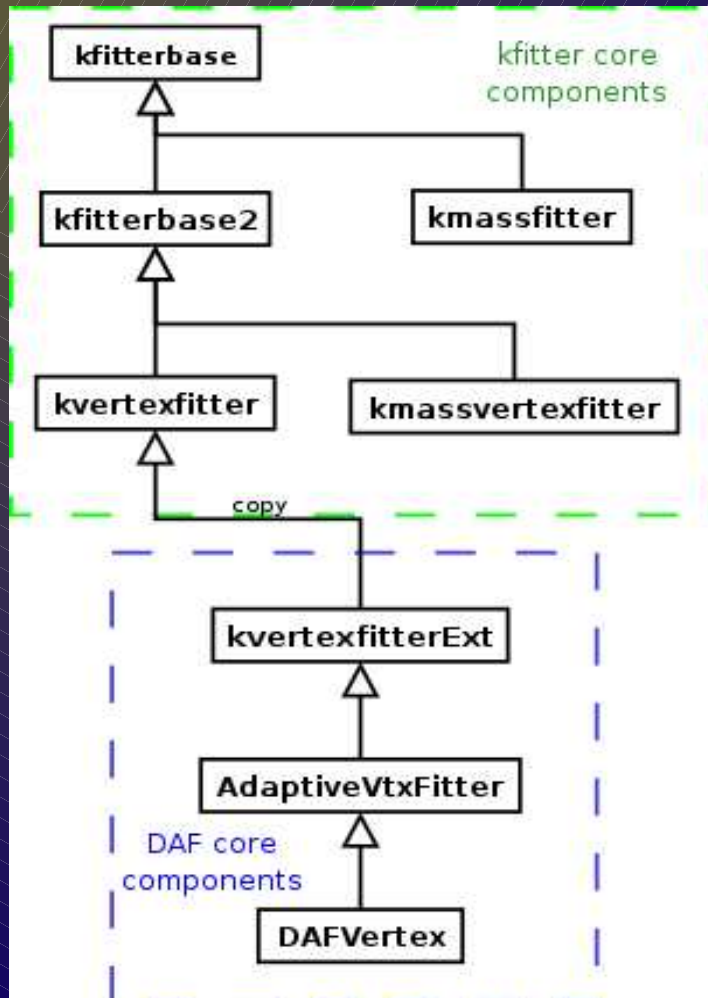
- Measurements are used in the fit according to their weight
- Iterative procedure
 - Temperature parameter T with tunable annealing scheme enters weight calculation
 - New weights are calculated
 - Termination criteria:
 1. On convergence
 2. Maximum iterations

LOOP



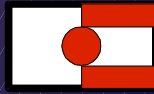
$$w(\chi^2, T) = \frac{1}{1 + \exp\left(\frac{\chi^2 - \chi_{cut}^2}{2T}\right)}$$

Module architecture & extensions



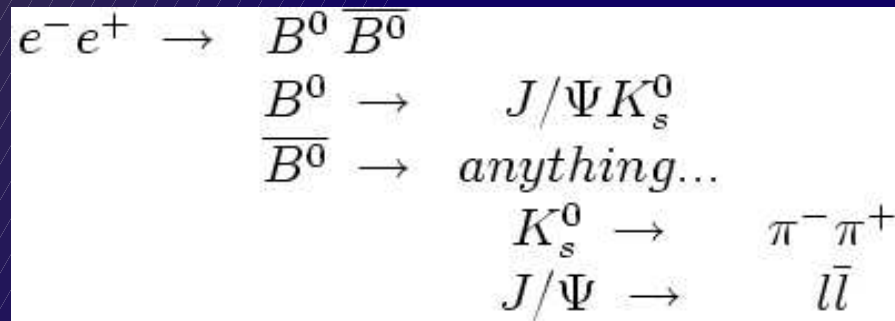
DAF concept:

- Fully based on present vertexing module and algorithms
- Extension done by a copy of `kvertexfitter`
- Almost totally decoupled from `libkfitter`, using it as "black box"
- Currently 4 significant tunable parameters



Preparations, examined data

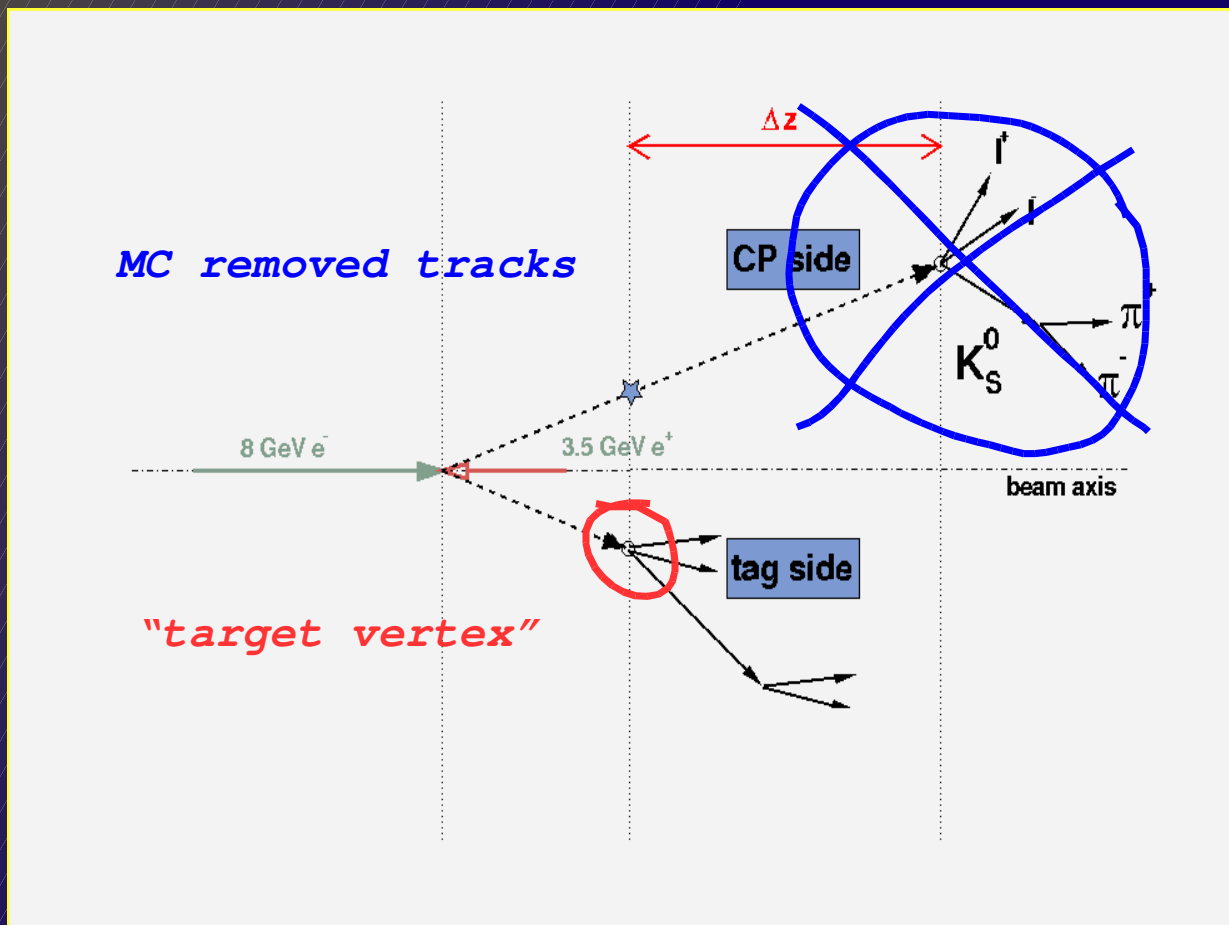
- Tests performed on **MC-data**, 10000 events
- **generic B decays**, generated by **EvtGen**, examination of **tag-side vertex** (as proposed by Ishino-san)

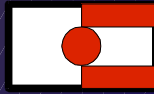


Preparations and cuts on the data:

- **CP side removal** based on **MC-info**
- **K0s removal** using class **findKs**

Investigation focus





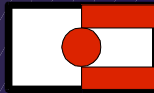
Cuts and parameters of the comparison

KVF:

- initial fit with KVF, cut on track χ^2 probability (1%)
 - (tracknumber + (BIP used)) > 2
 - Initially cut away the worst and 0.05% of good tracks
 - Use of BIP
 - initial position and error (BIP 1)
 - initial position, B-decay smeared error (BIP 2)
 - SVD track cut (at least 2 z-hits and 1 $r\phi$ -hit)

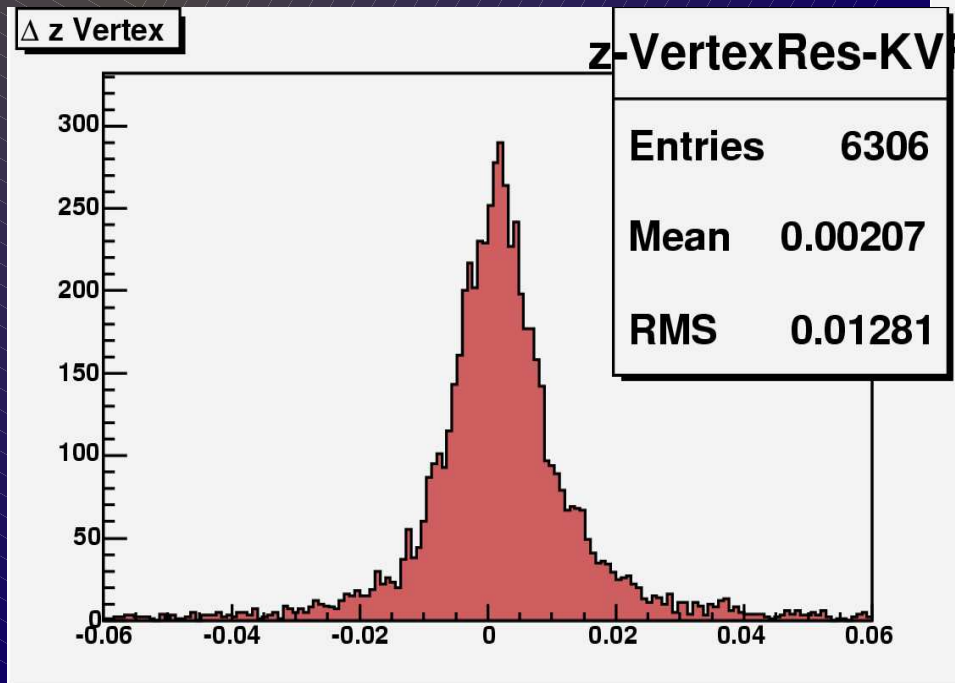
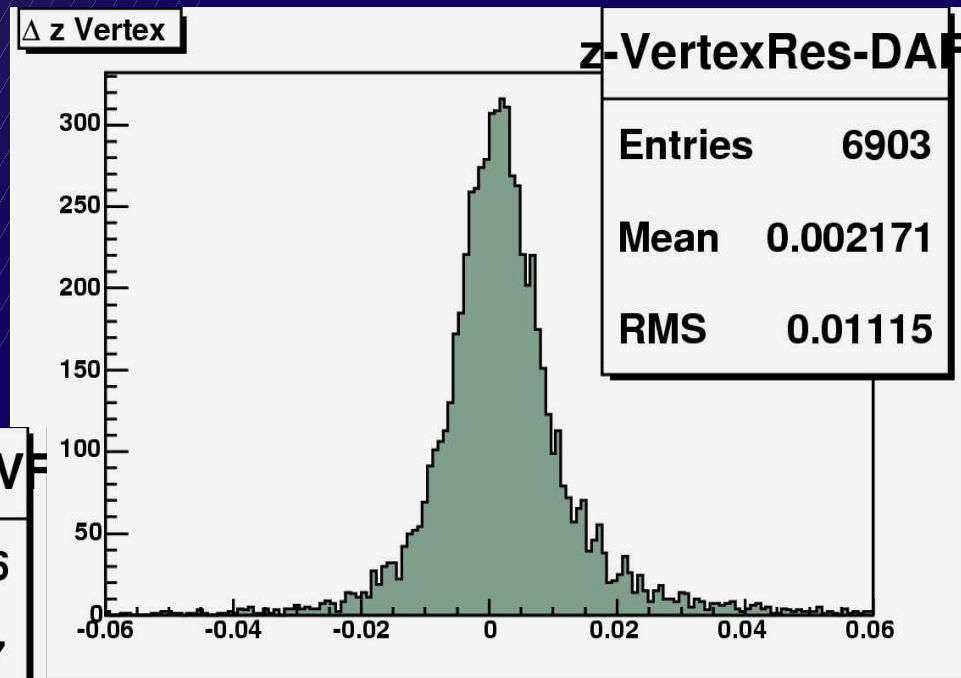
DAF:

- Use of algorithm- intrinsic χ^2 - cut value, equivalent to probability of 1%



Performance comparison (MC)

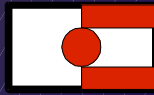
- **KVF**: initial fit cut $< 1\%$
- **DAF**: nominal values
- normal BIP 1 given as vertex constraint



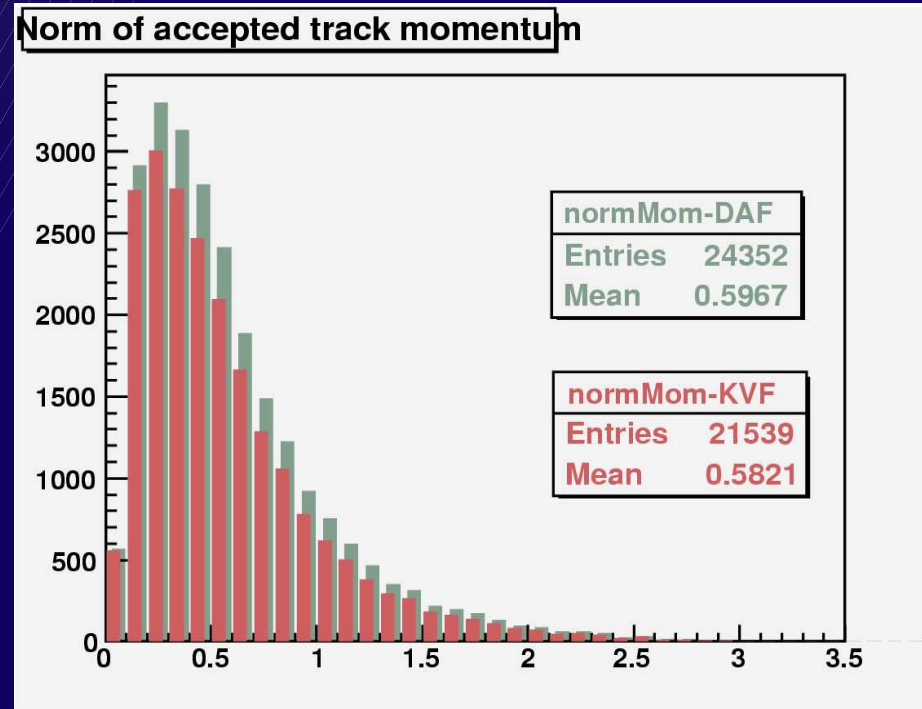
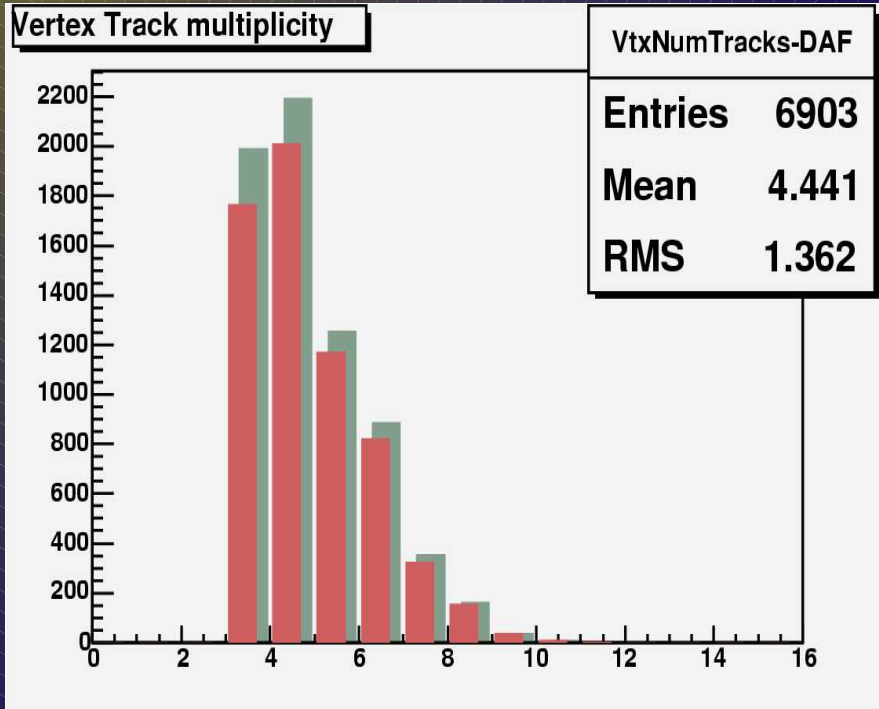
In 10000 events:

- From **6306** good events to **6903**
- *RMS on z-resolution*

128,1 μm to 111,5 μm

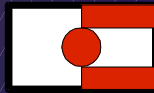


Source of additional tracks

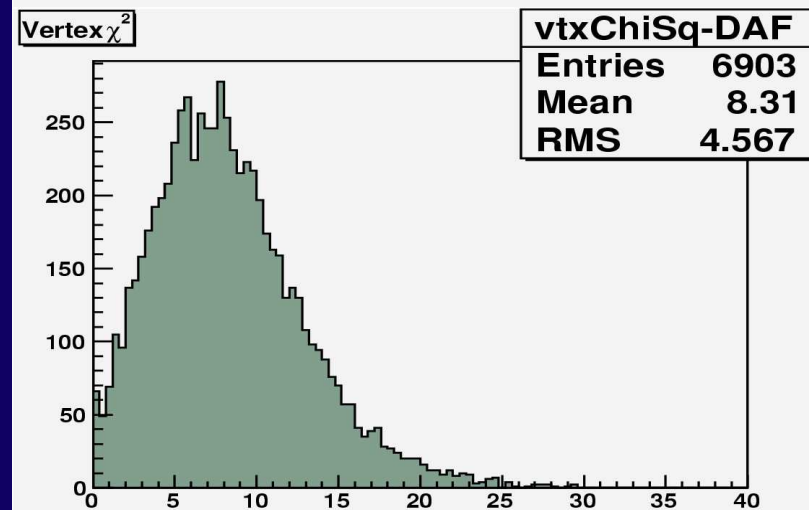
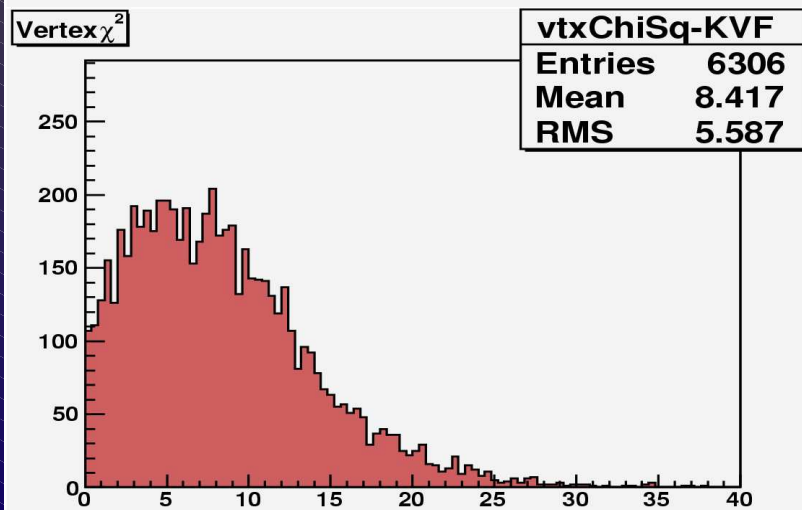
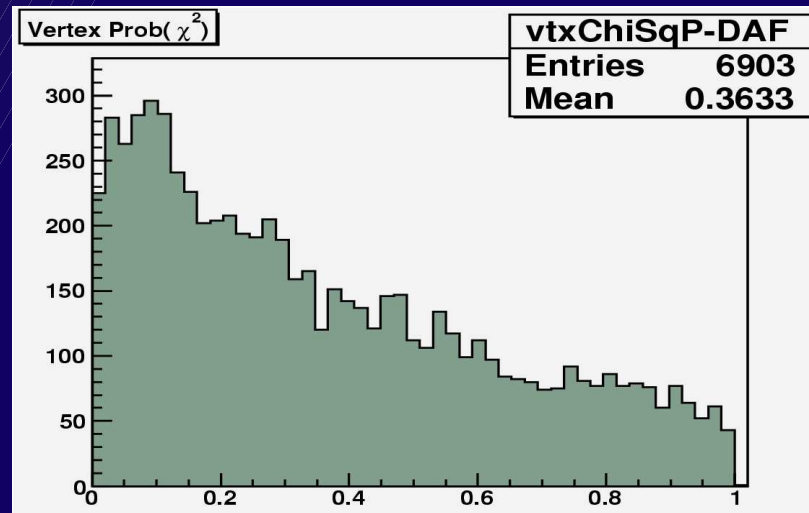
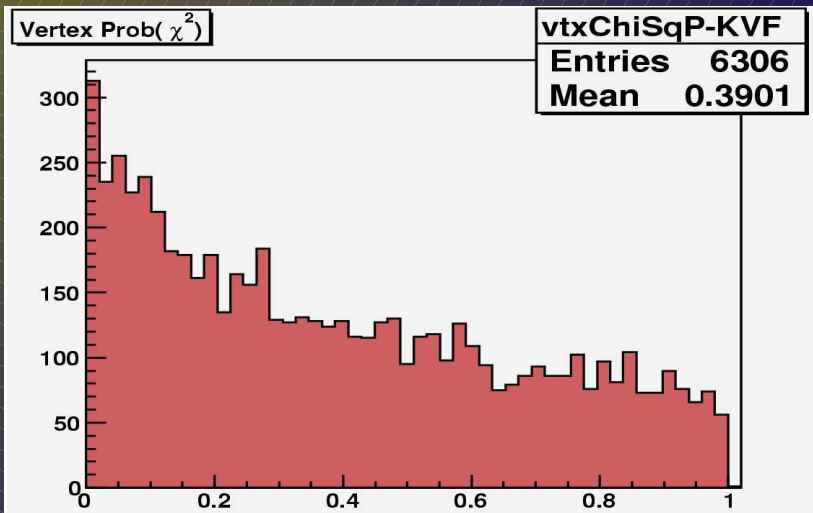


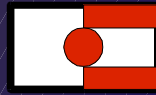
No special preference
for certain track
multiplicities

Evenly spread over whole
momentum range

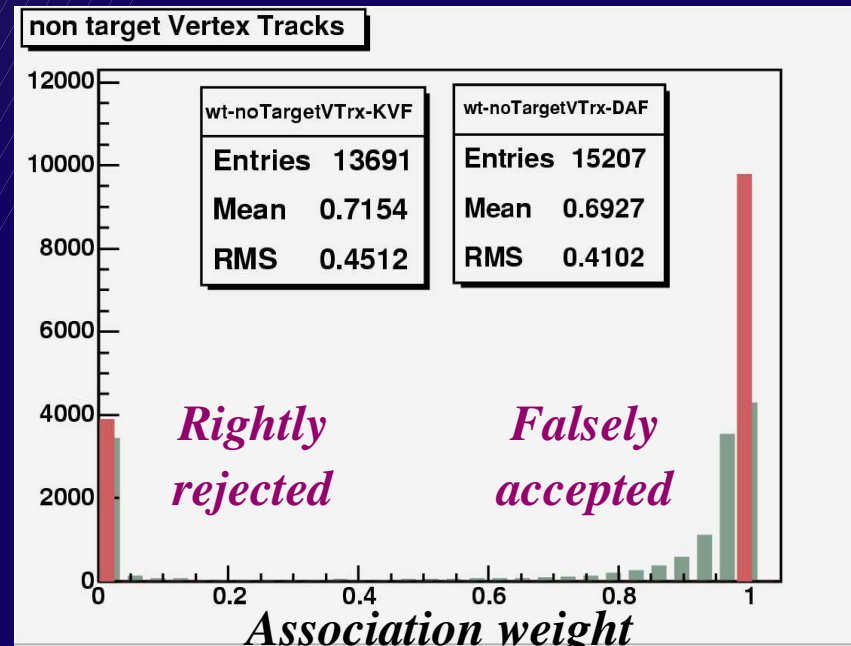
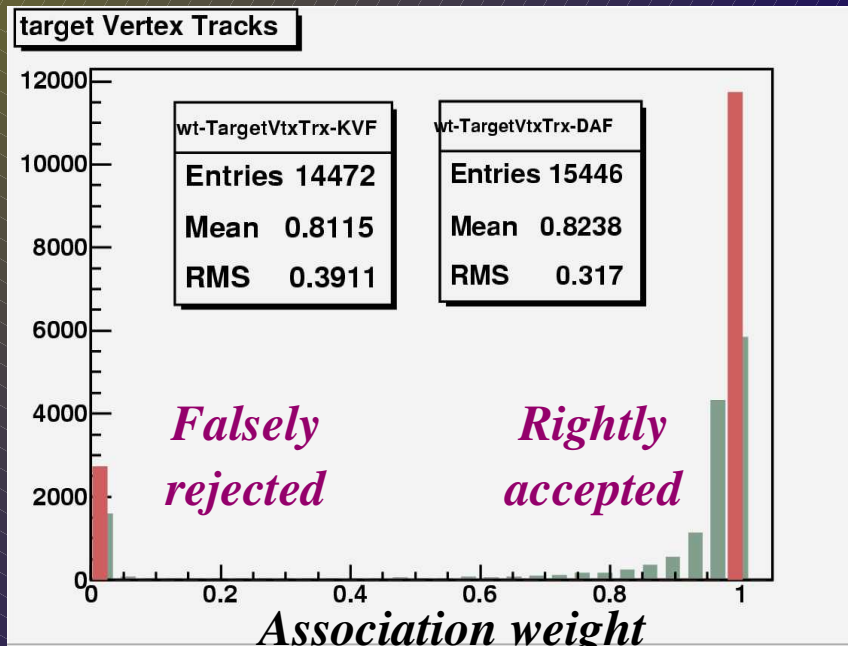


Vertex χ^2

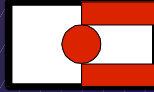




Track association



- **KVF** tends to use more bad measurements, and also use less good measurements
- **DAF** uses more measurements in total, moderately weighted
- Upper range > 0.8 : comparable amount of entries, but less disturbing influence



performance overview tag-side reconstruction (MC)

- Initial KVF fit, cut on χ^2 prob $< 1\%$
- Histogram range: $[- 600; +600] \mu\text{m}$

best resolution of DAF

- $107.7 \pm 1.43 \mu\text{m}$
- $111.5 \pm 1.34 \mu\text{m} @ 6903$

best resolution of KVF

- $115.5 \pm 1.59 \mu\text{m}$
- $128.1 \pm 1.61 \mu\text{m} @ 6306$

Efficiency gain of approx. 6 – 16%

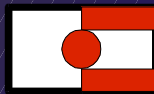
Precision gain between:

- $16.6 \pm 2.09 \mu\text{m}$

and

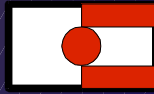
- $4 \pm 2.08 \mu\text{m}$

	KVF		
	(none)	1	2
BIP type:	(none)	1	2
preFitTrkC2]	0	0	0.05 %
K0s cut:	no	no	YES
dz [μm]	119.4	128.1	115.5
variance	1.58	1.61	1.59
# events:	5678	6306	5289
	DAF		
	(none)	1	2
BIP type:	(none)	1	2
preFitTrkC2]	0	0	0.05%
K0s cut:	no	no	YES
dz [μm]	124.4	111.5	107.7
variance	1.56	1.34	1.43
# events:	6360	6903	5677



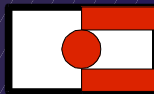
Proposed improvements & further steps

- Compare to **TagV** with **PID** and **emphasized measurements**
- **Per-event examination**
 - Fine grained data extraction to ROOT or AIDA
 - Interface to graphical 3D analysis
 - Fine tuning of parameters for certain topologies
- **Real data** application and move to **SVD 2.0**
- **Linearisation point** finding and optimization
- Implementation of **multi-vertex** hypothesis fit
- ...suggestions are much valued and welcome



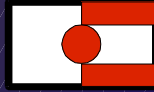
Conclusions

- Iterative, general purpose, purely geometric vertex fitter DAF shows increased reconstruction efficiency of 5-15% at increased vertex resolution
- Robustification can replace and automate certain aspects of vertex fitting
 - soft removal (downweighting) of outlier measurements
 - involve correct measurements “gone astray” in the fitting process (not possible with hard cuts), employing deterministic annealing
- Less tight initial cuts necessary



Thank you for your attention

BGM March '04, Tsukuba/Japan: 22.-24. Mar 2004



Full comparison set

	KVF					
BIP type:	(none)	(none)	1	1	2	2
preFitTrkC2	0	0.05 %	0	0.05 %	0.05 %	0.05 %
K0s cut:	no	no	no	no	no	YES
dz [μm]	119.4	113.2	128.1	116.6	116.6	115.5
variance	1.58	1.71	1.61	1.6	1.6	1.59
# events:	5678	4402	6306	5302	5302	5289
	DAF					
BIP type:	(none)	(none)	1	1	2	2
preFitTrkC2	0	0.05%	0	0.05%	0.05%	0.05%
K0s cut:	no	no	no	no	no	YES
dz [μm]	124.4	120.4	111.5	108.1	107.7	107.7
variance	1.56	1.66	1.34	1.43	1.43	1.43
# events:	6360	5291	6903	5694	5685	5677

smaller effect for x and y axis

