Track fit and seeding on HLT2

$B_s \rightarrow D_s\ \pi$ as example selection

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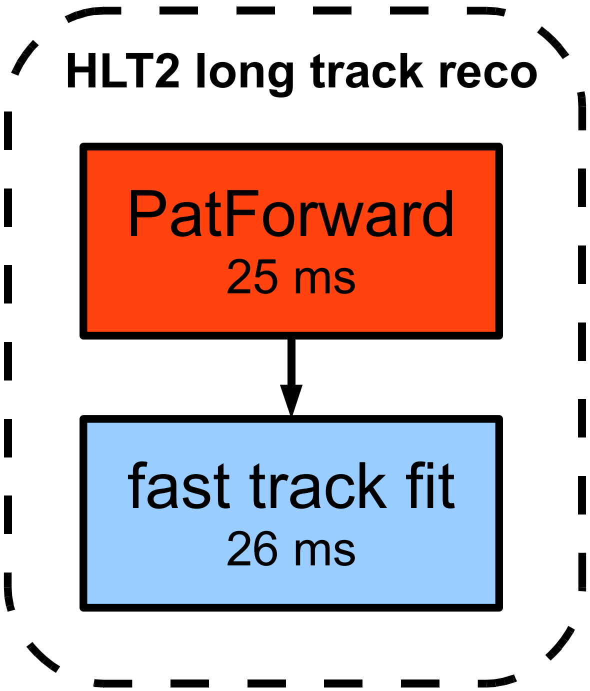
Introduction

- Inclusive B→Dh selection triggers for $B_s \to D_s \pi$, $B_d \to D\pi$, $B_s \to D_s K$, $B_s \to D_s^* K$
- Used HLTSelections/Hlt2SelB2DplusH and DC06SelBs2DsPi selections (thanks to Vava)
- Use fast Kalman track fit and seeding → how is reconstruction improved
- Davinci v22r0p2*, used data
  - 68k Offline selected, L0 accepted (true) Bs candidates
  - 3.5M L0 accepted MB events

* some differences to v20r3 not yet understood!

Fast Kalman track fit

- Online tracking should be as close as possible to Offline tracking, so why don't we use just Offline tools?
  - Problem: Timing, HLT should be fast → use fast track fit
- Fast Kalman track fit means
  - Simplified geometry
  - Only 1 iteration
    - No outlier rejection
    - No smoother
  - Timing:
    - 26 ms/all tracks per event (≈PatForward)
    - Fit only B candidate tracks after cuts → extra CPU time negligible



Interesting Cuts

- What do we expect from the fit? → Better track quality → better p, IP resolution & correct error estimates
- Where do we profit?

Particle	Cut Name	HLT2 (inclusive)	Offline (exclusive)
All K's and π's	IP significance	> 2	> 3
D	Mass	-200, +100 Mev	± 25 MeV
B	Mass	± 500 MeV *	± 60 MeV

→ Better error estimate (IP significance)

} Better momentum resolution (D and B mass)

* Around average of Bd and Bs mass

- HLT2 uses simple parametrisation as error estimate → errors are usually overestimated at DC06

Results of the track fit

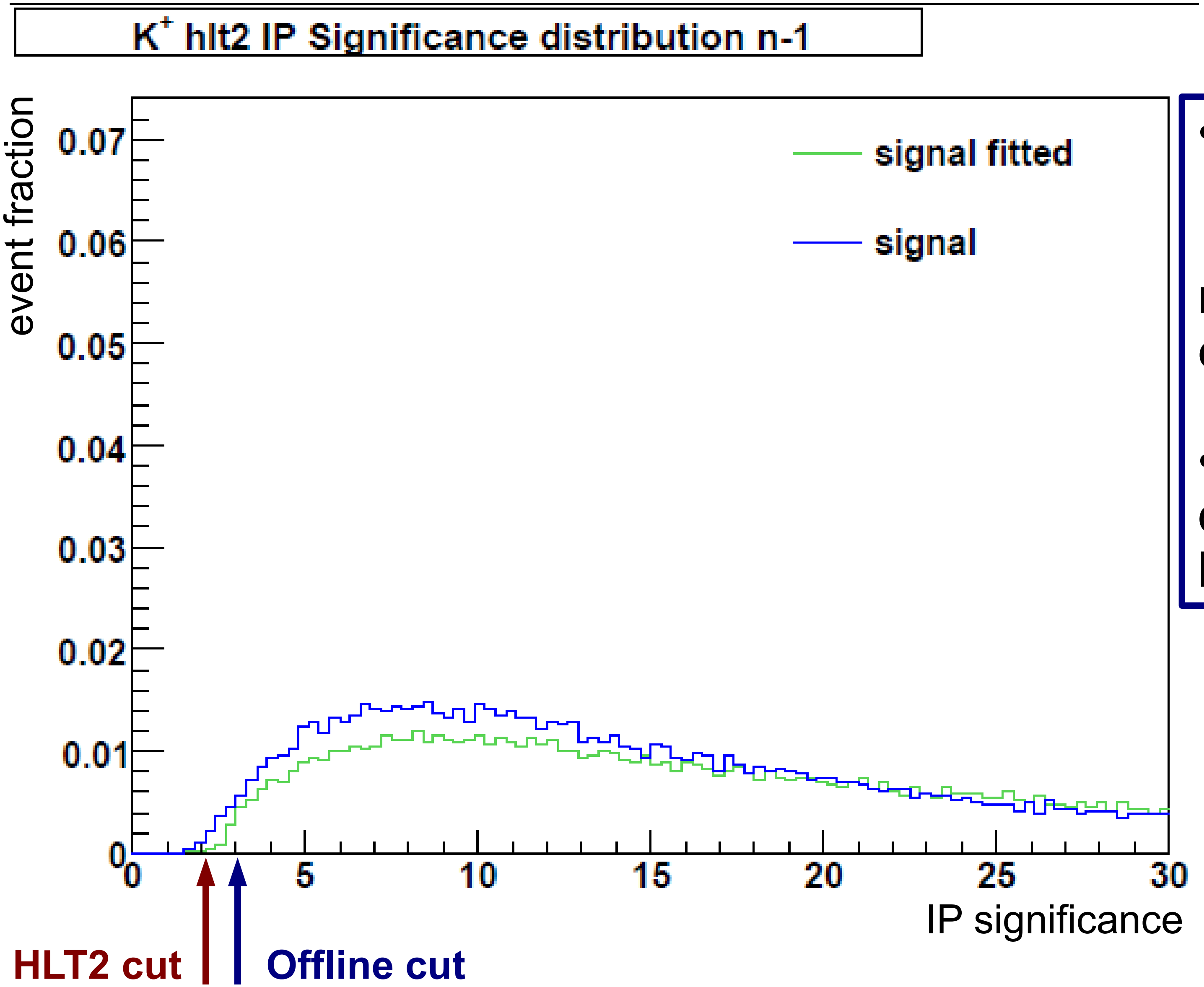
- Results with standard cuts:

	standard cuts	
w/o fit	Eff: 74,7%	± 0.3 %
	rate: 58 Hz (230 events)	± 3 Hz
with fit	Eff: 78,7 %	± 0.3 %
	rate: 48 Hz (192 events)	± 3 Hz

Vava's results	
Eff: 72%	± 0.6 %
Rate: 52 Hz (59 events)	± 7 Hz

- First observations:
  - Efficency goes up by 4%, rate goes down by 10 Hz
  - Not 100% agreement with Vava, but used different VertexIsolation tool
- So, what about IP significance and mass resolution?
- What do we keep on minimum bias?

IP Sig distribution of K's and π's

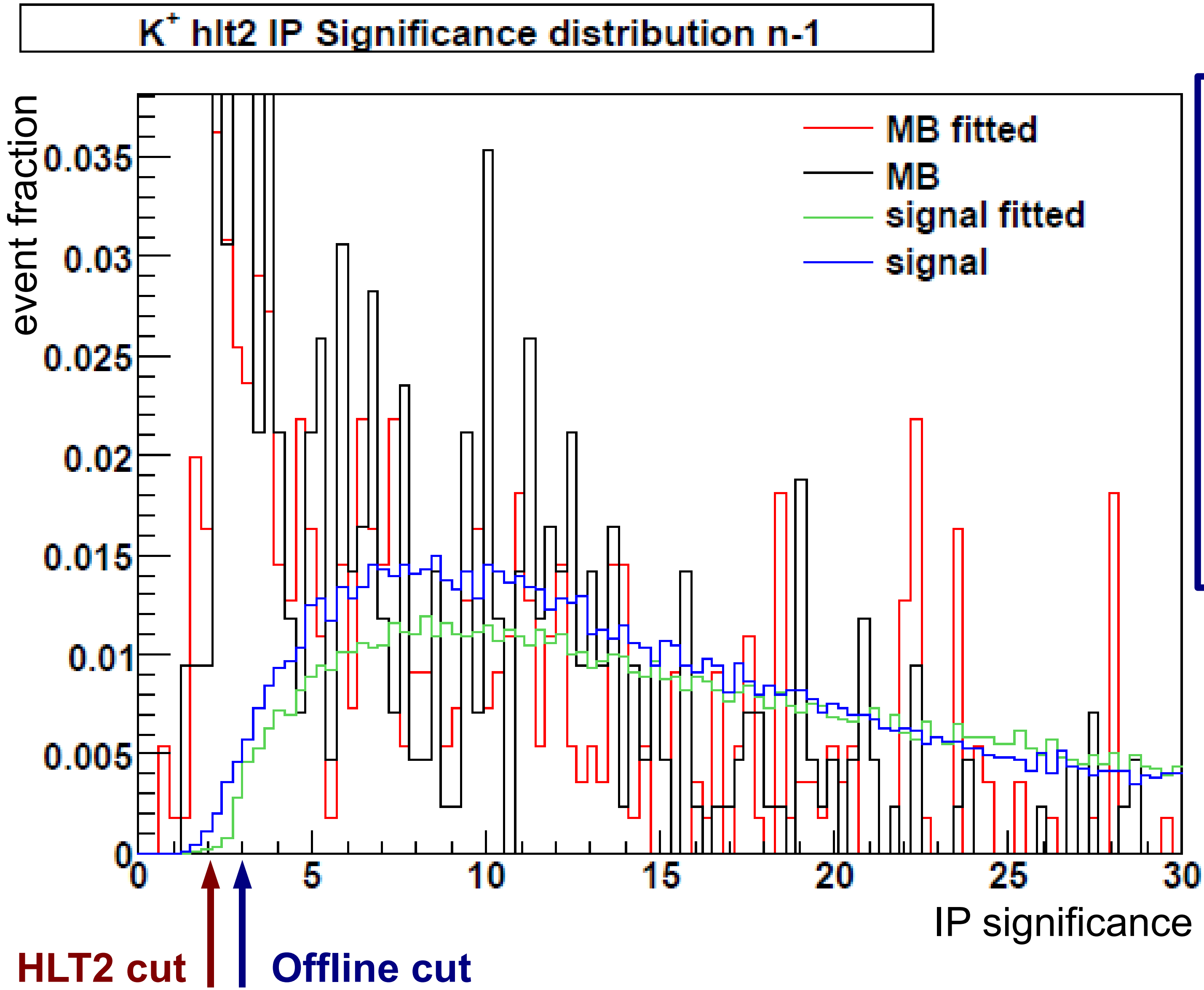


- $IP\ sig = \frac{IP}{\sigma_{IP}}$

  → profit from better IP resolution and error estimate!

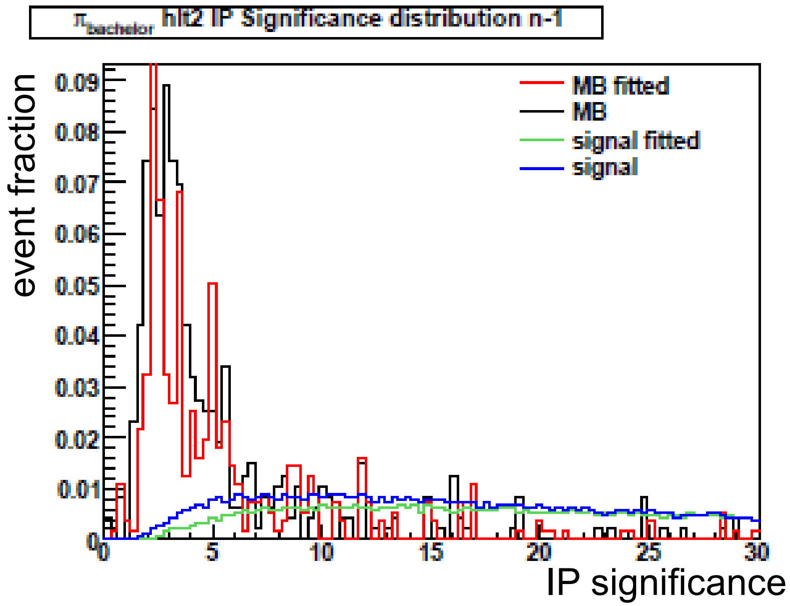
- Fit shifts IP significance distribution of signal to higher values!

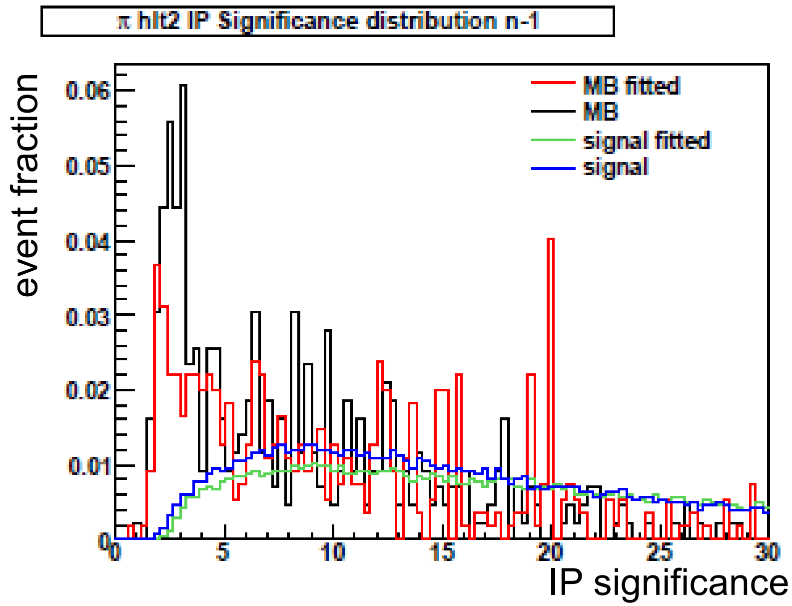
IP Sig distribution of K's and π's

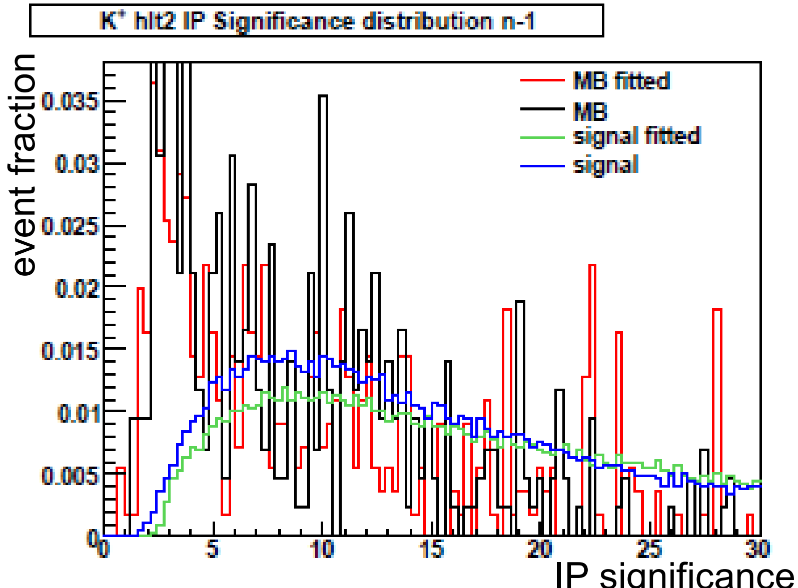


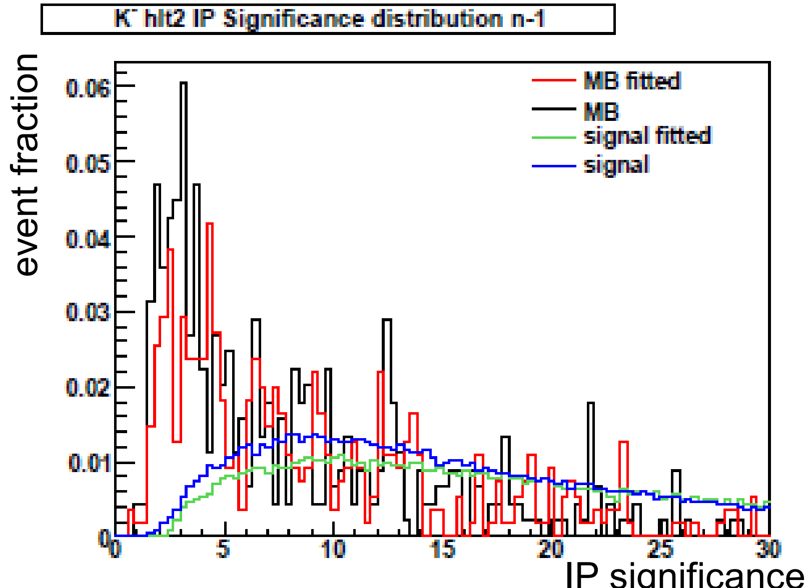
- Distribution of minimum bias background is not affected by fit.
- If one shifts the cut, a reasonable amount of background could be supressed.

IP Sig distribution of K's and π's









Same behaviour for all stable particles!

Adjusted Cuts: IP significance

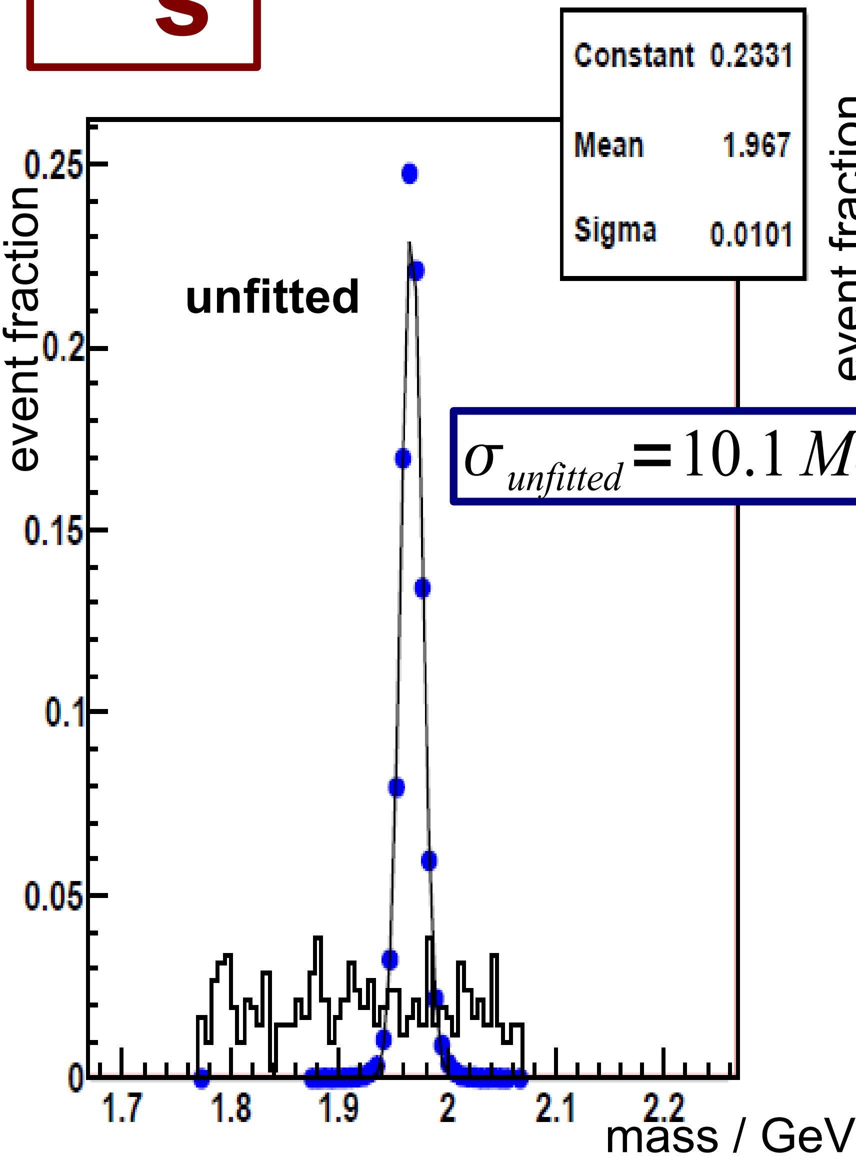
- With the results from the fit we can tighten the cuts:
  - The offline IP significance cut is IP sig > 3 for all Pions and Kaons
  - As we have seen, the fit shifts the IP significance distribution to higher IP significances, so we can tighten the cut from
    - IP sig > 2 → IP sig > 3 for all stable particles
  - Results with tight IP sig cuts:

	standard cuts	
with fit	Eff: 78.7%	± 0.3 %
	rate: 48 Hz (192 events)	± 3 Hz

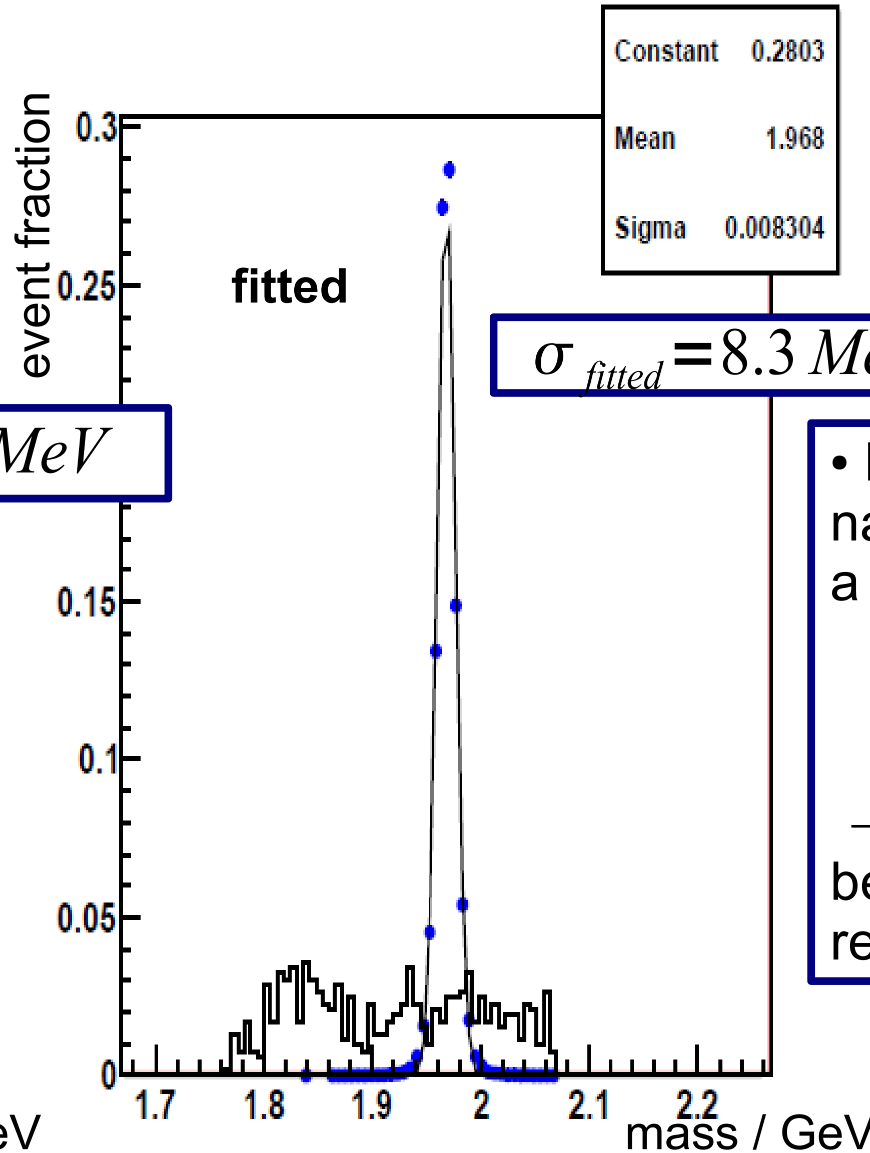
	tight cuts (IP sig > 3)	
with fit	Eff: 77.6%	± 0.3 %
	rate: 27 Hz (108 events)	± 2 Hz

Mass distribution of the Ds

D_s



$\sigma_{unfitted} = 10.1\ MeV$



$\sigma_{fitted} = 8.3\ MeV$

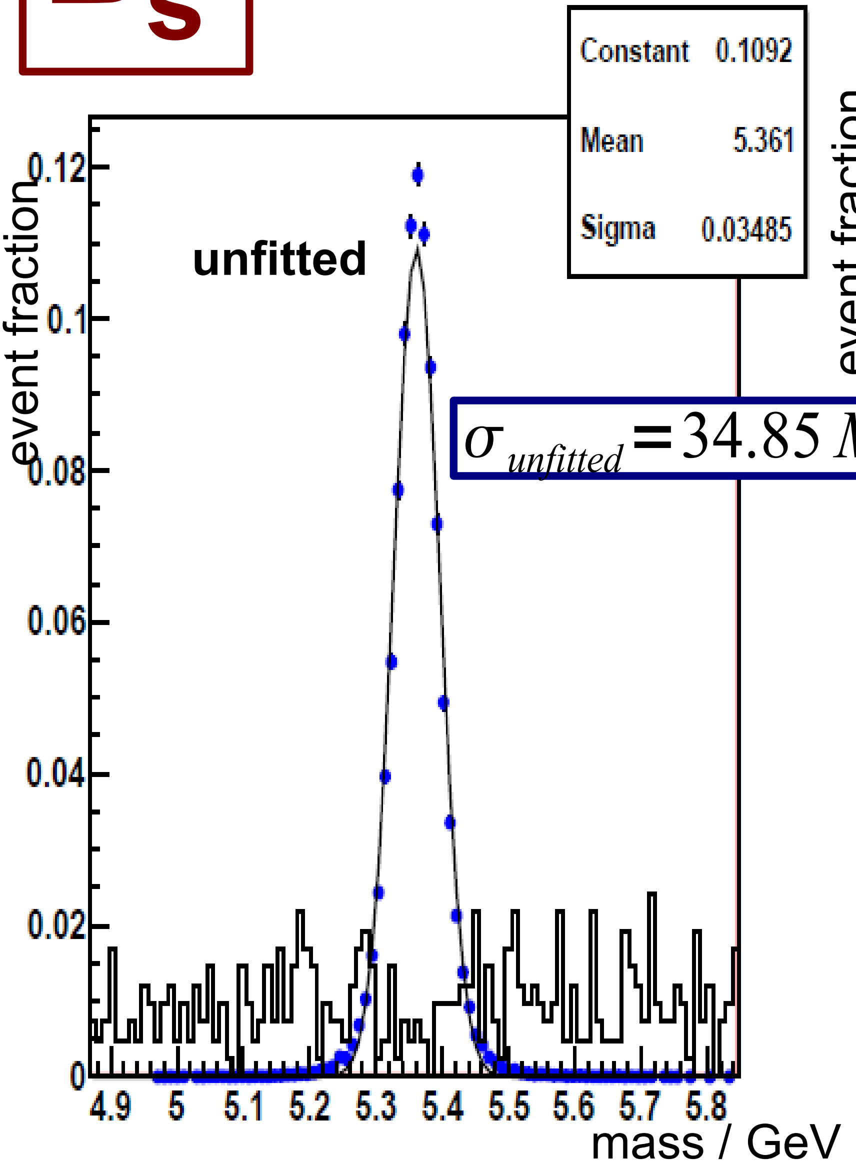
- Peak width narrowed down by a factor

$$\frac{\sigma_{fitted}}{\sigma_{unfitted}} = 0.77$$

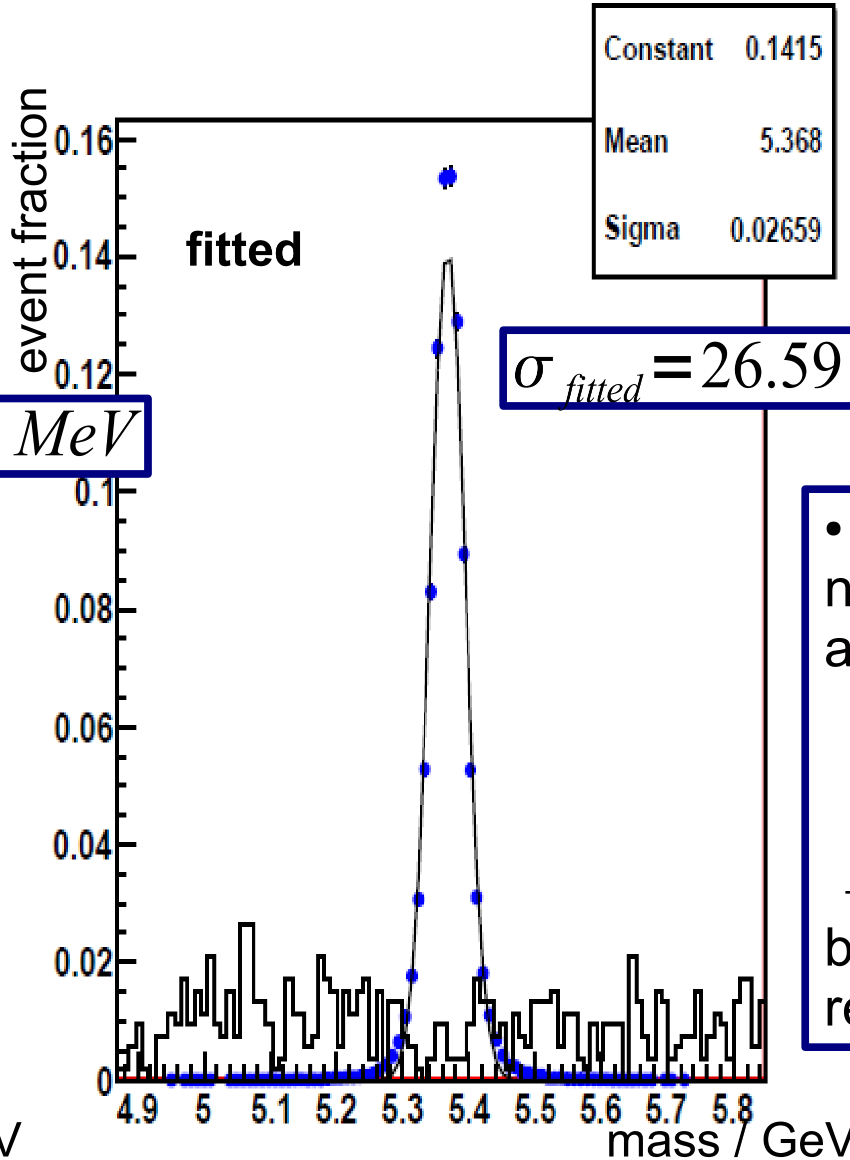
$\rightarrow$ profit from better momentum resolution

Mass distribution of the Bs

B_s



$\sigma_{unfitted} = 34.85\ MeV$



$\sigma_{fitted} = 26.59\ MeV$

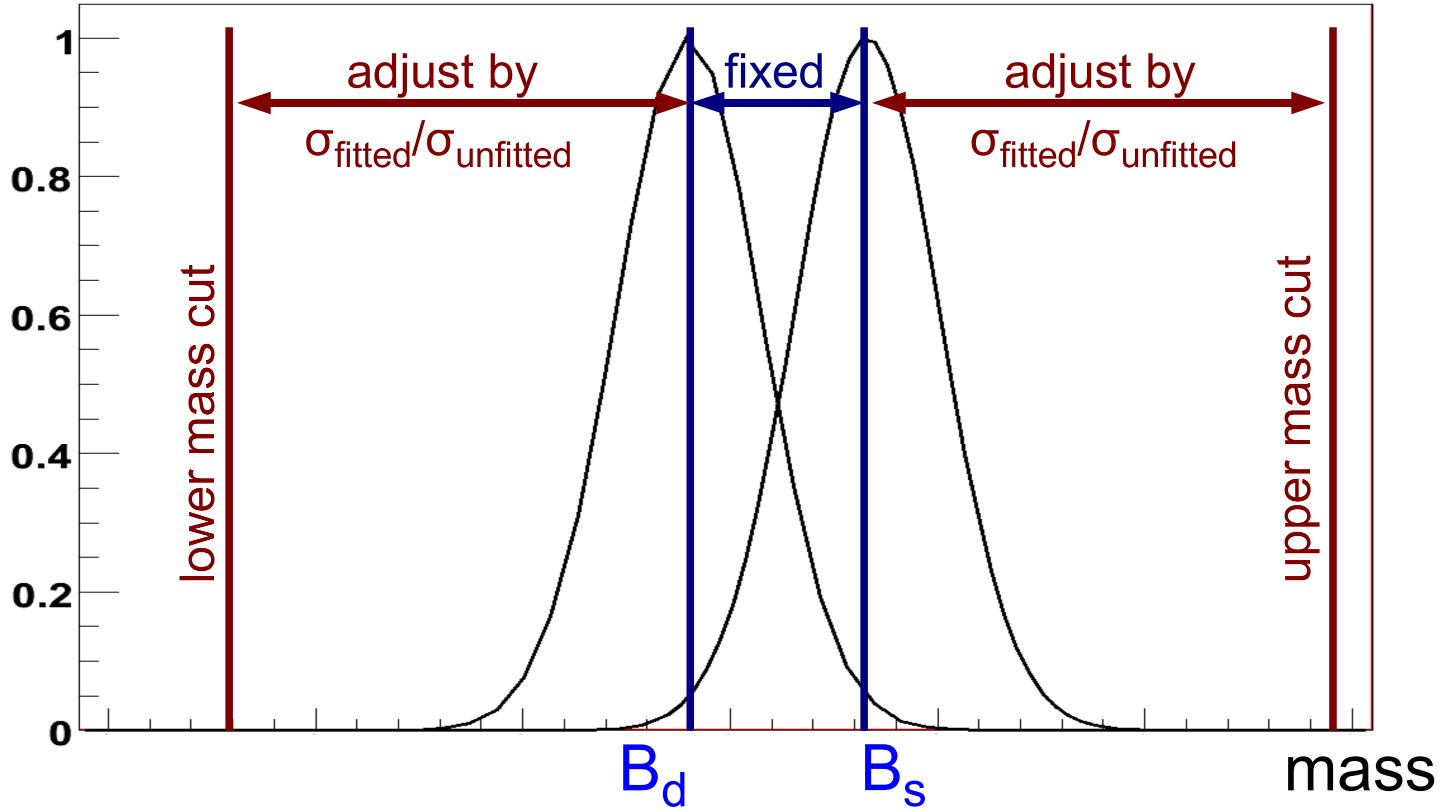
- Peak width narrowed down by a factor

$$\frac{\sigma_{fitted}}{\sigma_{unfitted}} = 0.76$$

$\rightarrow$ profit from better momentum resolution

Adjusted Cuts: Mass Window

- With the results from the fit we can (again) tighten the cuts:
  - Inclusive selection also contains B_d's and D_0's
    - Resize sidebands by the factor $\sigma_{fitted}/\sigma_{unfitted}$
    - Keep the distance between B_s and B_d, respectively D_0 and D_s fixed.



Results with adjusted cuts

- Final adjustment of cuts:

Particle	Cut Name	standard HLT2	tight cuts
Bs	Mass	± 500 MeV *	± 390 MeV
Ds	Mass	- 200, +100 Mev	-178, +77 MeV
All K's and π's	IP significance	> 2	> 3

* Around average of Bd and Bs mass

- With this we get the following results:

	standard cuts	
w/o fit	Eff: 74,7% rate: 58 Hz (230 events)	± 0.3 % ± 3 Hz

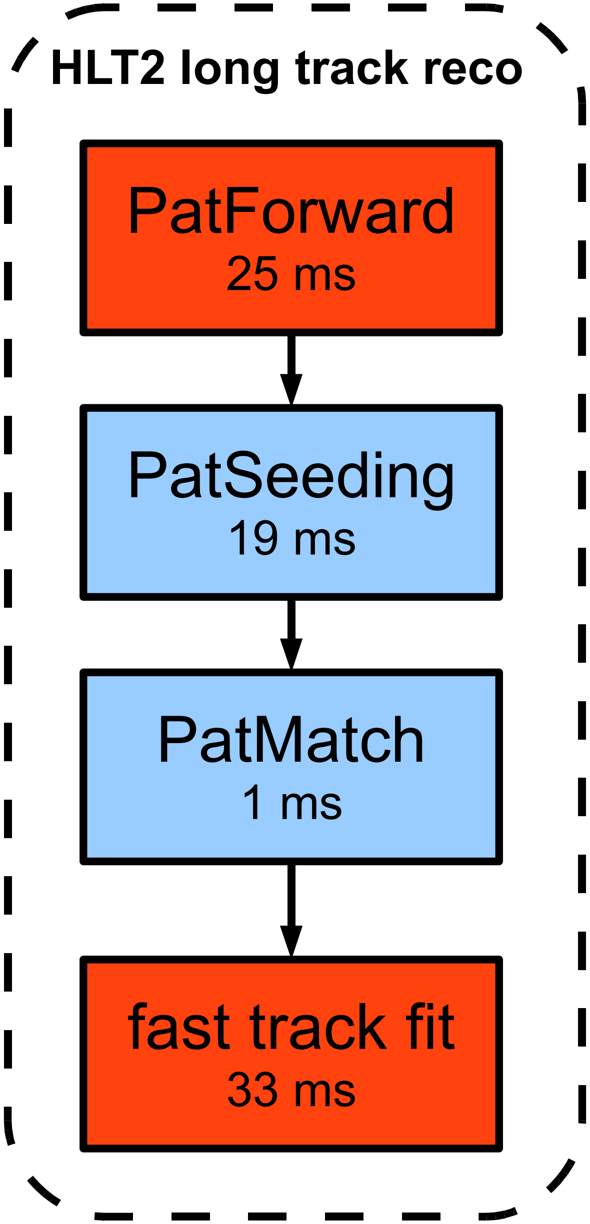
	tight cuts (IP sig & mass)	
with fit	Eff: 77.6% rate: 20 Hz (80 events)	± 0.3 % ± 3 Hz

PatSeeding

- Usually, long tracks are produced by PatForward from Velo seeds and T station hits
- Additional tracking algorithm:
  - PatSeeding on unused hits

    → only on hits which are not on forward tracks

    → faster, less clones
  - PatMatch matches T station tracks with Velo tracks to produce long tracks



Results with PatSeeding

- Seeding improves selection efficiency by 3.6% (0.9% per track)
- Minimum bias rate goes up by 22 Hz (mostly due to ghosts)
- Timing is about 20 ms for seeding and matching + 10 ms for fitting additional tracks

	standard cuts	
with fit	Eff: 78,7%	± 0.3 %
	rate: 48 Hz (192 events)	± 3 Hz

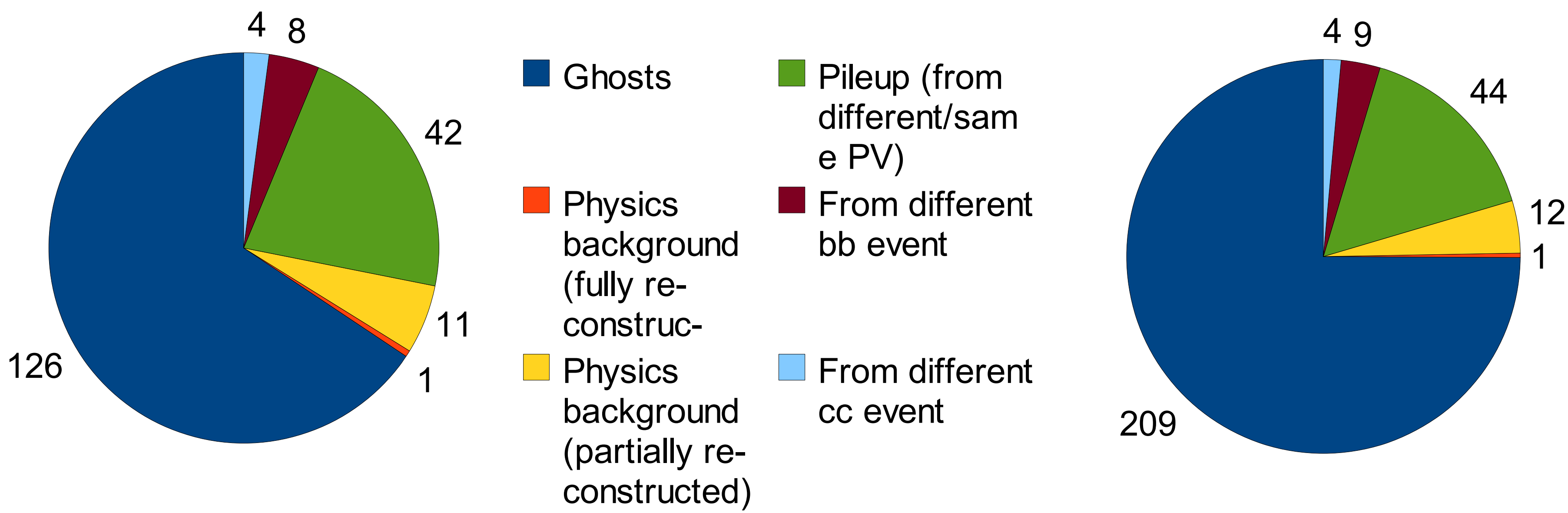
	standard cuts	
with fit & seeding	Eff: 82.3%	± 0.3 %
	rate: 70 Hz (279 events)	± 3 Hz

Everything from now on with Vava's standard cuts!

MB Background

with trackfit / standard cuts

with trackfit & seeding / standard cuts

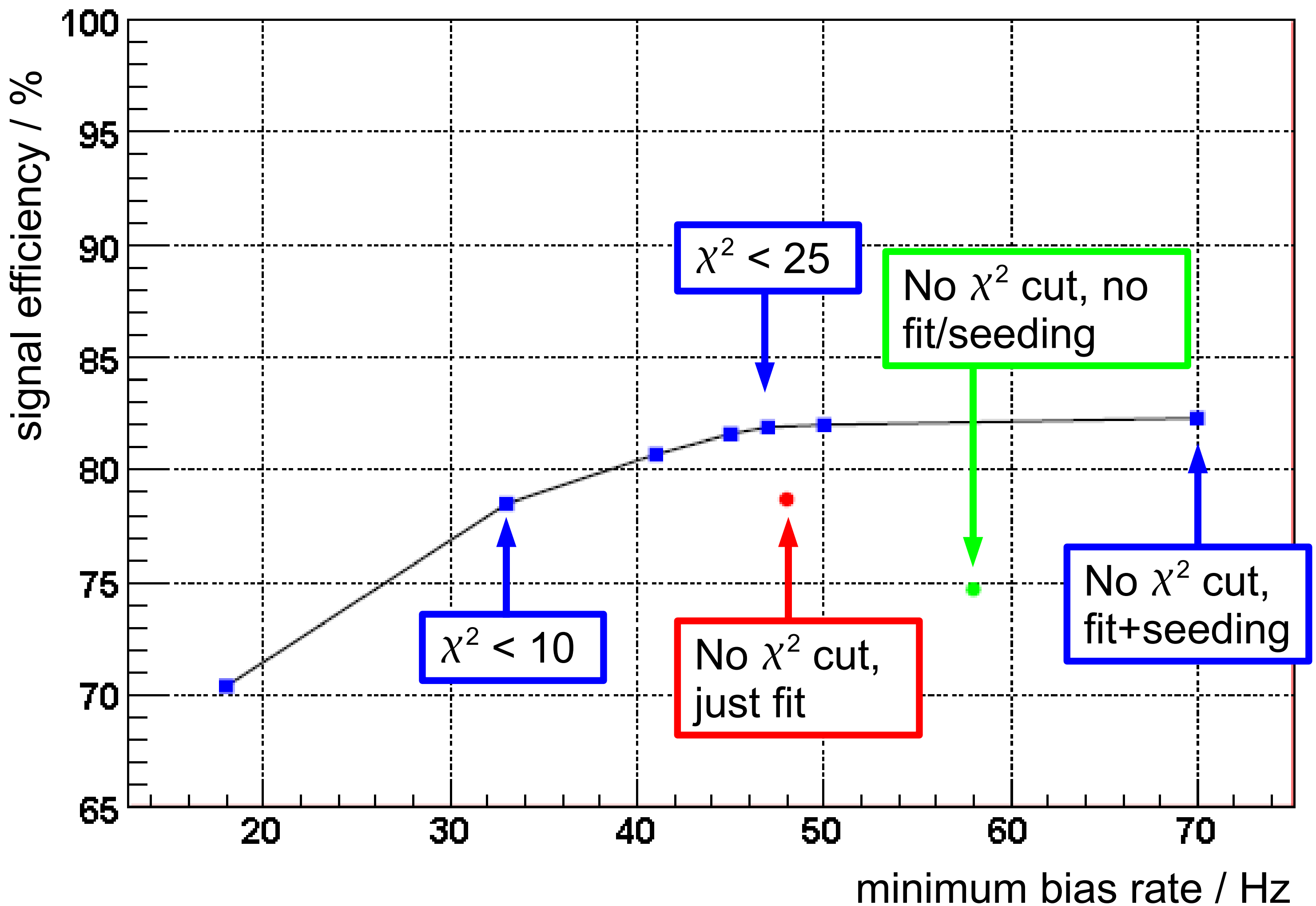


192 events

279 events

- Most background contribution from ghosts
- Effects are basically the same with tighter cuts!
  → Ghost rate is not supressed by 'normal' cuts!

Performance of a Track χ^2 cut



- By applying a simple χ^2 cut we gain an additional 3.4% efficency with respect to the fit while staying at the same MB rate!
- Offline we can do better – online also?

Work in progress!

Conclusion and Outlook

- Fast track fit and tighter cuts can improve efficency and minimum bias rate:
  - Cuts have to be reoptimized to profit best from fit
- PatSeeding on unused hits improves efficency by an additional 1% per track
  - You pay by an increased ghost rate
- Ghosts remain a major problem in the trigger → next step:
  - Improve ghost rate on HLT

Backup

Backup

Selection Cuts (1)

Particle	Cut Name	HLT2	Offline
π, K	P_t	> 300 MeV	> 300 MeV
	P	> 2 GeV	> 2 GeV
	IP sig.	> 2	> 3
All K's	DLL K/π		> 0
	DLL K/p		> -10
All π's	DLL K/π		< 5
$\pi_{bachelor}$	P_t	> 500 MeV	> 500 MeV
Ds	Mass	-200, +100 Mev	± 25 MeV
	FD χ^2	> 81	>100
	P_t	> 1.5 GeV	> 2 GeV
	DIRA	> 0	
	IP sig.		>3
	Vertex χ^2	< 10	< 15
	Vertex Iso.	< 4	
Ds, $\pi_{bachelor}$	$p_{T,D} \times p_{T,\pi}$	> 5 $(GeV)^2$	

Selection Cuts (2)

Particle	Cut Name	HLT2	Offline
Bs	Mass	± 500 MeV *	± 60 MeV
	FD χ^2	> 4	> 6.25
	DIRA	> 0.9995	> 0.9999
	IP Sig.	< 5	< 5
	Vertex χ^2	< 5	< 10
	Vertex Iso.	< 5	< 10

* Around average of Bd and Bs mass

Results with adjusted cuts

- Results with DaVinci v22r0p2

	standard cuts	tight IP Sig cut	tight cuts (mass & IPSig)	
w/o fit	Eff: 74.7% Rate: 58 Hz	Eff: 72.1% Rate: 26 Hz	Eff: 72.0% Rate: 19 Hz	± 0.3% ± 3 Hz
with fit	Eff: 78.7 % Rate: 48 Hz	Eff: 77.6 % Rate: 27 Hz	Eff: 77.6% rate: 20 Hz	± 0.3% ± 3 Hz
with fit & seeding	Eff: 82.3 % Rate: 70 Hz	Eff: 81.2 % Rate: 37 Hz	eff: 81.2% rate: 27 Hz	± 0.3% ± 3 Hz

- Results with DaVinci v20r3

	standard cuts	tight IP Sig cut	tight cuts (mass & IPSig)	
w/o fit	Eff: 77.7% Rate: 33 Hz	Eff: 75.0% Rate: 16 Hz	Eff: 75.0% Rate: 7 Hz	± 0.3% ± 3 Hz
with fit	Eff: 80.0 % Rate: 33 Hz	Eff: 79.9 % Rate: 16 Hz	Eff: 79.9% Rate: 8 Hz	± 0.3% ± 3 Hz

- Results different but relative improvement stays the same

Vertex Isolation Cut

- Different Tools are available, but so far none can be used directly on HLT2.
- Used VtxIsolationFilterCriterion by Luis Fernandez
- Tool gives a yes/no depending on # tracks within 0.2 mm IP window of B/D production vertex.
  - # particles < 4 for D_s
  - # particles < 12 for B_s

	with Vertex Isolation	without Vertex Isolation	
w/o fit	Eff: 77,7% Rate: 33 Hz	Eff: 79.6 % Rate: 92 Hz	± 0.3 % ± 5 Hz
with fit	Eff: 80,0 % Rate: 33 Hz	Eff: 82.0 % Rate: 91 Hz	± 0.3 % ± 5 Hz

- Timing: ≈ 1 - 3 ms per call

Background Categories

- Physics background, fully recontructed: True and correct recontructed decay that did not match with the given decay descriptor (eg. due to intermediate states)
- Physics background, partially recontructed: same as above but not all particles have been (correctly) reconstructed.
- Ghost: at least one final state particle is a ghost
- Pileup from different PV: Final state particles used to form a candidate originated from different colissions
- bb event: at least one final state particle originated from a b-hadron but it was not a signal b

How to calculate MB rate...

```
#===========================================================================
# Efficiency of L0 trigger applied to minimum bias events, computed by Hans Dijkstra:
eff_mbL0=0.05991328 # DC06-L0-v1-lumi2
# Rate of bunch crossing with at least one interaction (in Hz)
BC_rate =14763987.7826
# so 14.76M mb events before L0 stripping corresponds to 1s of real data
taking.
# Reminder:
#  The proba to have a bunch crossing with N int is given by Poisson(mu,N)
#   where mu=sigma_tot * L /r_BC = 102.4*2/295 = 0.695
#   r_BC =  (2622./3564.)*40.08 MHz = 29.5 MHz is the nom-empty BC
#  BC_rate = r*(1.-Poisson(mu,0.))  # =14.8 MHz


NmbInput=5867735 # put here the number of L0-stripped mb events taken
from DC06-L0-v1-lumi2
NmbOutput=2. # put here the number of remaining events after your selection
mbrate = NmbOutput/((NmbInput/eff_mbL0)/BC_rate)
print " "
print "=============================================="
print " Minimum bias rate:  = ", " %4.2f "%(mbrate), " Hz"
print "=============================================="
```

https://twiki.cern.ch/twiki/pub/LHCb/ParamSensit/checkNumberRoadMap.py.txt

Amounts to:

$$R_{mb} = \frac{N_{output}}{N_{input}} \cdot 0.88 \cdot 10^6$$