Detector Potential for Heavy Quark Physics at HERA 2

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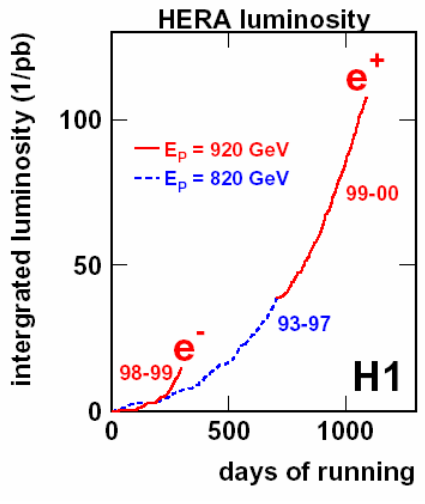
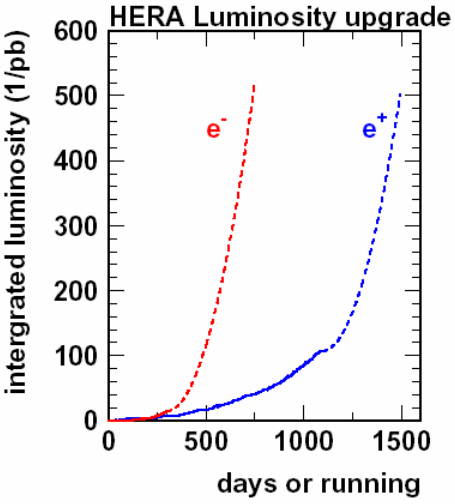
Unfinished business

- Higher scales: Q^2, p_T, m_Q
- The Beauty case: just lucky with charm?
- The role of resolved photons
- "See" NLO effects
- Tools to search for non-standard production, or top
- Match Tevatron range
- Precision F2c
- Diffractive pdf's
- ...

See B.Fosters talk





HERA 1 limitations

- Statistics:

Channel	Events	s/n	$\sim$ equivalent bg free events
D^* in γp	1100	1:4	200
D^* in DIS	2600	1:1	1000
Diffractive D^* in DIS	200	1:2	64
$b \to \mu x$ in γp	500	1:2.5	100
$b \to \mu x$ in DIS	250	1:2.5	50

(Behnke)

- Acceptance (forward!)

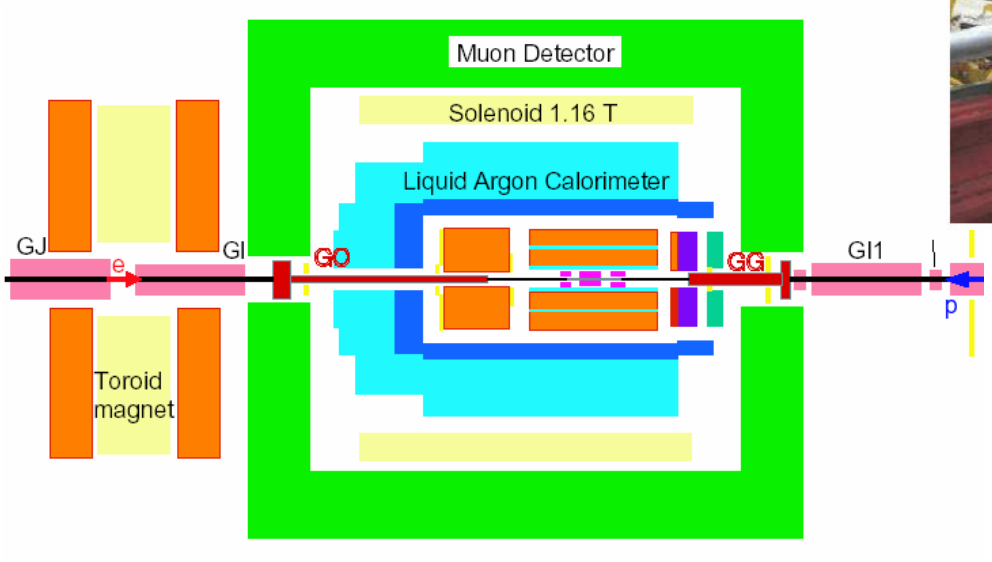
Outline

- Luminosity upgrade
- Trigger upgrade
- Tracking upgrade
- Precision vertexing

Luminosity upgrade

- Superconducting low beta quadrupoles

0.1mm tolerances

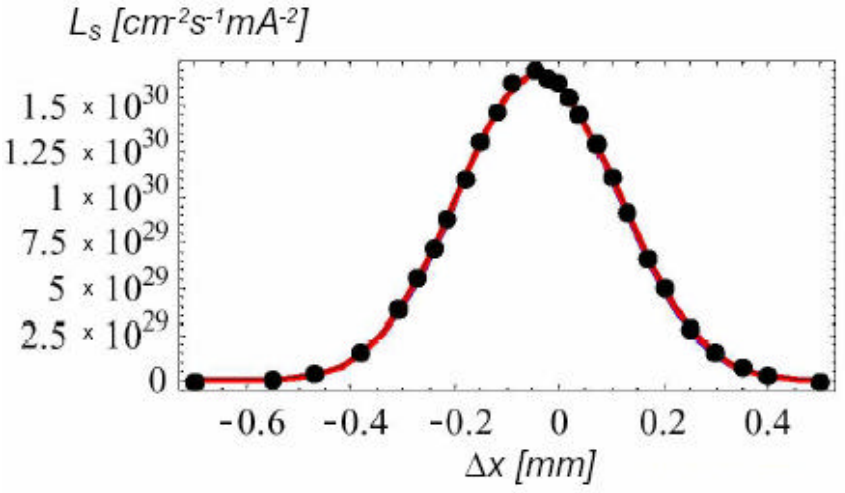


Luminosity upgrade

- HERA tunnel end 2000

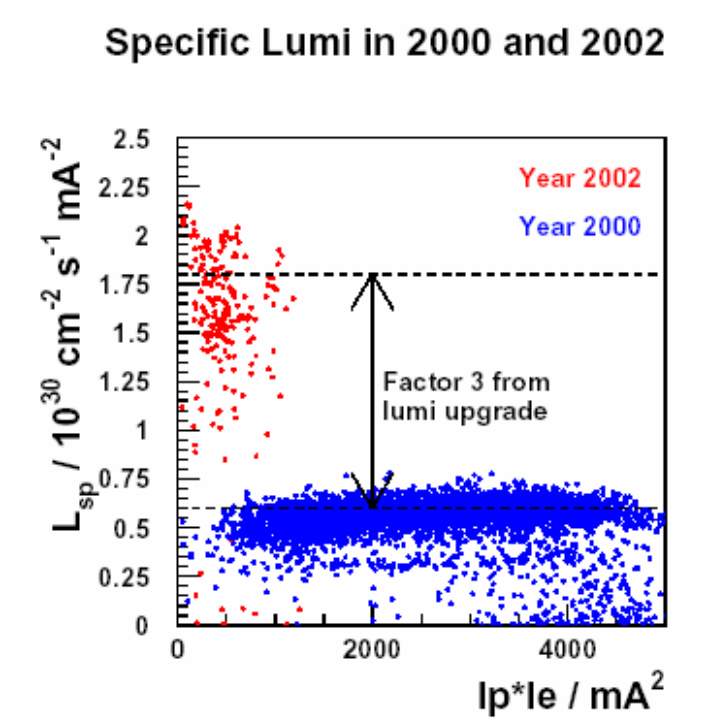
60 new magnets

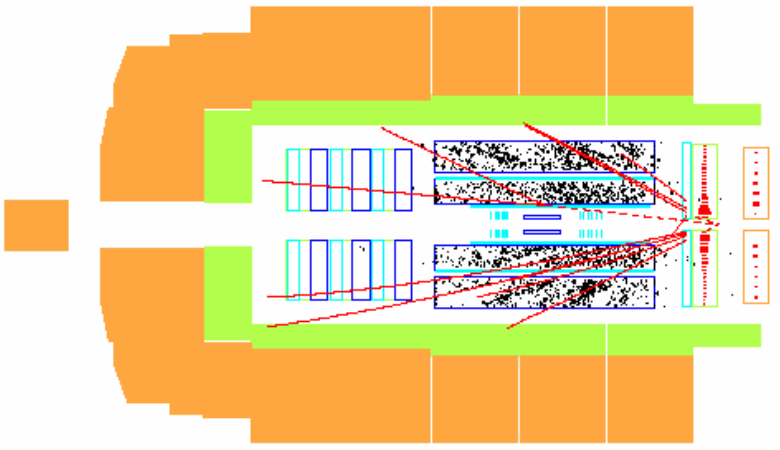
- Specific luminosity measured in 2001/02: 3 times HERA 1



Machine & Detector

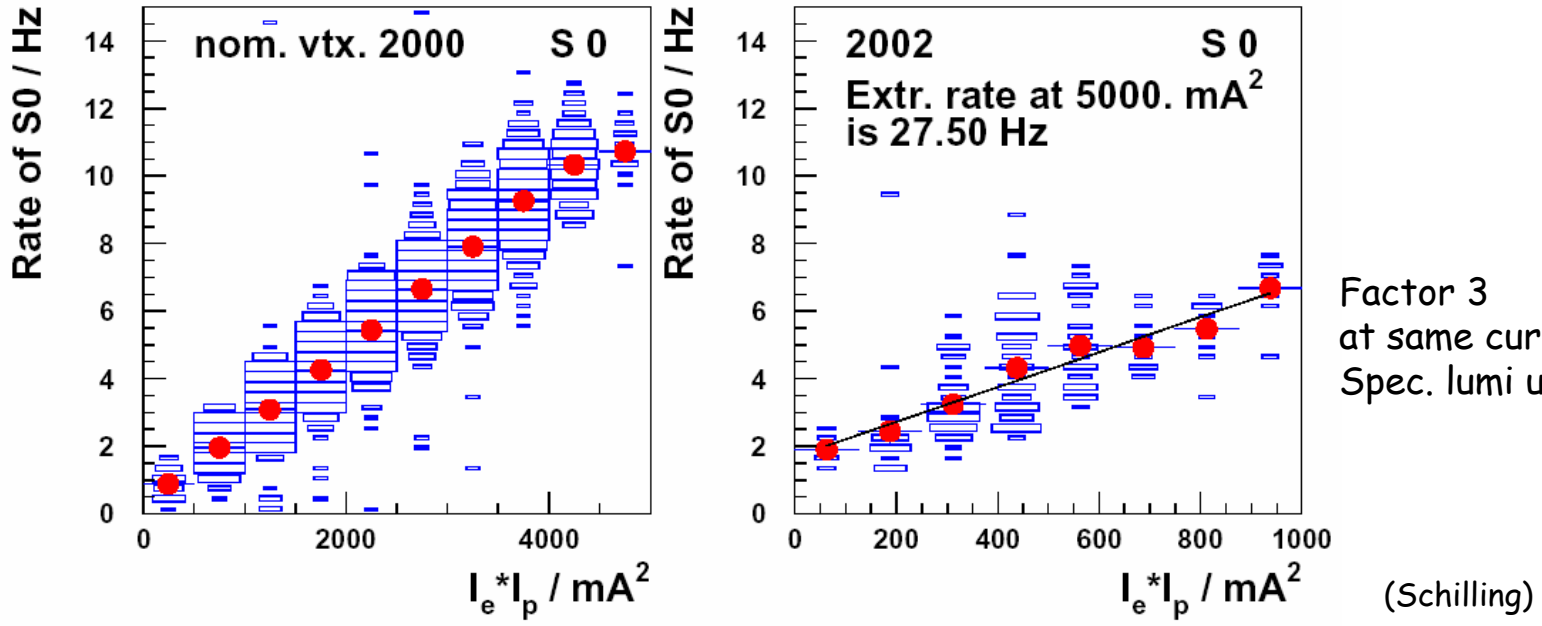
- Severe background conditions at HERA 2
  - A genuine ep problem, scales with Ie * Ip
  - Limits tracking chamber operation and challenges the trigger





Trigger rates

- Example low Q^2 inclusive DIS electron trigger
  - Scales with luminosity,
  - But inclusive "min. bias" triggering even for DIS impossible with given H1 bandwidth limitations



Factor 3
at same currents:
Spec. lumi upgrade

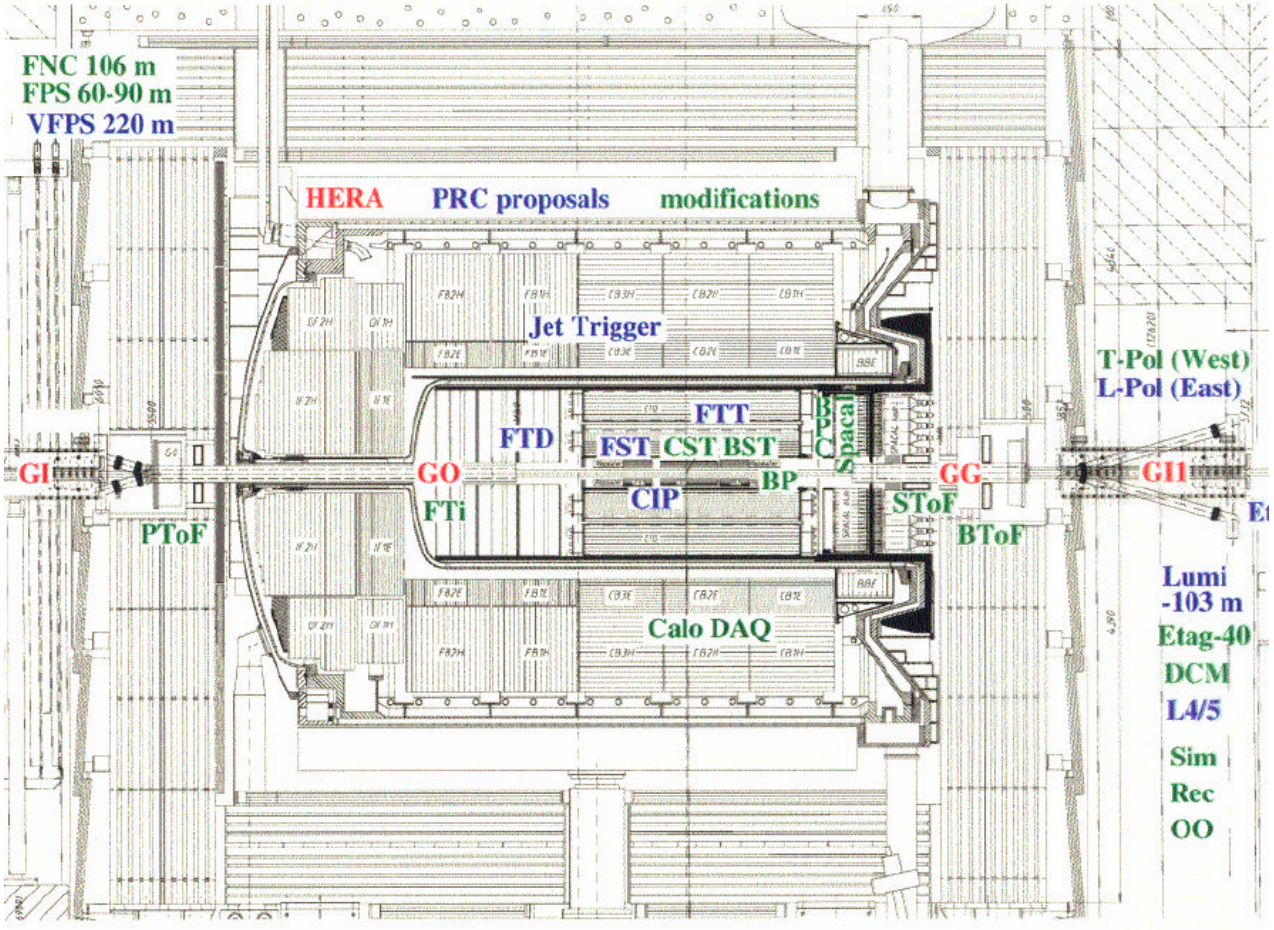
(Schilling)

Lumi and trigger

- HERA 2 **is** 3 times more luminous
- With present, revised schedules we expect about 500 pb^{-1} till 2007
  - i.e. factor 5 to 10 w.r.t HERA 1
- To fully exploit the potential, the H1 Trigger needs care

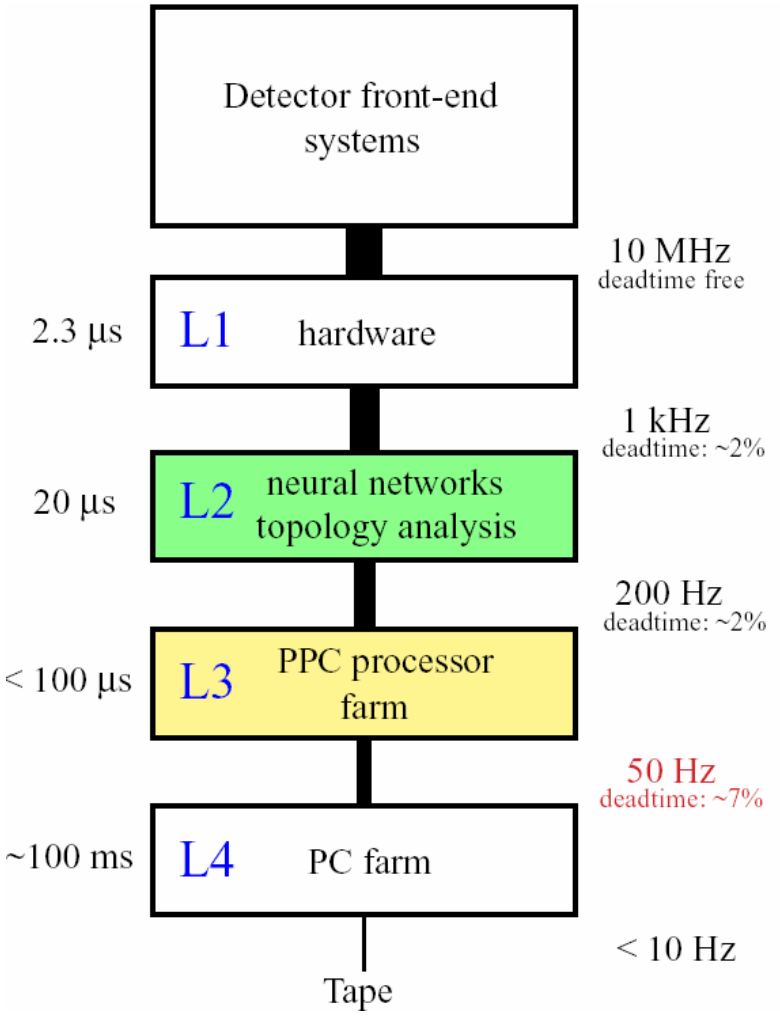
Detector upgrade

- Beam line, detectors and triggers: 19 projects



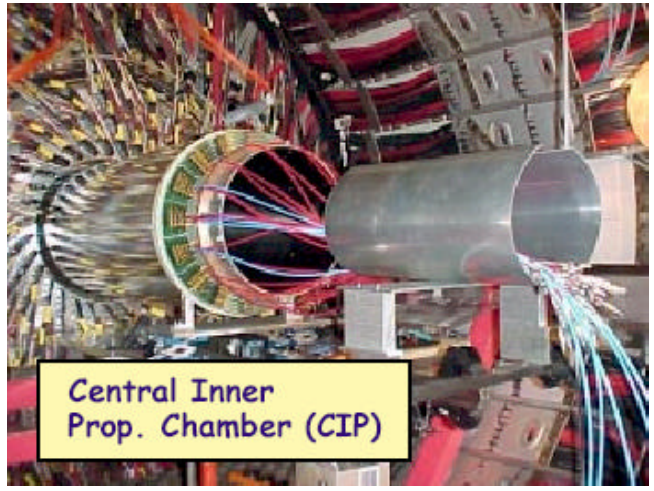
H1 trigger system

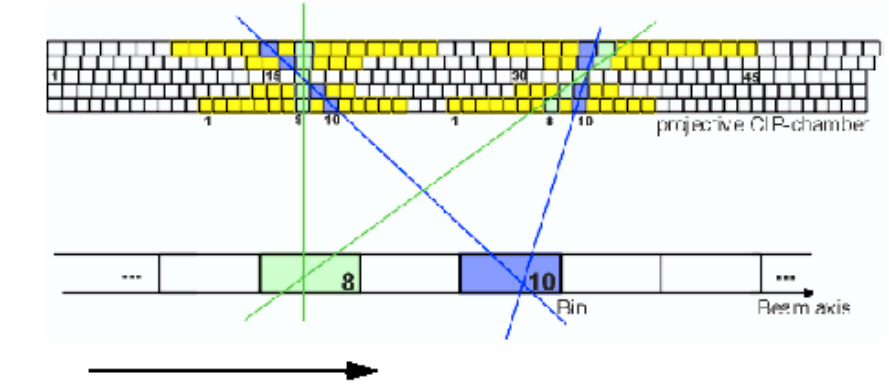
- Due to the large number of calorimeter channels, H1 front end pipelines are short
- The trigger must decide fast (short "latency")
- Using fast and coarse Level 1 data up to Level 3
- Hardware must be smart

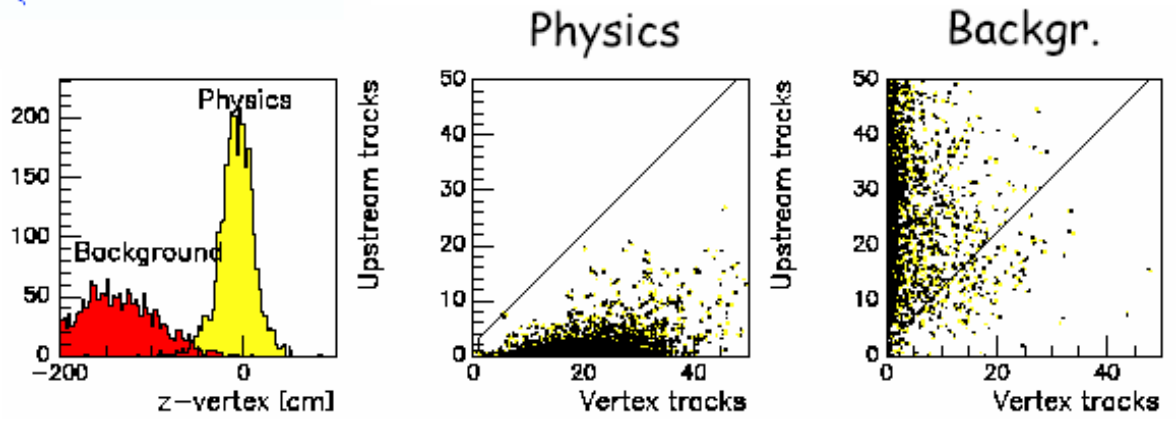


New MWPC z-vertex trigger

- Projective geometry, 10k ch'ls
- Optical readout @ 10 MHz, FPGAs, decision every bunch Xing

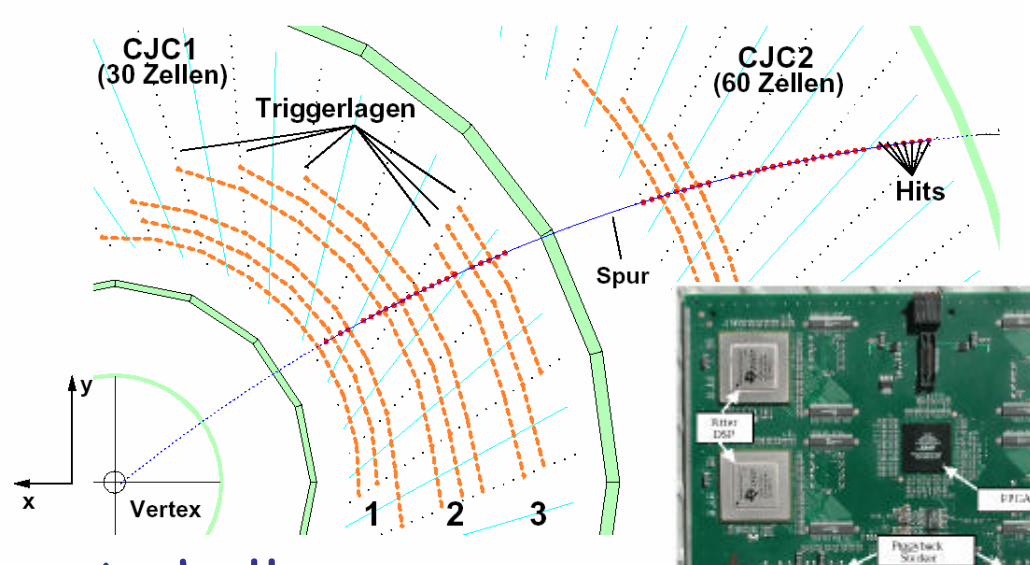


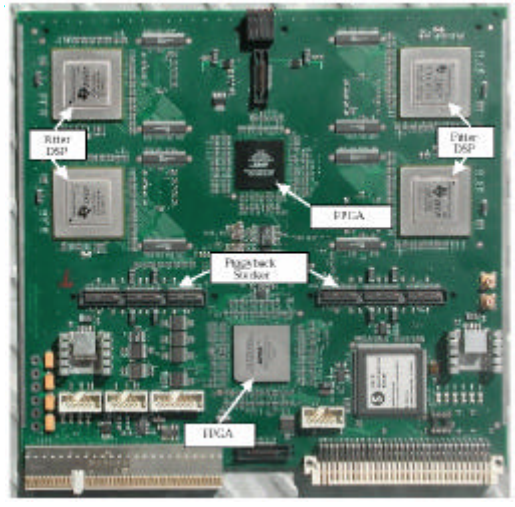




Fast track trigger

- D* (or J/?) background is min bias physics
- Need to trigger on invariant mass signal





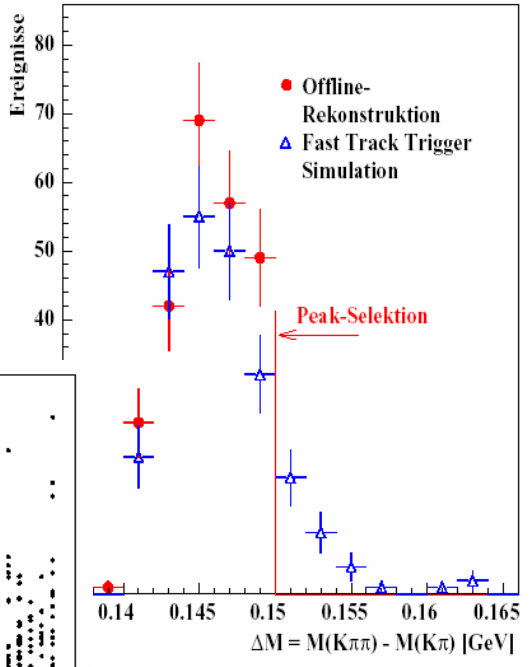
- Tracks on L1 (2 μs)
- Momenta on L2 (20 μs)
- Masses on L3 (100 μs)

- A challenge even for the fanciest latest electronics

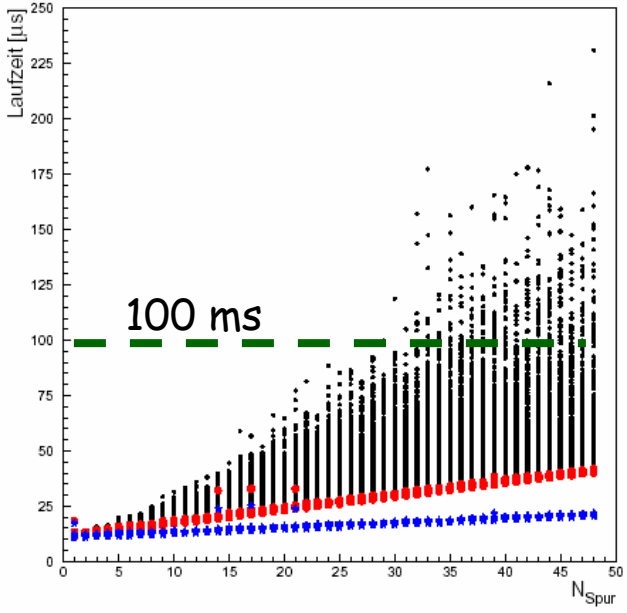
D* trigger

- Rejection power: achieve about 1 Hz for DIS and photoproduction
- Hardware timing tests passed for 99% of events

- Mass difference resolution: good efficiency



(C.Wissing)



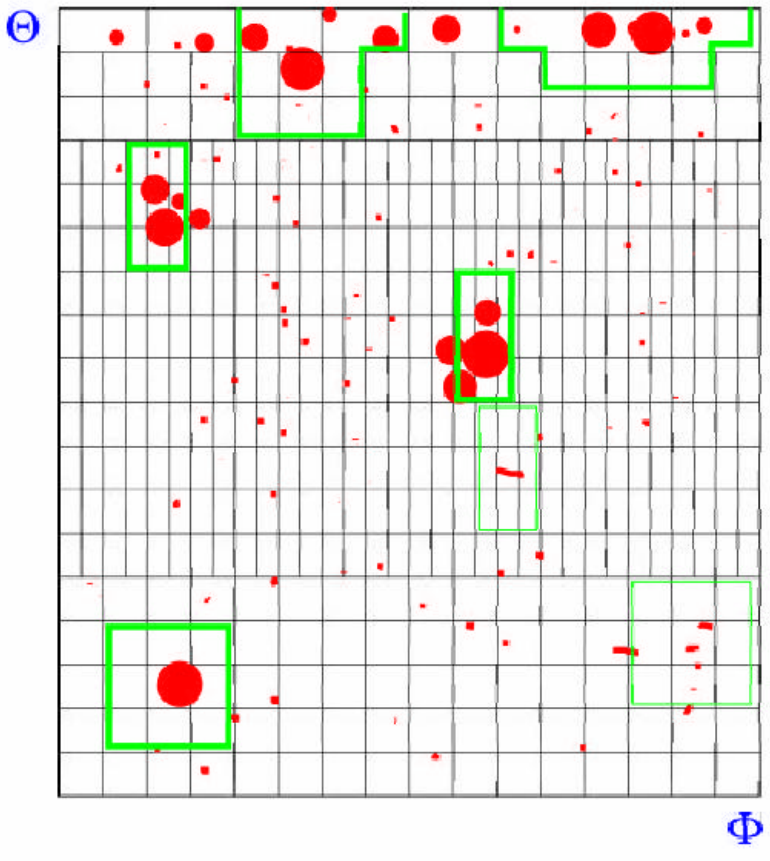
Fit up to 48 tracks

(J.Naumann)

Jet trigger

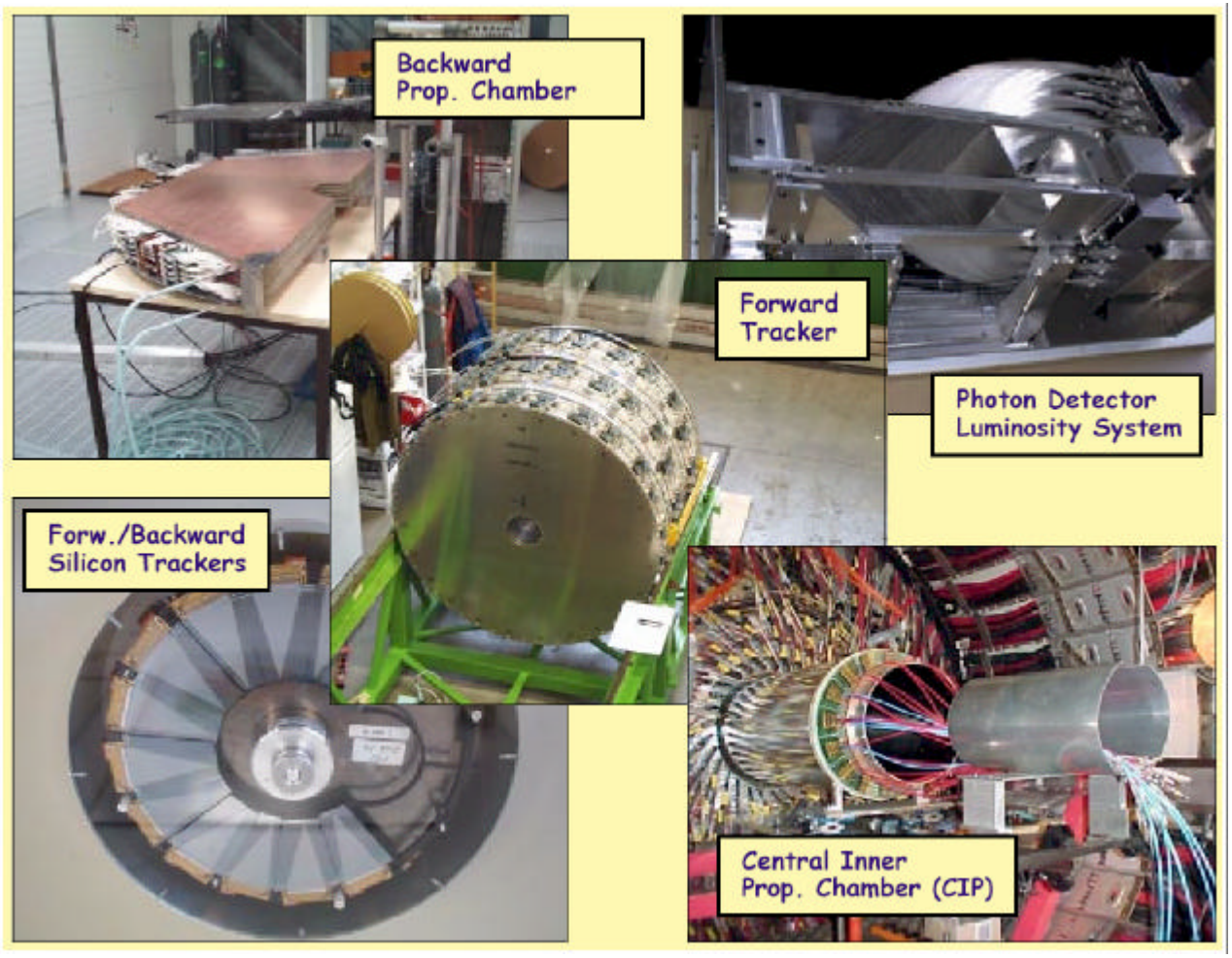
- Detect "regions of interest"
- Energy ordered list of jets at level 1

- b jets possible
  - Low pt + muon (present cuts)
  - Medium pt inclusive



LAr calorimter trigger towers

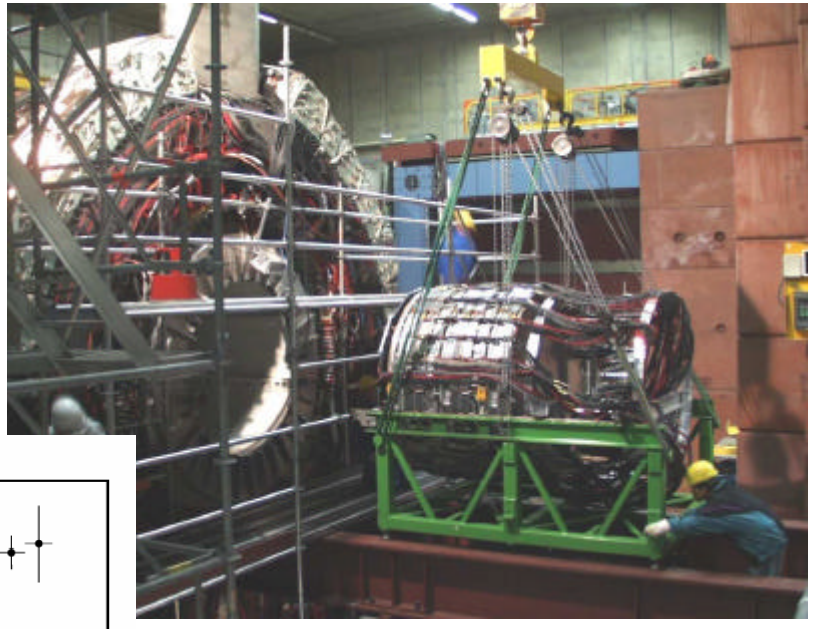
Tracking upgrades

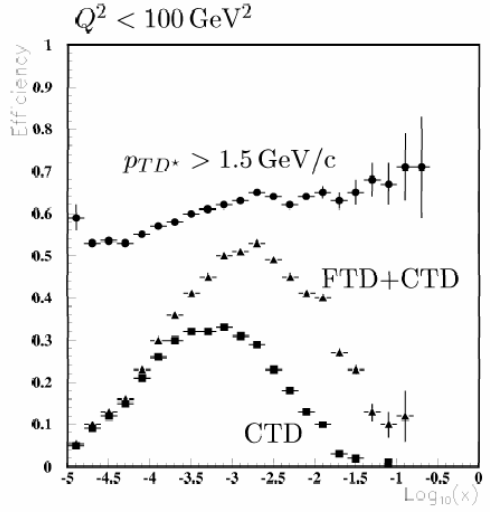


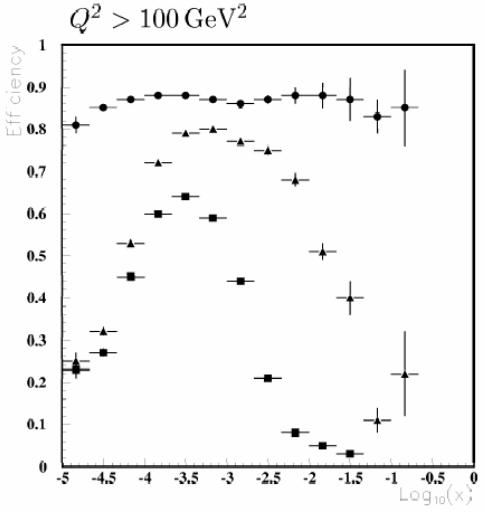
(Schutlz-Coulon)

Forward tracking

- Additional planar chamber layers to add redundancy for pattern recognition
- D* range:
  one O.o.M more in x



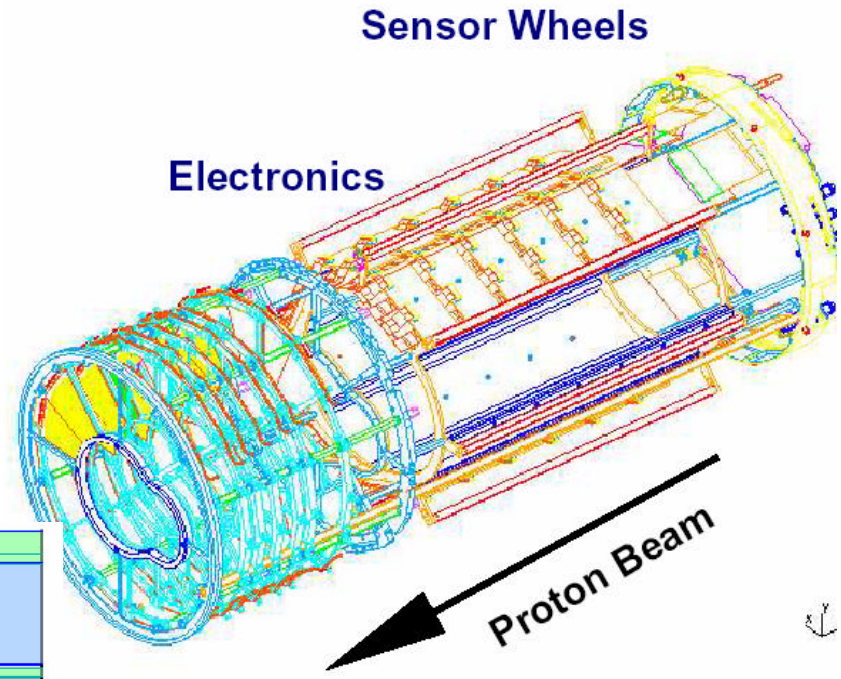


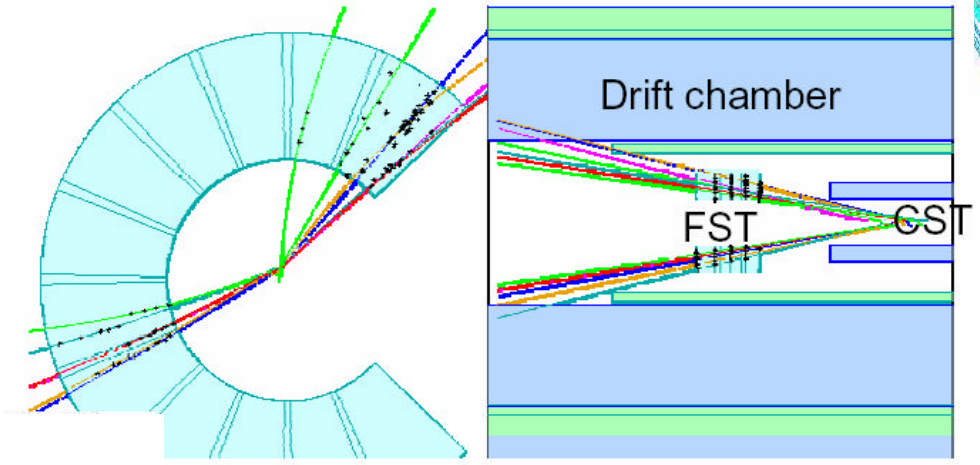


Log x

Forward Silicon Tracker

- 7 disks, 5 u/v + 2 r, 92k channels
- After alignment: Resolution 12 μm

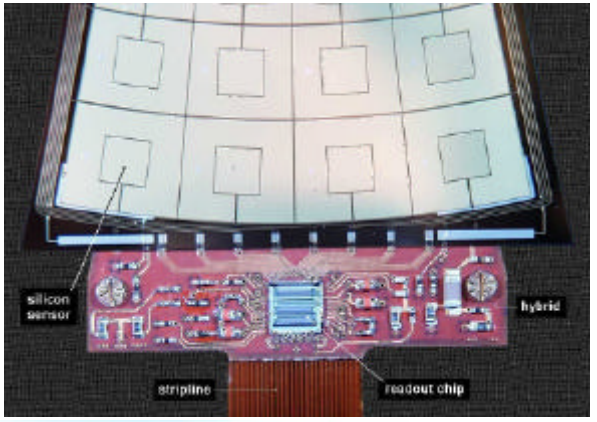


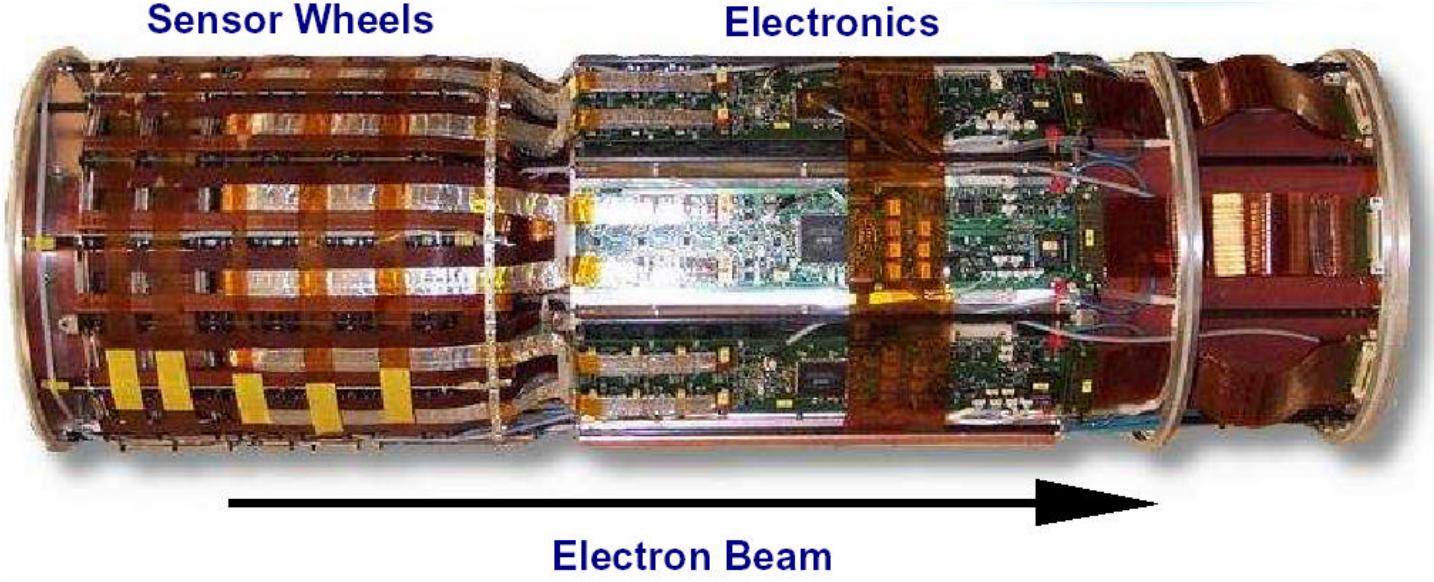


Reconstructed multi-track event

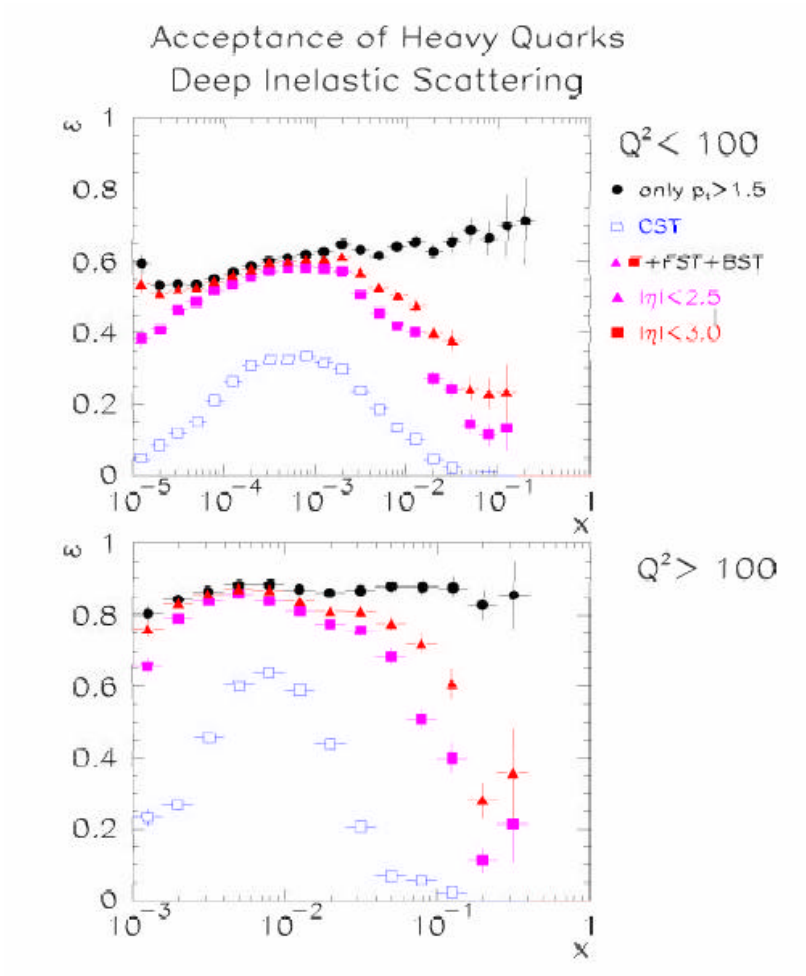
Backward Silicon tracker

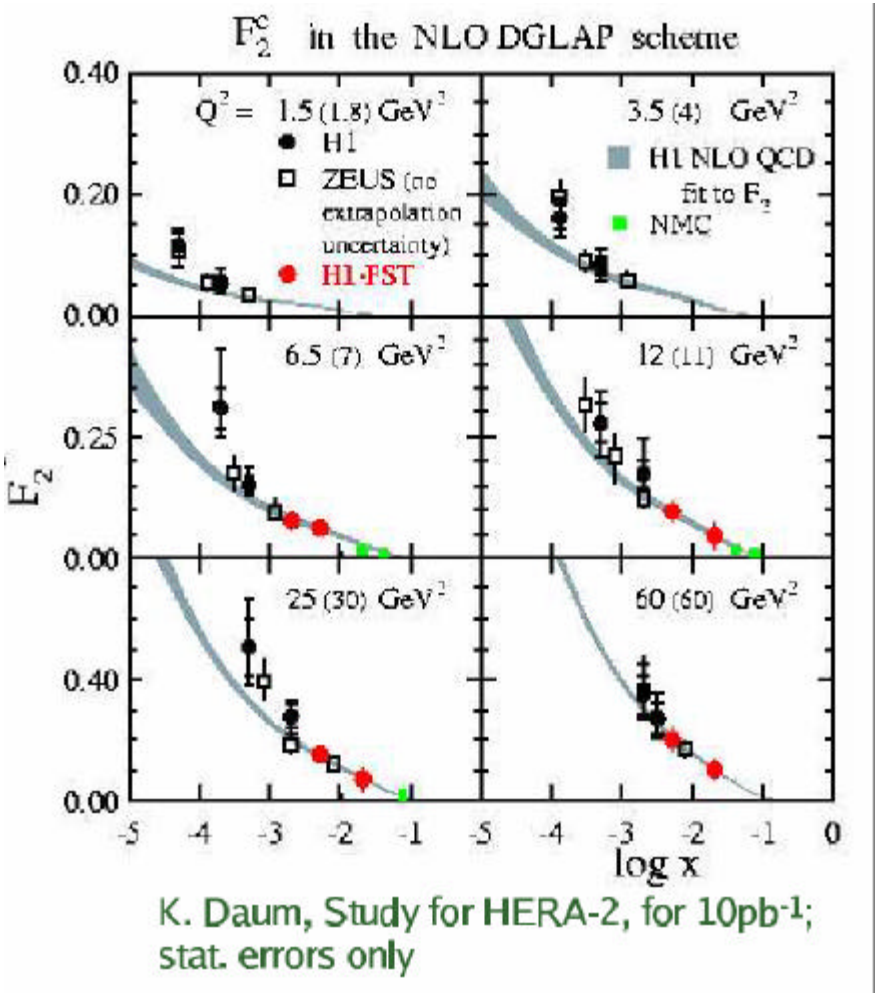
- 6 wheels (u/v) for tracking
- 84k channels
- Plus 4 trigger wheels with pads →





FST and BST range

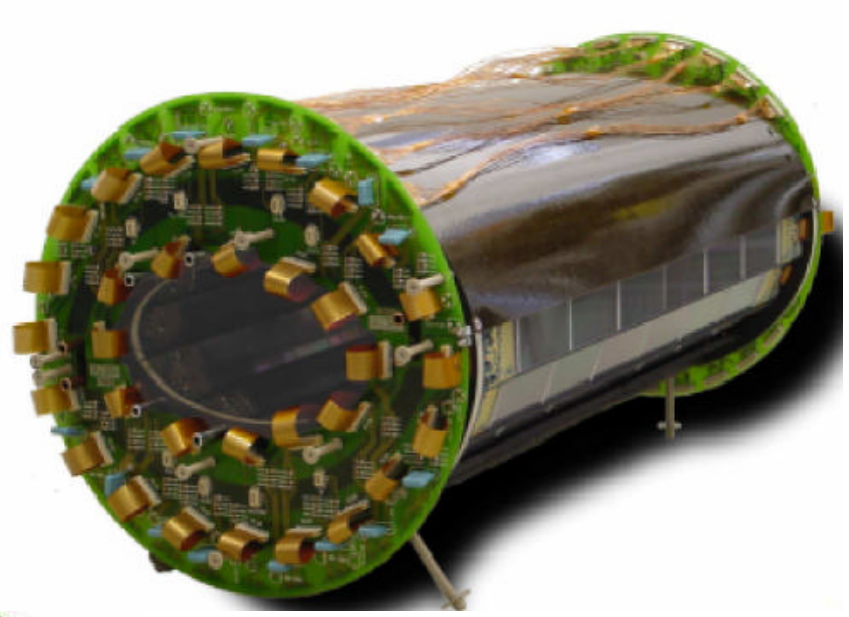


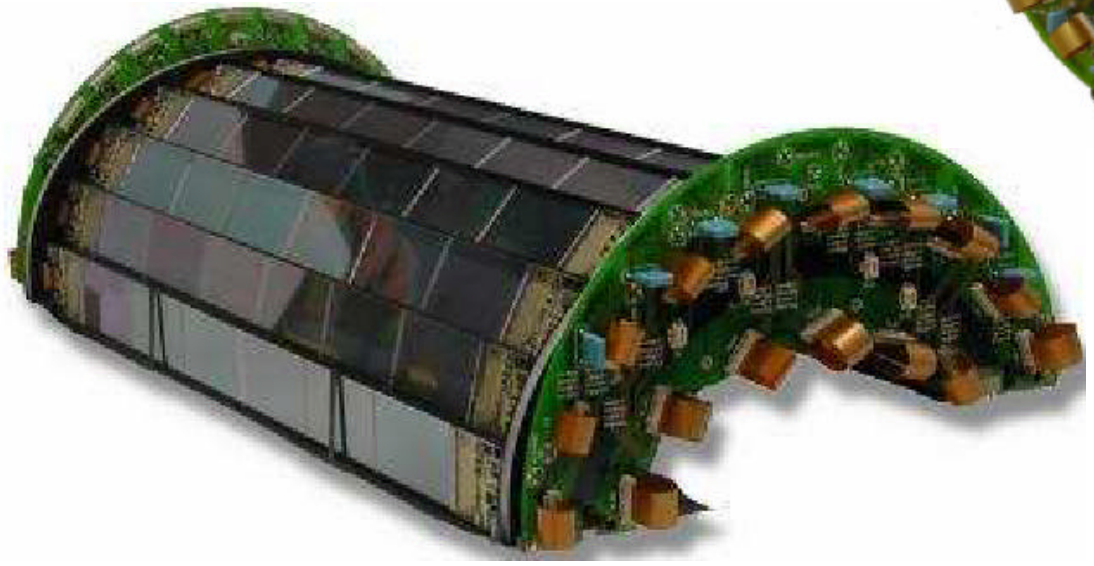


K. Daum, Study for HERA-2, for 10pb^{-1}; stat. errors only

The new H1 CST

- 2 layers, 82k channels
- Radiation hard electronics
- 1.4% Xo

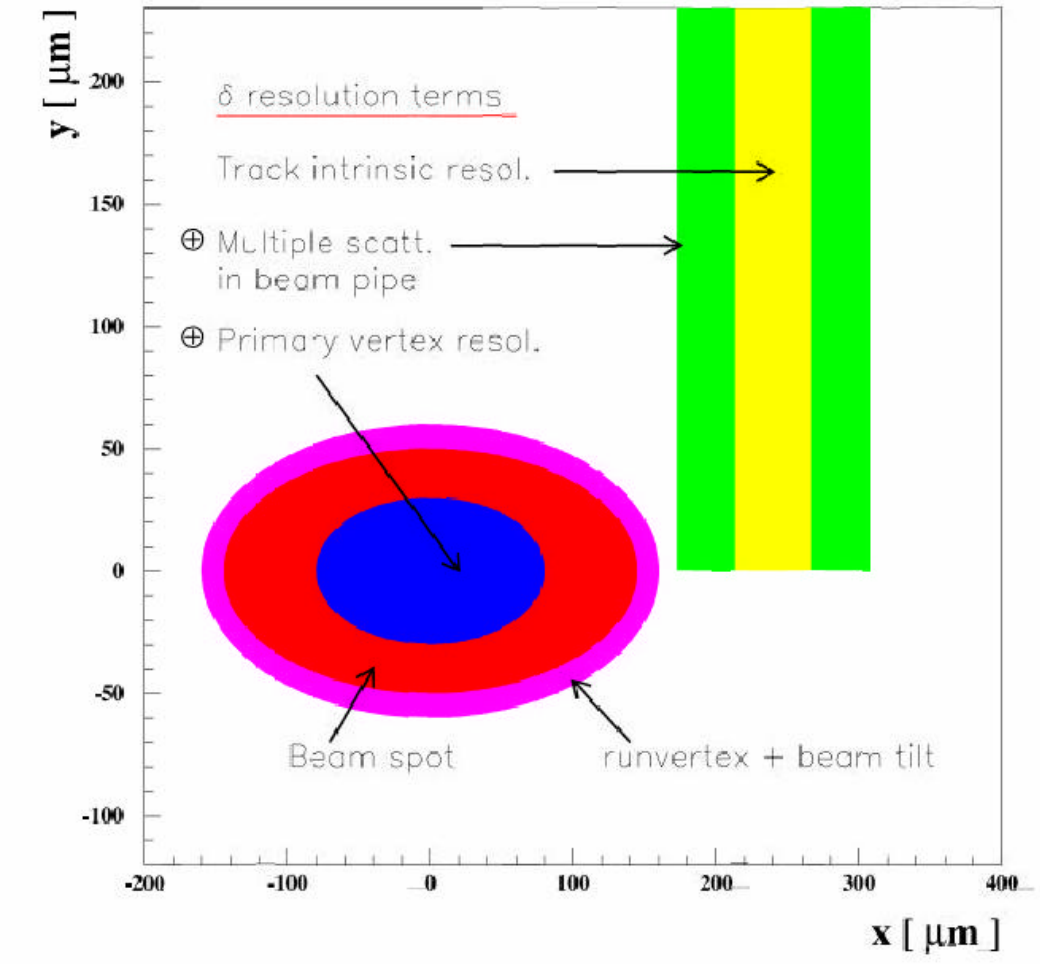




Detector upgrade

- Fascinating new trigger tools – more potential than just for coping with HERA 2 backgrounds
- Increased tracking acceptance for new kinematic ranges
- Almost full coverage with vertex detectors

Track and vertex resolutions

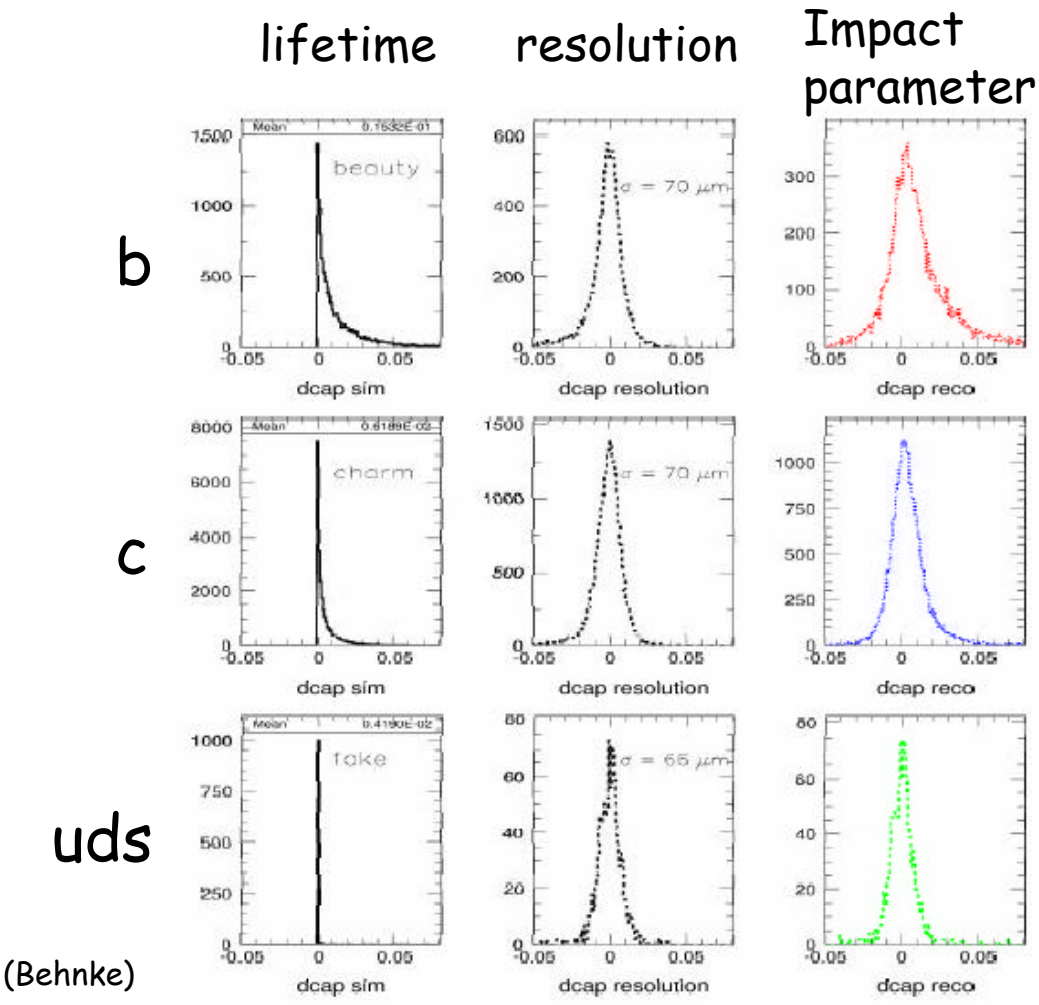


Source	99/00 Data	
intrinsic	$\approx 33\ \mu m$	
M.S.	$\approx \frac{90\ \mu m}{p_T}$	Hera 2
Beamsp. x	$145\ \mu m$	80
Beamsp. y	$25\ \mu m$	20
$\sigma_{Runv.}$	4-20 μm	

(Behnke)

Heavy flavour signatures

- Lifetime effects and resolution are of similar magnitude



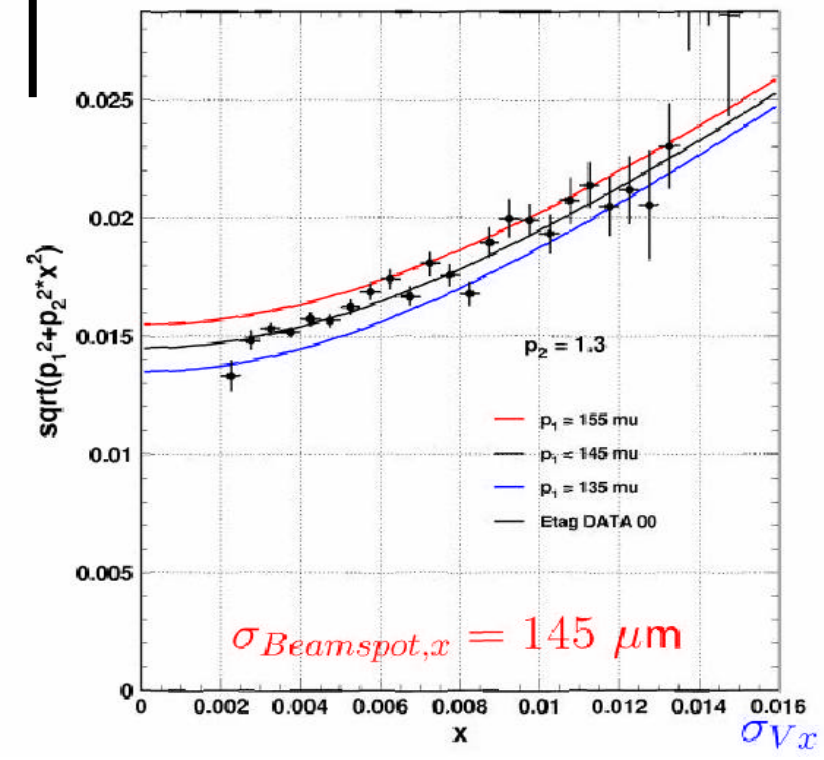
(Behnke)

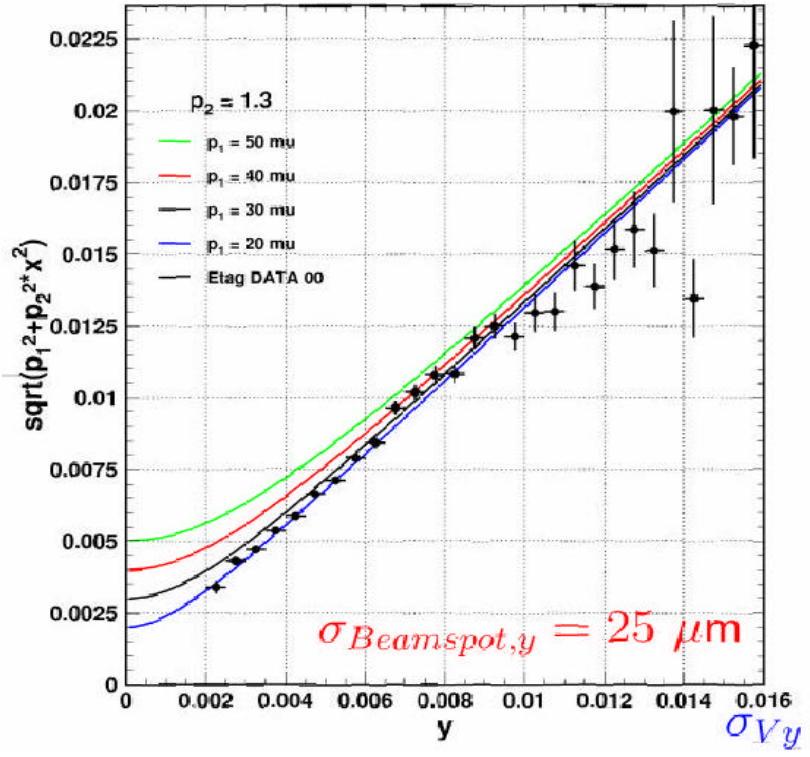
Lifetime tagging

- H1 (and ZEUS) vertex detector resolutions and HERA beam spot size are comparable to situation at other colliders
- In our p_T range mult.scatt. is important
- Track impact parameters are boost-independent (almost)
- Inclusive lifetime tagging should be possible
  - But requires otimized resolution and systematics
  - And excellent detector simulation

Measure the beam spot

Observed width = resolution beam width





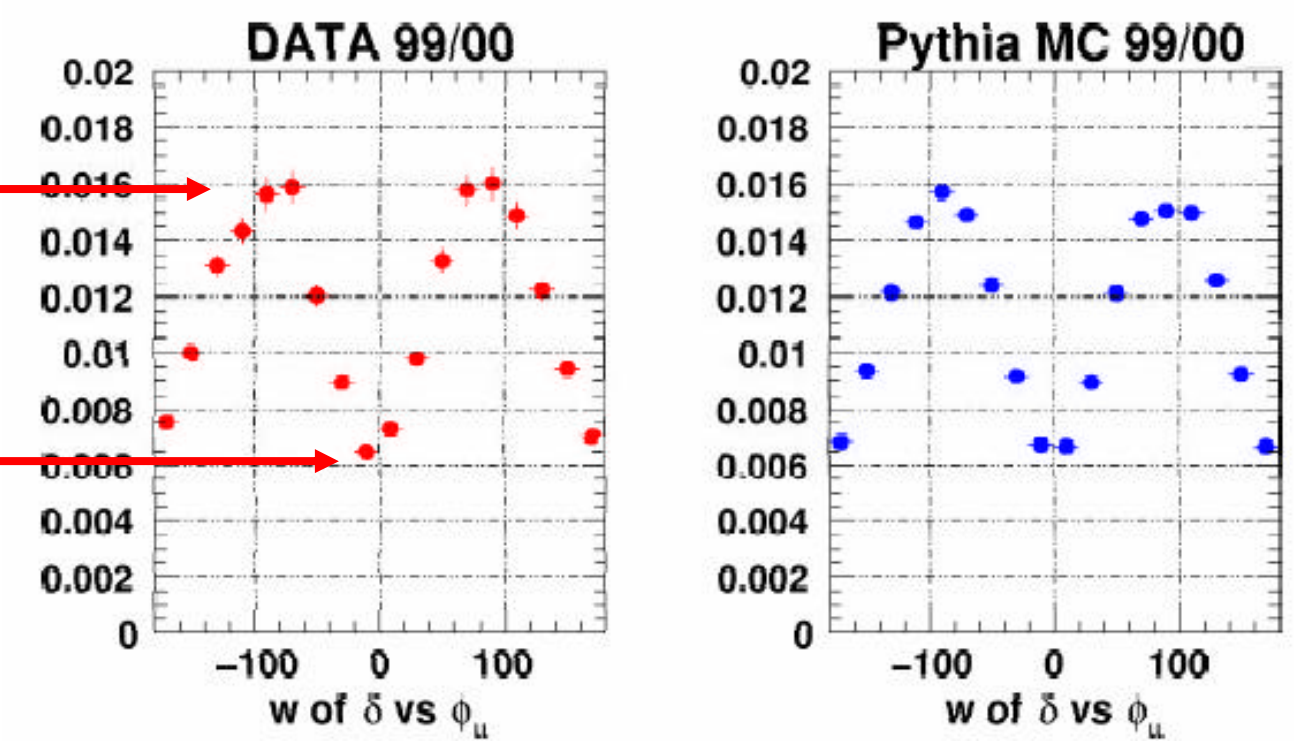
Event-by-event vertex resolution →

Control with MC

Width of
|impact parameter|
distribution

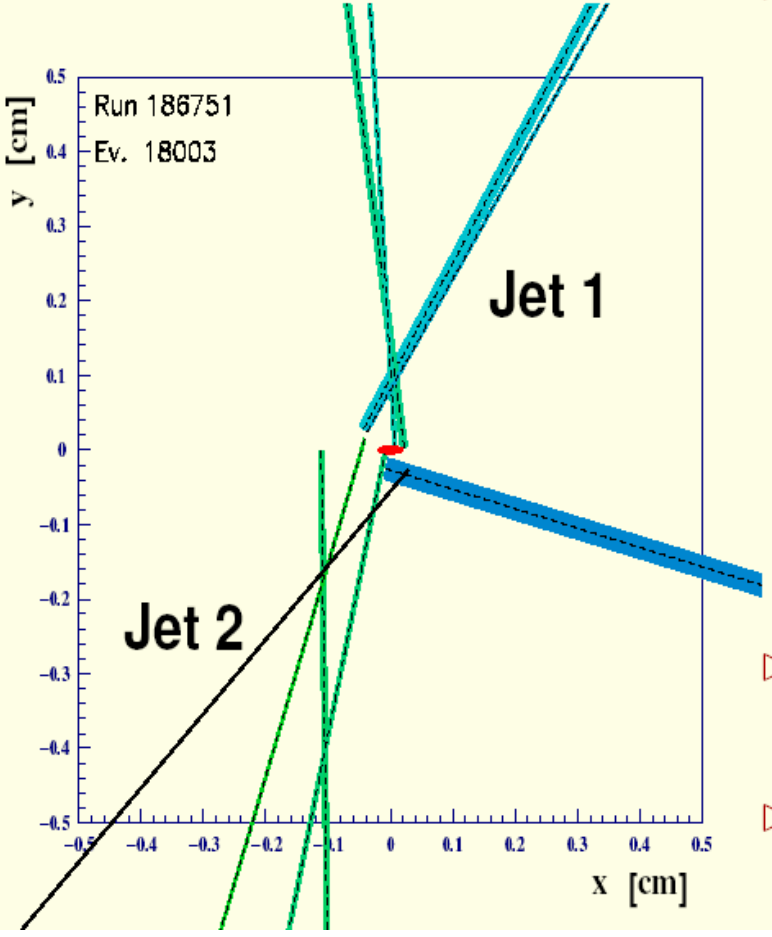
vertical tracks

horizontal tracks



Varies properly with pt

Multi-Impact parameter tag



- Combine δ's of well measured tracks in a jet

Taking track resolutions into account:

$$S_i = \frac{\delta_{xy}}{\sigma(\delta_{xy})}$$

Track compatible with 1st vertex?

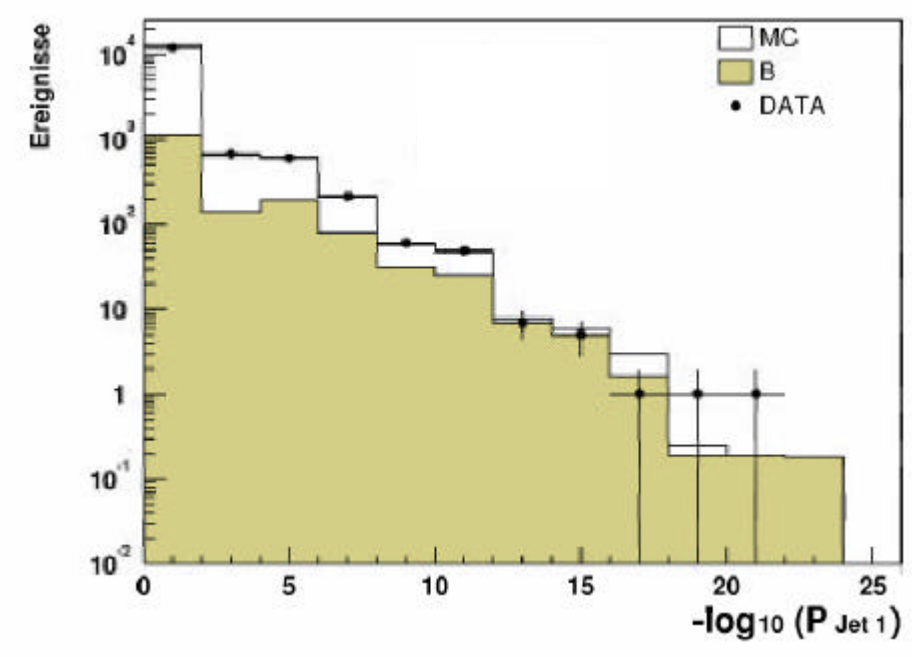
$$p_i(S_i) = \frac{1}{\sqrt{2\pi}} \int_{\chi^2}^{\infty} e^{-t^2} dt \quad , \chi^2 := S_i^2$$

- Combining all track-probabilities
  $\Rightarrow$ **tagging variable** P_{Jet}
- P_{Jet} is the probability that a group of N tracks emerge from primary vertex

(courtesy L.Finke)

B in high pt jets

- Ongoing analysis: try high p_T(>15(10) GeV) photoproduction
- Seems possible to obtain reasonably pure b sample with good efficiency



Diploma thesis L.Finke

Conclusion

- The major part of the H1 upgrade is devoted to heavy quark physics
- We have now more luminosity and the best H1 detector we ever had
- Lifetime tagging analyses: the exciting future has begun