The LHCb Experiment

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Just another B-experiment??

Why is CP violation highly interesting?

- No precision test of the Standard Model in CP violation so far: we cannot exclude that CP violation is partly due to new physics. (Why strong CP is small but weak CP not?)

- Since CP violation is due to an “interference“ it is sensitve to a small effect due to new physics.

- Cosmology (baryon genesis) suggests that an additional source of CP violation other than the Standard Model is needed.

Physics of B-Mesons (very short)

- SM can naturally describe CP violation with single complex phase in the quark mixing matrix V_{CKM}
- unitarity of matrix
  $\rightarrow$ four independent parameters
  $\rightarrow$ Wolfenstein parametrisation (unitarity triangles)

Present experimental activities

- FNAL & Na 48 ($K^0 \to \pi\pi$)
- CDF ($B_d \to J/\psi K_s$)
- E787 at Brookhaven (rare K-decays)
- B-factories BarBar & BELLE $\to$ first results (sin(2β))

Standard Model prediction (0.65<sin(2β)<0.77) presently consistent with experimental results

- HERAb
- upgraded experiments CDF & D0

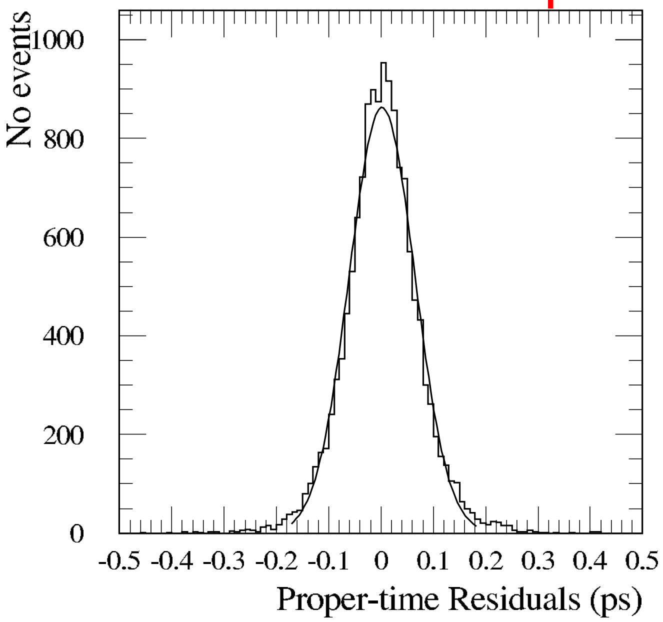
BUT:

- measuring sin(2β) does not allow to judge the validity of SM
- high precision of many different decay modes $\to$ search for sign of new physics
- small branching ratios

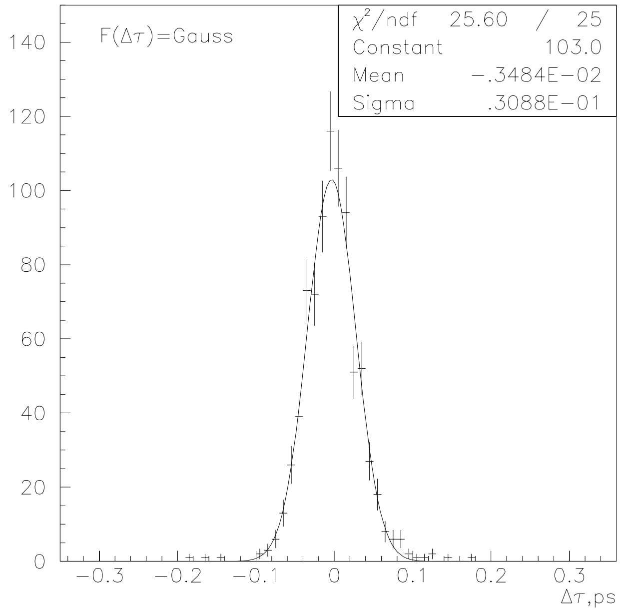
Why a special experiment for B physics at LHC?

- CP asymmetry of B_S-decays a very good eigentime resolution

ATLAS 0.06 ps



LHCb 0.03 ps



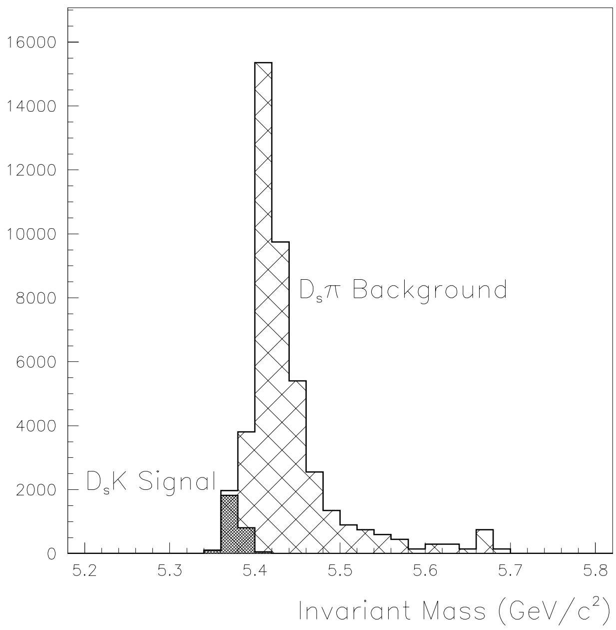
- a trigger for optimized for B-decay channels is needed $\rightarrow$ hadron trigger (semileptonic decays are least effected by new physics)

Why a special experiment for

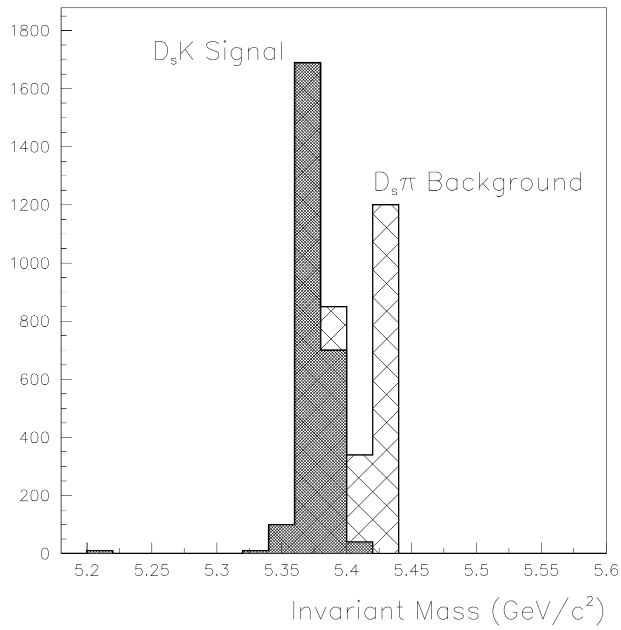
B physics at LHC?

- many channels need very good particle identfication $\rightarrow$ seperation of π and K over a wide range of momenta

before RICH



after RICH



- invariant mass resolution of B

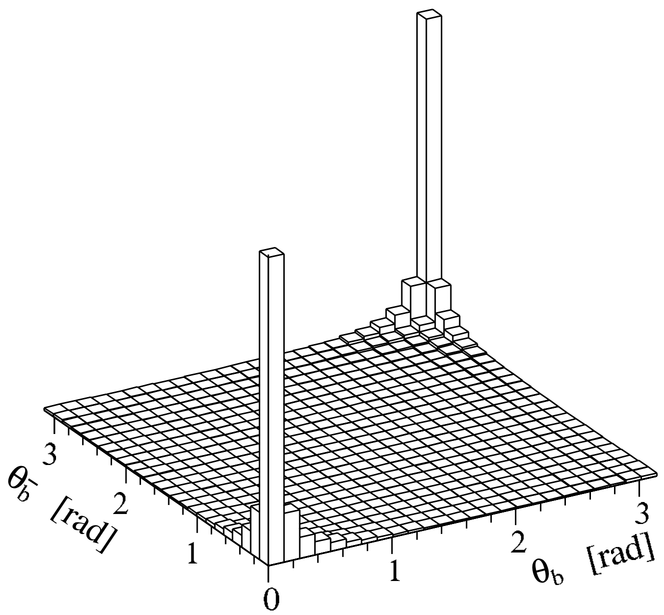
Discovery potentials

channel	measures (method)	Atlas	CMS	LHCb	comment
$B_d \to J/\psi K_S^0$	$\sin(2\beta)$ (t-dep)	165k 0.017	430k 0.015	88k 0.021	
$B_d \to \pi^+\pi^-$	$\sin(2\alpha)$ (t-dep)	2.3k	0.9k	4.9k 0.07	need P/T,δ S/B = 15
$B_d \to \rho\pi$	α (t-dep)			1300 0.04 - 0.09	full 11 param Dalitz analysis
$B_d \to D^{*\pm}\pi^{\mp}$ $B_d \to D^{*\pm}a_1^{\mp}$	$2\beta + \gamma$ (t-dep)			703 k 0.26	tiny interference no full sim. yet
$B_s \to D_s K$	$\gamma - \delta\gamma$ (t-dep)			2400 0.11 - 0.23	Bkgd: $D_s\pi$
$B_d^0 \to DK^{*0}$	γ BR - ratio			300 0.07 - 0.31	
$B_s \to J/\psi\phi$	$2\delta\gamma$ (t-dep)	300k 0.03	600k 0.014	370k 0.02	
$B \to \pi K$	γ BR-ratio			90k (175k) 0.03 - 0.10	$K^0\pi^+$, $(K^+\pi^-)$ need T/P
$B_s \to J/\psi K_s$	γ (t-dep)		4100		S/B = 0.5
$B \to DD$ and $B_s \to D_s D_s$	γ (t-dep)			300k (190k) 0.02	B_d,(B_s) B_s: rate only
$B_d \to \pi\pi$ and $B_s \to K^+K^-$	γ (t-dep)	1400 0.09 - 0.13	960 0.10 - 0.33	4600 0.034 - 0.068	B_s 5 years
$B_s \to D_s\pi$	x_s	3500 46	4500 42	86000 75	(measurable)
$B \to K^*\gamma$				26000 0.01	S/B = 1 CP - Asym.
$B \to K^*\mu^+\mu^-$		1995	12600	22350	

Design of LHCb

- note: collider experiment

- b quarks are mainly produced through gluon-gluon fusion. Angular distribution is peaked in the forward direction $\Rightarrow$ forward spectrometer



- $b\bar{b}$ pairs are leaving into the same hemisphere $\Rightarrow$ single spectrometer arm

- most important: measurement of lifetime of b mesons $\Rightarrow$ vertex detector with very good resolution

Design of LHCb

- reconstruction of invariant mass
  $\Rightarrow$ magnetic spectrometer

- good particle identification (rare decays)
  $\rightarrow$ muon system
  $\rightarrow$ electromagnetic calorimeter
  $\rightarrow$ ring imaging Čerenkov counter (pion-kaon)

- many channels of interesting decay channels contain only hadrons in final state
  $\Rightarrow$ hadronic calorimeter (high p_T trigger system)

Tracking system

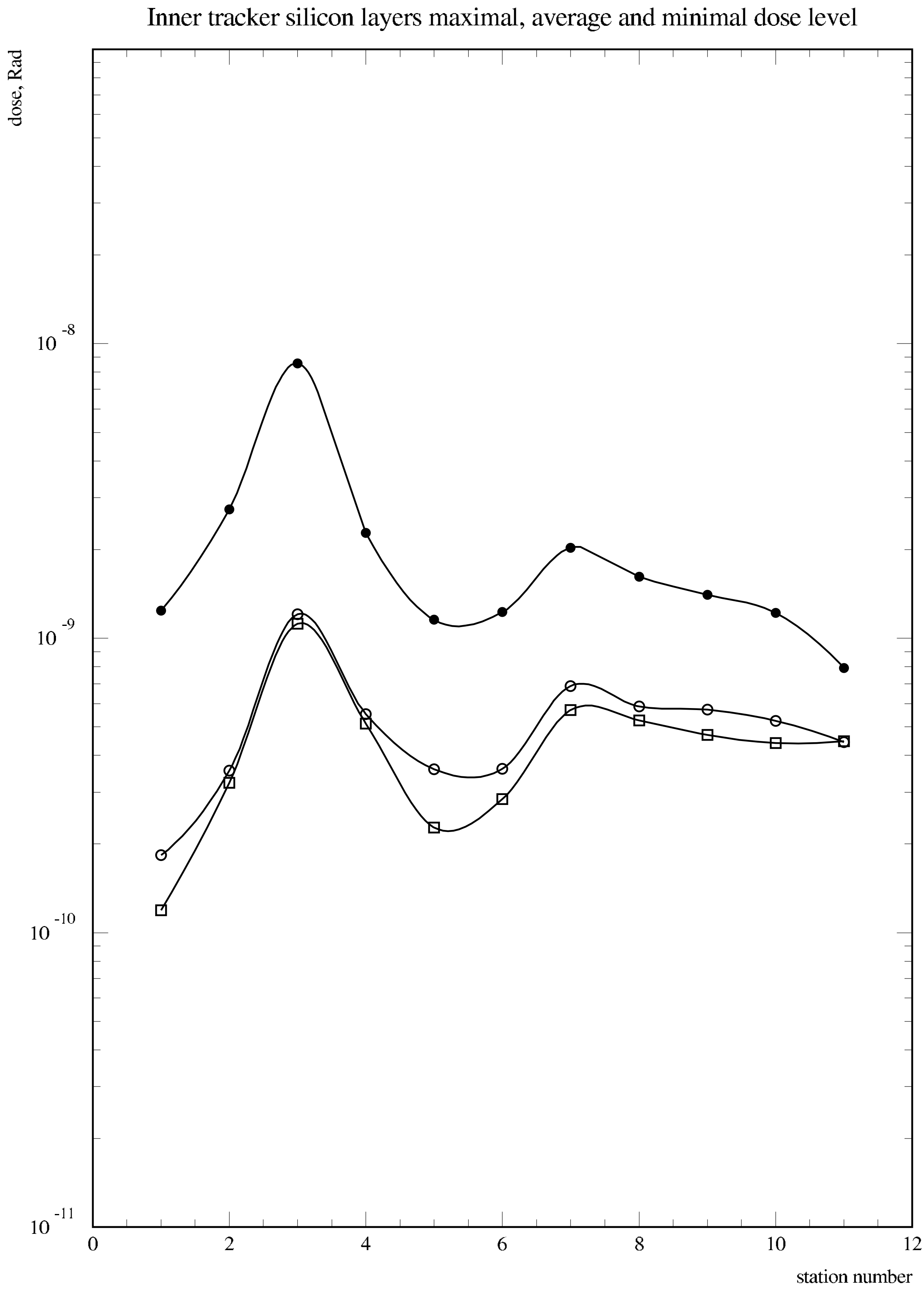
- very good momentum resolution
  crucial quantity not spacial resolution
  limiting factor is multiple scattering
  $\rightarrow$ low material budget (still good pattern recognition)
  $\Rightarrow$ 11 tracking stations

- withstand high particle rates (up to 10^4 s^{-1}mm^{-2})

- occcupancy has to stay low
  $\rightarrow$ is devided into two parts

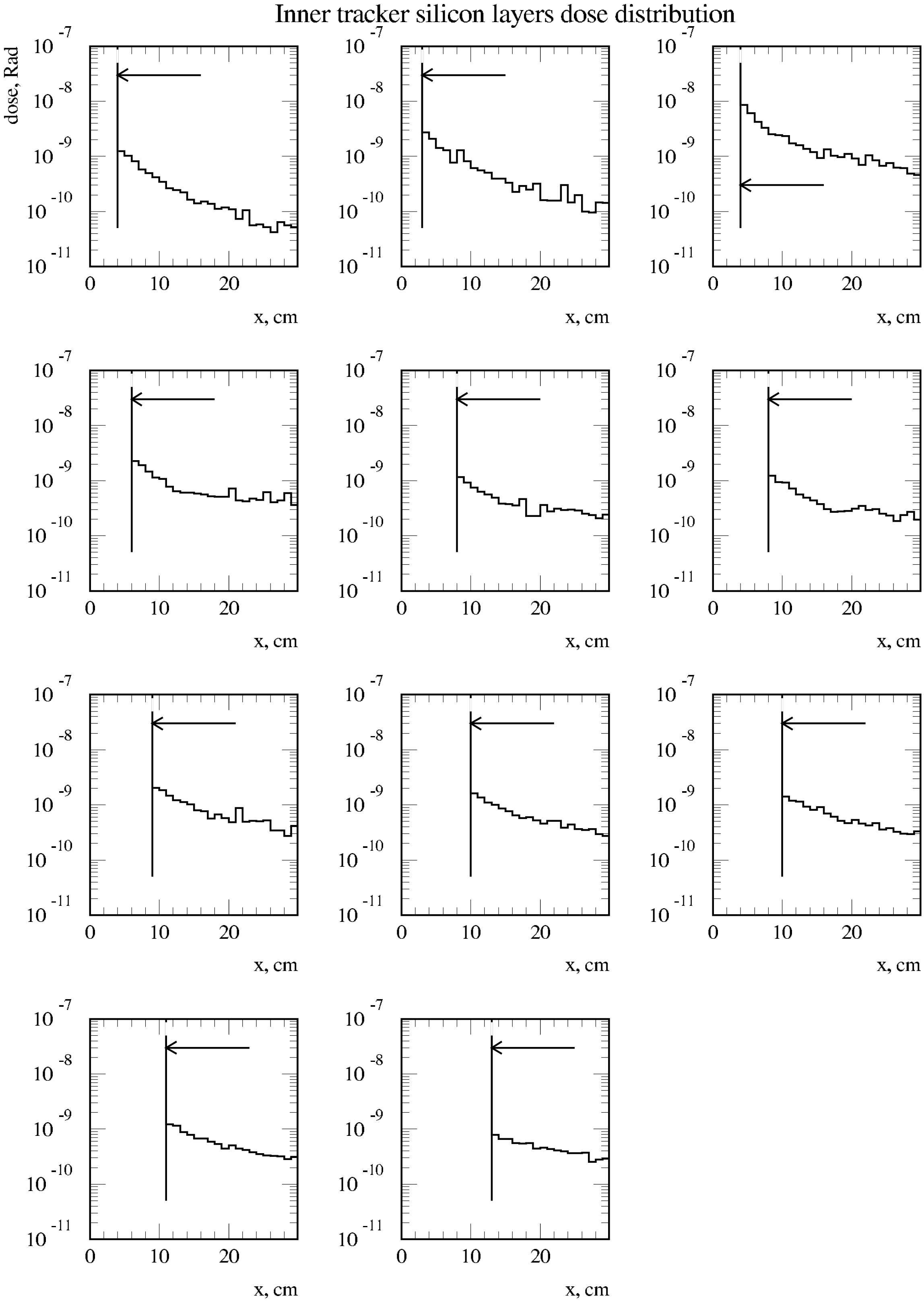
  - outer tracking part
  - inner tracking part

Dose levels



Inner tracker silicon layers maximal, average and minimal dose level
dose, Rad
10 -8
10 -9
10 -10
10 -11
0
2
4
6
8
10
12
station number

Dose levels



Inner tracker silicon layers dose distribution
dose, Rad
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
0
10
20
x, cm

Inner Tracker

- conical beam pipe
  ⇒ active area of Inner Tracking system changes from station to station

station	z position	r_{min}
T1	970	??
T2	2290	36
T3	3350	47.5
T4	4850	61.5
T5	6250	75.5
T6	7050	84.5
T7	7950	93.5
⋮	⋮	⋮

- particle flux too high for conventional drift chambers → several detector technologies were investigated

- four layers per station were proposed (stereo angle of 5°)

- low radiation length

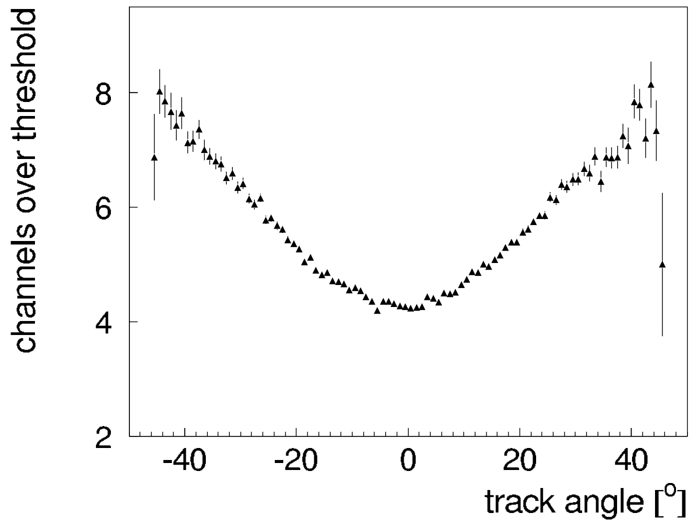
⇒ active area of 10 m^2 and $\sim$ 200000 readout channels (depends on technology)

Differnet technologies for the Inner Tracker

- originally MSGCs were intended
  they turned out to be unadequate to cope with high rate hadronic beams
- other options:
  Micromegas, Microwires and Triple GEM detectors
  Triple GEM showed best performance
  $\Rightarrow$ focus on this gas technology
- only competitor: silicon

Triple GEM – Silicon

- cost:
  - material
  - readout channels (pitch of silicon should not excced 250 μm)
- occupancy: large angle background leads to high occupancies for Triple GEMs



- radiation length including supporting structure
- long term stability (radiation hardness, sparks)

Specifications for Silicon prototype

- single sided
- n-typ oxygenated silicon
- wafer size 6“
- breakthrough voltage > 500 V
- AC readout coupling
- readout pitch of 240 μm

first detctors ordered