The TPC Tracker
for the DESY/ ECFA study detector

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DESY
1-May-1999

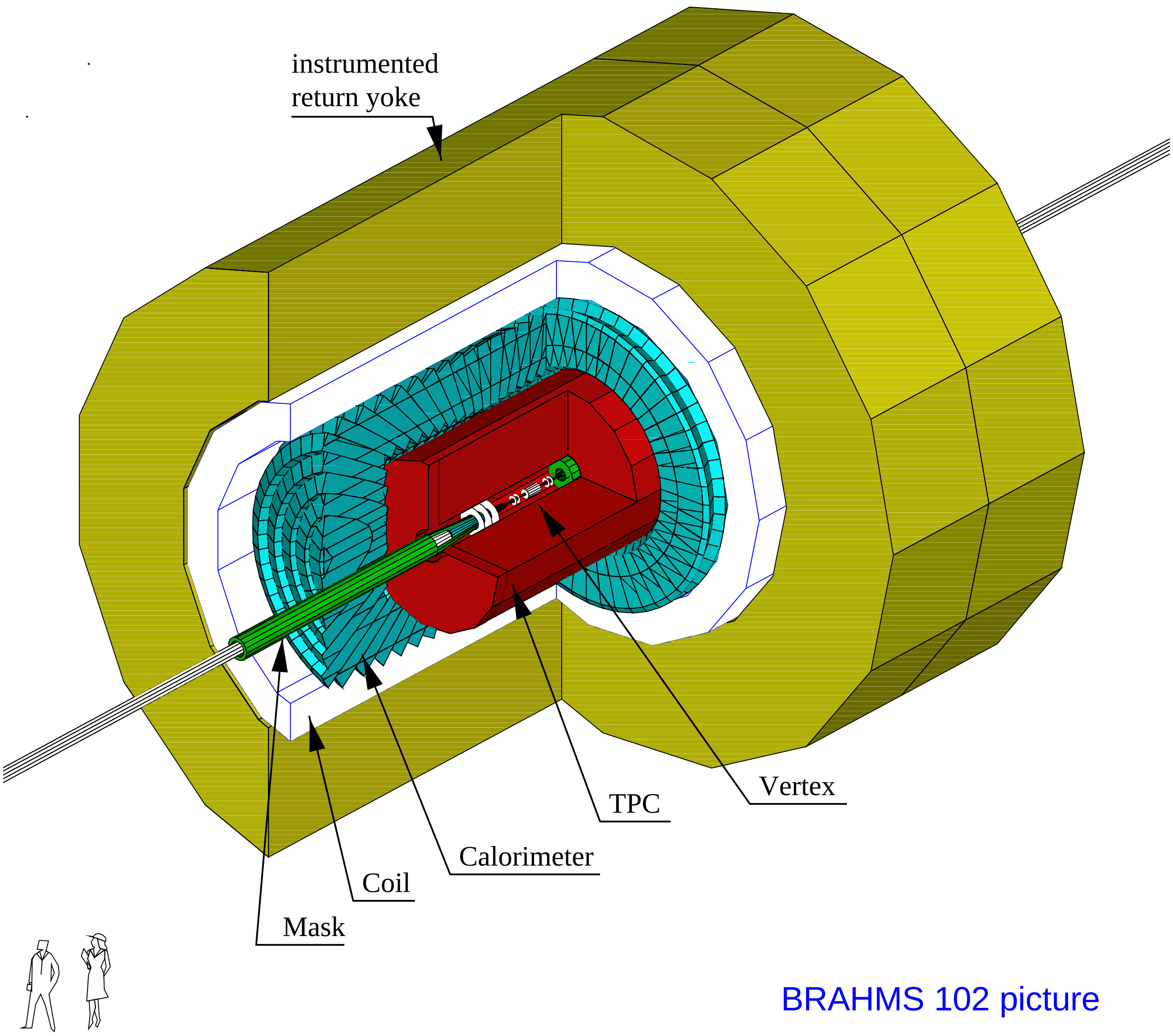
- the TPC tracker
- requirements from physics
- a TPC at TESLA: can this work?
- results from simulation
- technical issues
- conclusion

A Detector for TESLA

- general design criteria:
  - excellent vertex and momentum resolution
  - excellent tracking with high granularity
  - calorimetry with high granularity both transverse and longitudinally
  - hermetic coverage down to 20mrad or better

Overall very good energy flow measurement

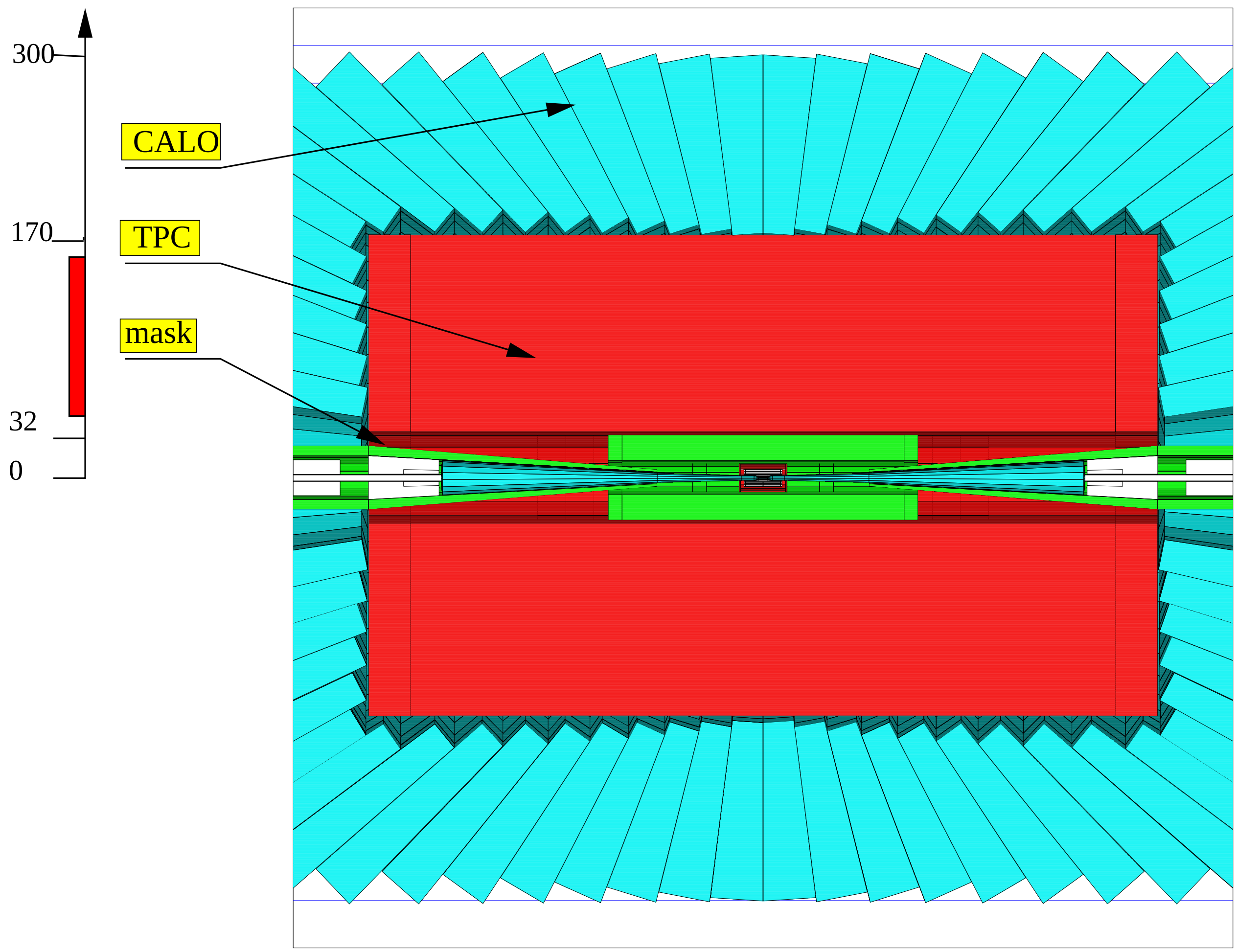
- first design iteration proposed in the TESLA CDR, 1997



BRAHMS 102 picture

A Detector for TESLA

- General concept: Large detector, gaseous tracking, large acceptance
- main tracking components:
  - high precision vertex detector (4-5 layers)
  - large TPC tracking chamber



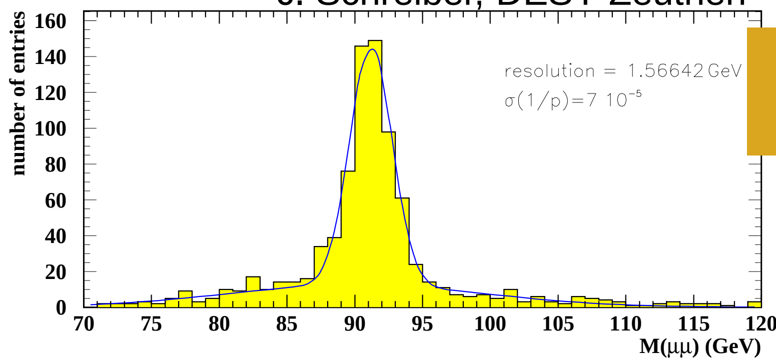
- configuration:

$$\begin{aligned} z &= \pm 250 \text{ cm} \\ R_i &= 32 \text{ cm} \\ R_o &= 170 \text{ cm} \\ N_{hit} &= 118 \\ \text{Gas} &= \text{Ar/CH}_4 \text{ 90-10} \end{aligned}$$

The TPC Tracker: Performance goals

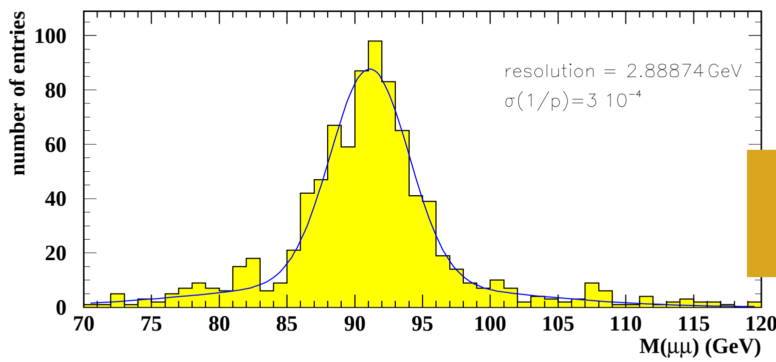
- physics drives the required momentum resolution: e.g. recoil mass measurement in $\mathrm{e^+e^-} \rightarrow \mathrm{Z^0H}, \mathrm{Z^0} \rightarrow \mu^+\mu^-$

J. Schreiber, DESY Zeuthen



$\sigma(1/p) = 7 \times 10^{-5}$

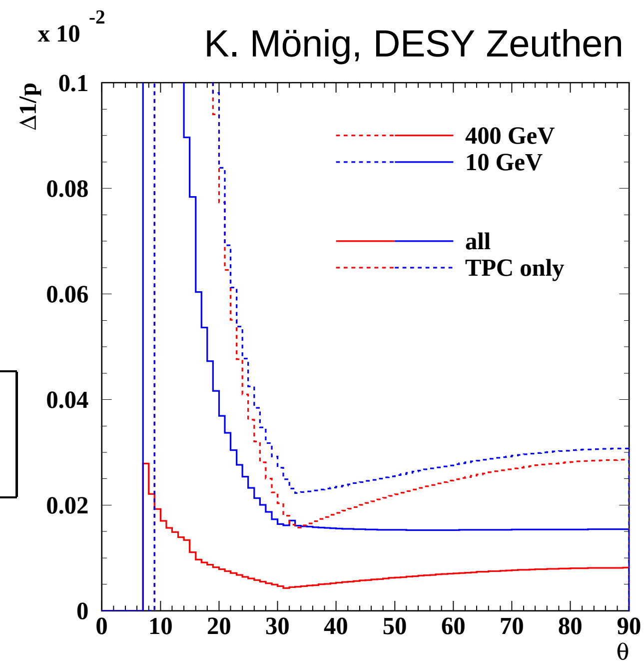
$\mathrm{Z^0} \rightarrow \mu^+\mu^-$ invariant mass



$\sigma(1/p) = 3 \times 10^{-4}$

- goal: better than intrinsic width of the Z $(2.49\mathrm{GeV}/\mathrm{c}^2)$

K. Mönig, DESY Zeuthen



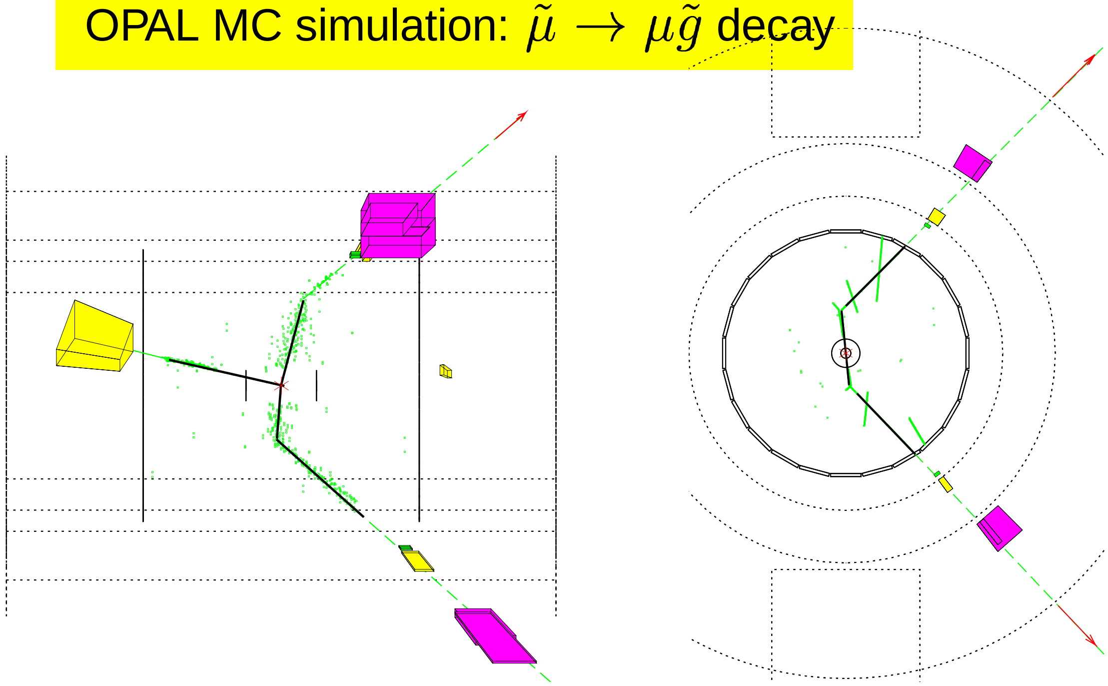
$\sigma(1/p) = 7 \times 10^{-5}$

LC TPC alone:	2.8×10^{-4}
LC ALEPH	12×10^{-4}

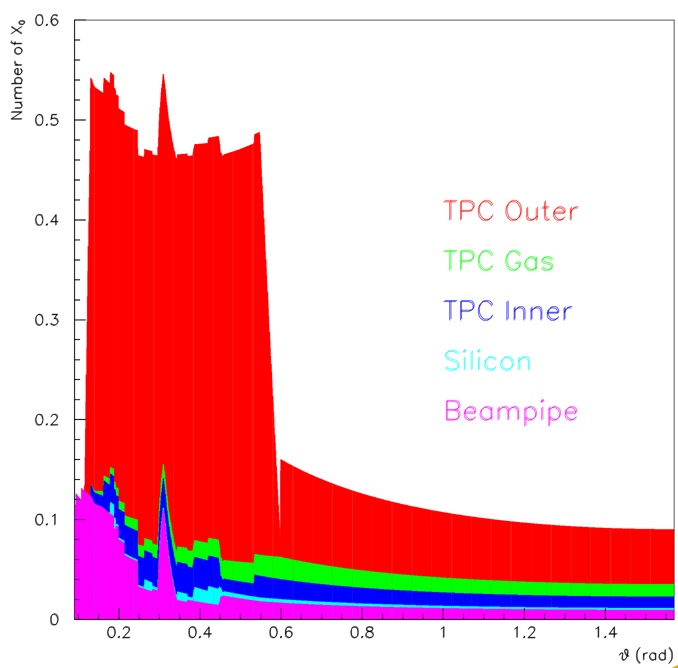
Advantage of a TPC

- tracking up to large radii

OPAL MC simulation: $\tilde{\mu} \to \mu\tilde{g}$ decay



- large redundancy through larger number of space points
  - maybe advantages for pattern recognition?
- true 3D reconstruction
- thin detector



- dE/dx comes "for free"

TPC at TESLA: can this work?

- basic problem:

$\Delta t_{TESLA} = 339$ns **BUT** $t_{drift} = 50\mu$s

TPC sees $\approx$ 150 bunches in one "picture"

- number of 3D (readout) pixels in TPC $\approx 7 \times 10^7$
- this corresponds to the following occupancies in the chamber for a "good" events (i.e., there is some interesting physics happening)

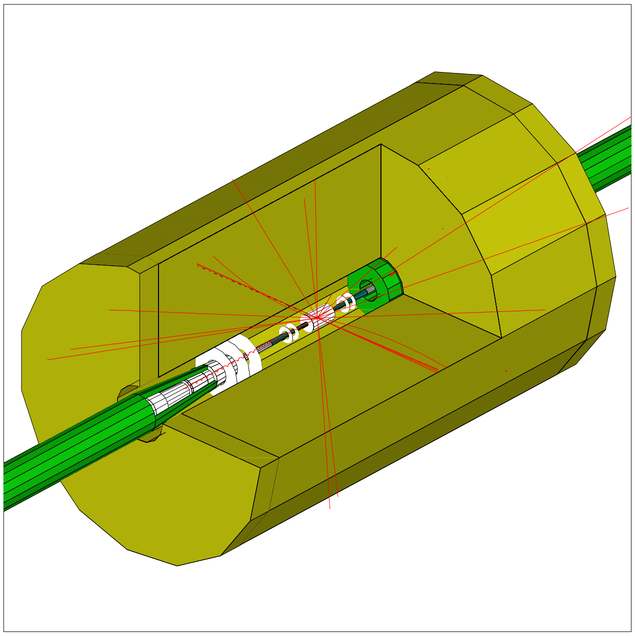
type	per BX	150 BX	hits
e^+e^- physics		22	3000
$\gamma\gamma$ physics	0.7	105	15000
photons	1350	202500	15000
beam beam bgd	1	150	100
neutron background	1000	150000	5000
total			38000

See talk by N. Tesch Friday afternoon

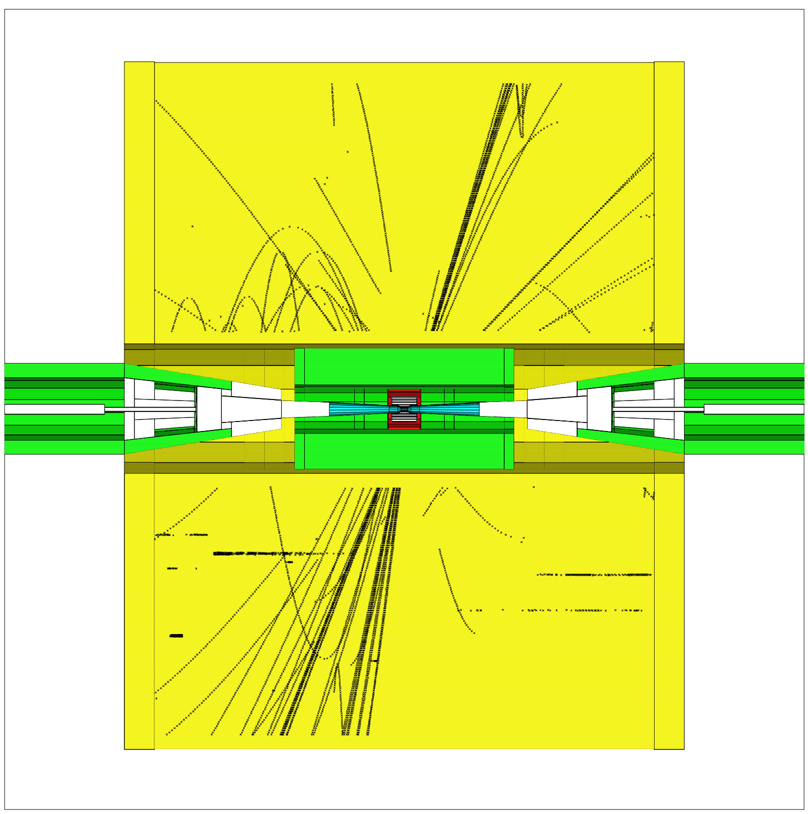
- This corresponds to an occupancy of $< 1\%$

TPC and TESLA: an event

- integrated over 150 bunch crossings
- contains physics and estimated background hits



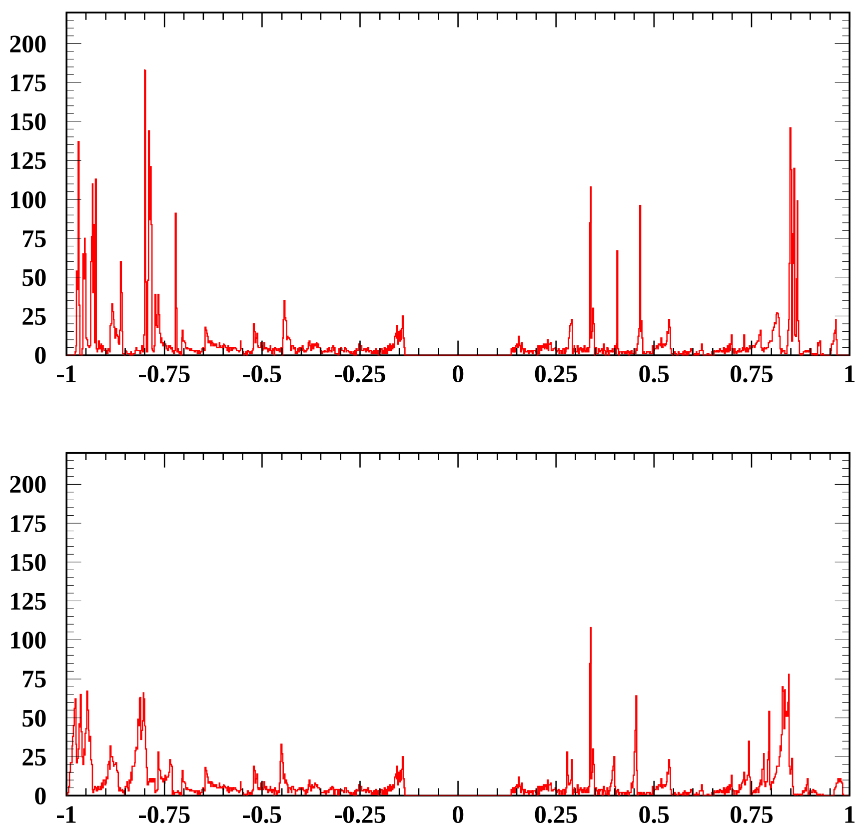
A WW decay at 500 GeV



WW decay +
3 $\gamma\gamma$ events

Track Finding

- Need to reconstruct the correct bunch crossing
- Average good event:
  - one e^+e^- physics events
  - 3 $\gamma\gamma$ events
  - approximately 15000 background hits
- Simulation of such an events in $\theta - z$ space:

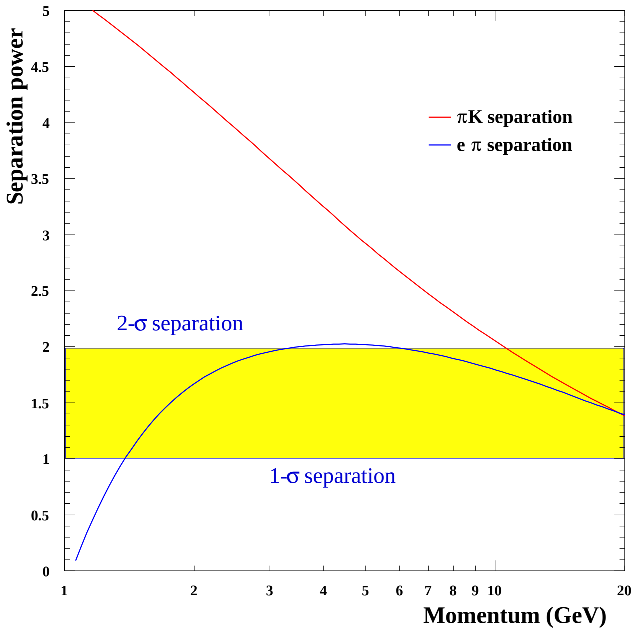


- Clear distinction between top(0 BX) and bottom (10 BX)
- Background adds appros. flat level of around 20 hits / bin

Track finding and reconstruction in TPC should not be a problem

dE/dx at a TPC

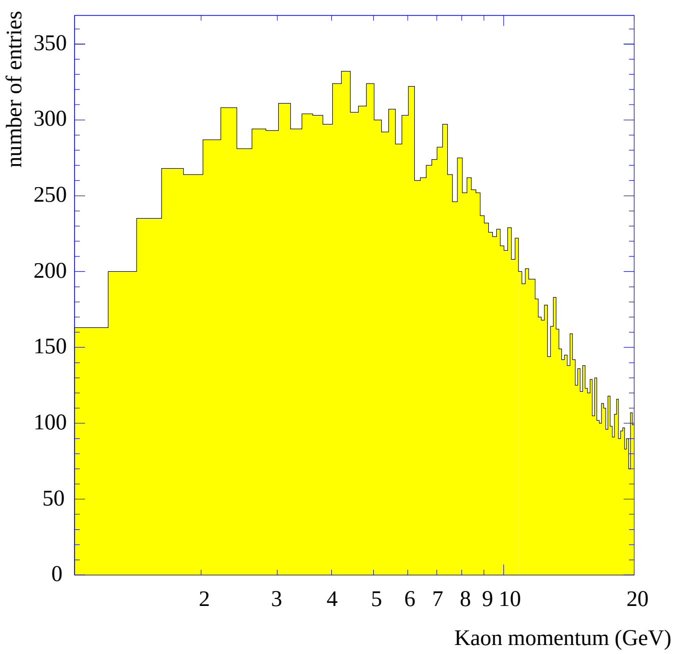
- per track 118 samples: expect at 1 bar reasonable dE/dx.
- predicted resolution: 7.5%



Calculation by M. Hauschild, CERN

Separation power

Separation $\approx 1.5 - 2\sigma$
for $2 < p < 20$ GeV

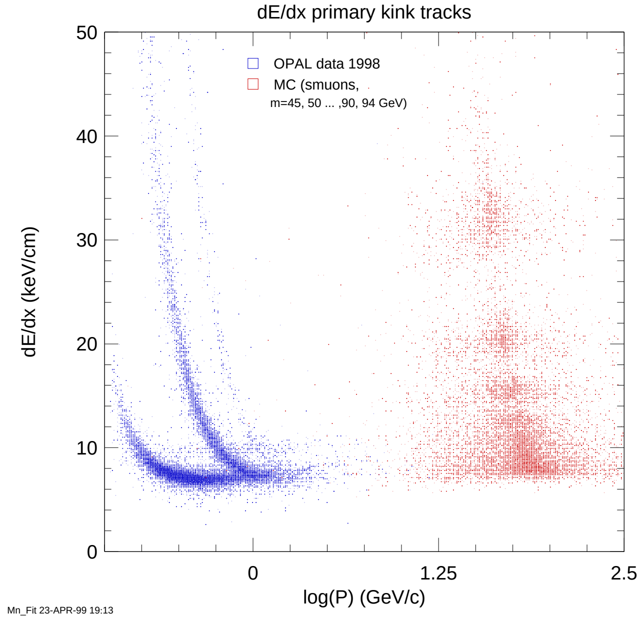


Kaons from $q\overline{q}$ events
at 500 GeV

The Role of dE/dx

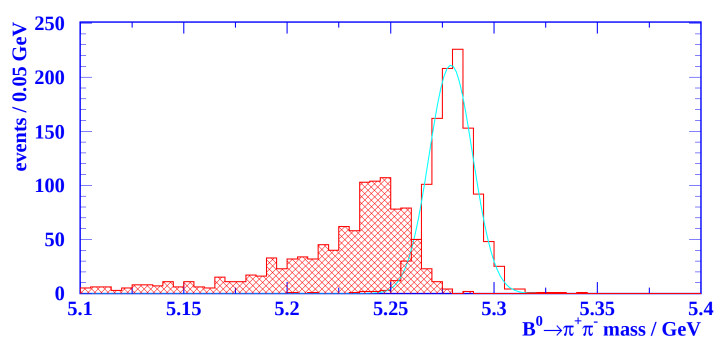
- particle ID in general not as important as at present machines
- some possible physics uses:
  - background cleanup (charm tag? bottom tag?)
  - heavy charged particle searches

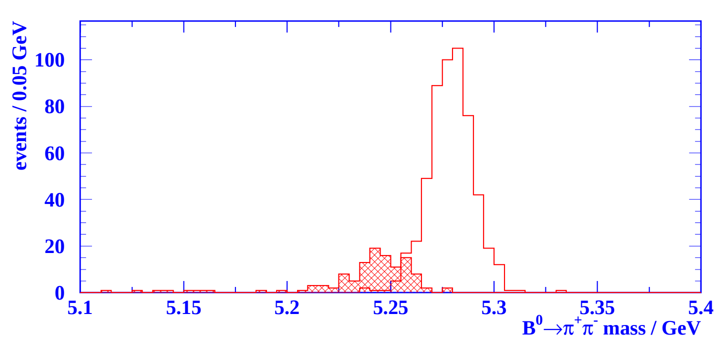
dE/dx for a $\tilde{\mu} \to \mu\tilde{g}$ decay (red)



  - Z^0 factory option

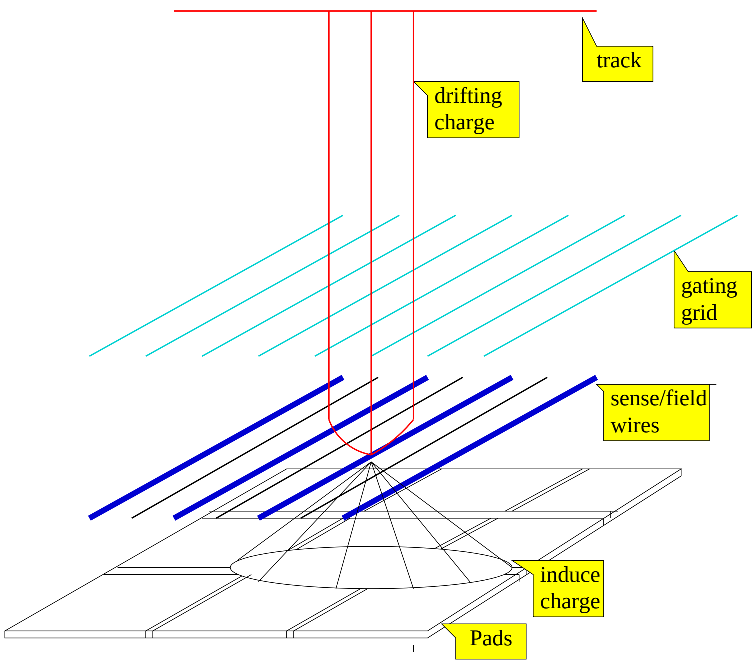
example: mass for $B^0 \to \pi^+\pi^-$
(red: $B^0 \to K\pi$ reflection)



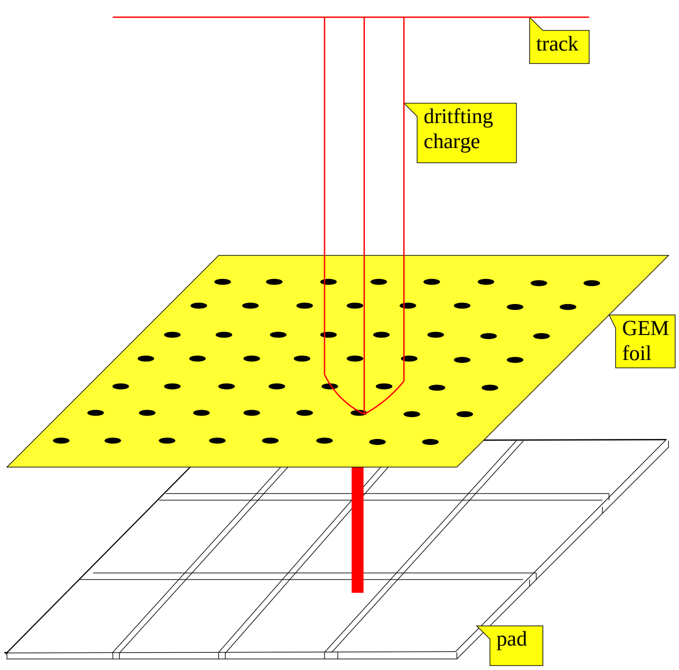


TPC readout

- number of 3D space points: 3×10^7
- need ungated operation to handle bunch trains without deadtime



conventional solution:
wire chamber readout
with PADS.
around 700k channels
typical PAD size
$\approx 10 \times 10$ mm

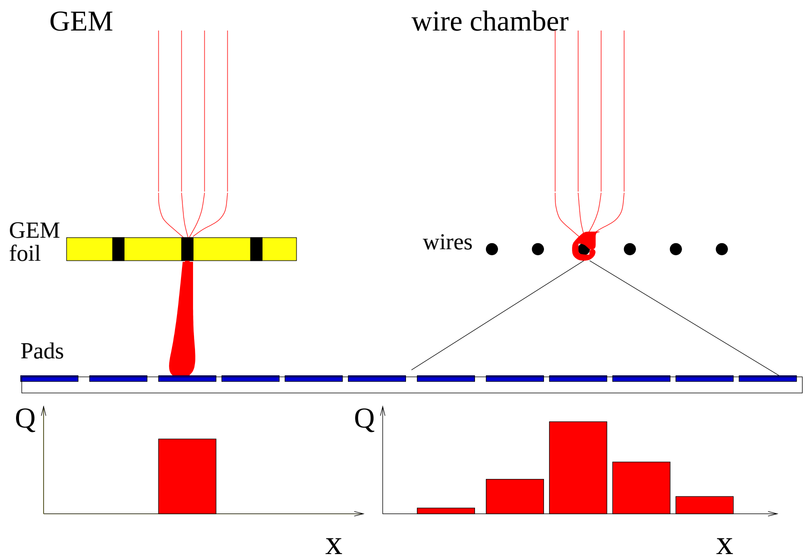


alternative solution:
GEM readout
simple, thin, high granularity
true 2D readout

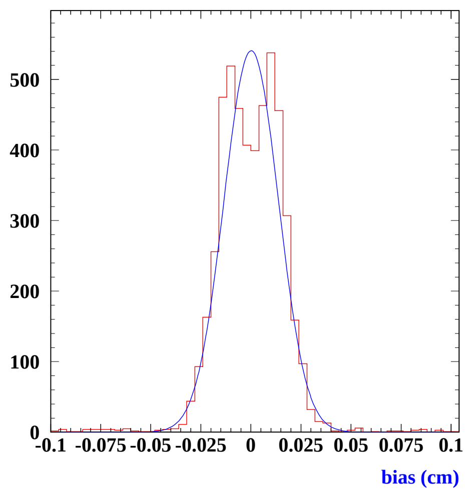
for more details:
see talk by M. Gruwé

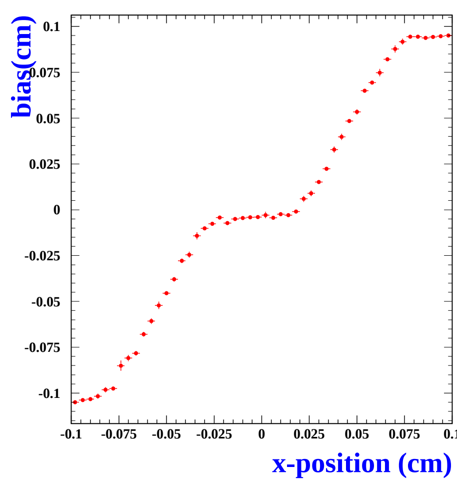
TPC: GEM readout Simulation

- problem: resolution might degrade when using GEMS



- Simulate the response of a TPC with GEM readout using PADS (roughly 10×10 mm)
- plot the reconstruction bias:

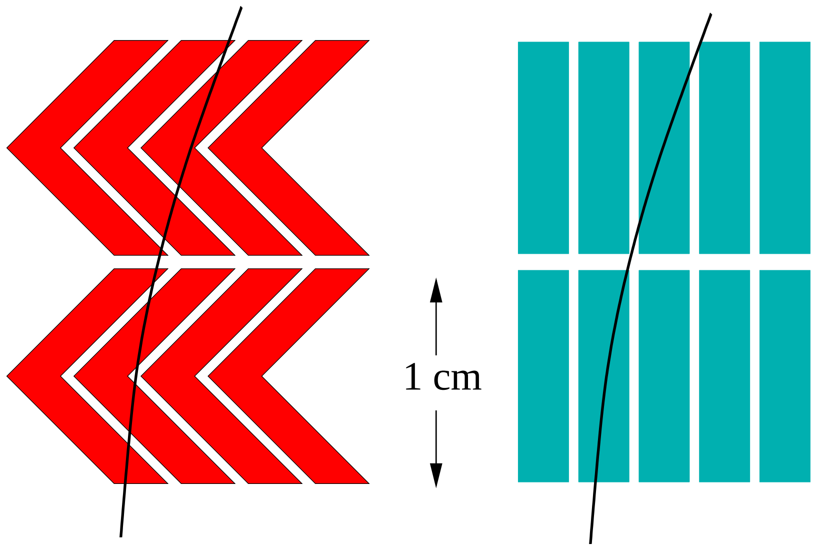


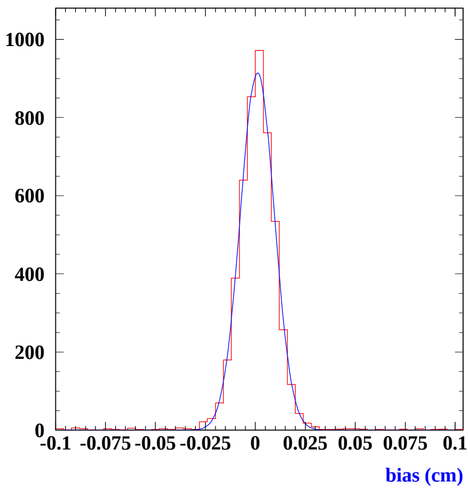


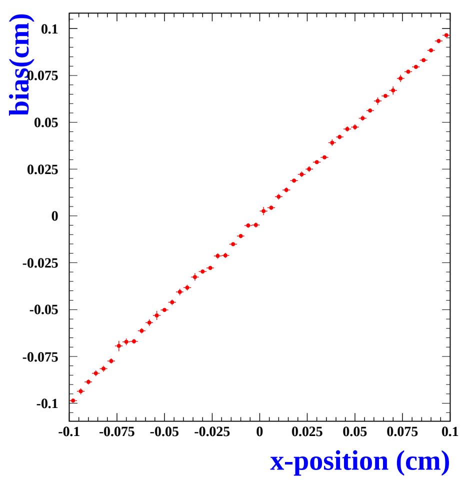
- observe significant bias for rectangular pads and GEM readout
- "solution" for rectangular pads: huge number of channels.

TPC: GEM readout

- proposed solution for roughly equal number of channels (700 k):
  - "Chevron" pads.







much reduced bias, linear dependence input - output

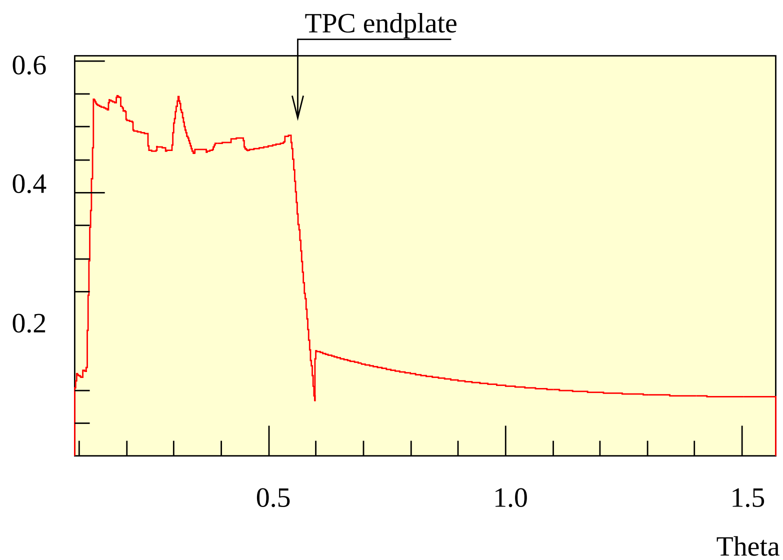
GEM with special PAD geometry seems attractive solution

GEM readout for a TPC

(similar points apply to other technologies like micro - omegas etc.)

- advantages:
  - mechanically simple
  - compact, good granularity
  - possibility of thinner and mechanically simpler end caps
  - technically feasible already today
  - suppression of ion feedback: $f_{ion} < 10\%$ from calculations and measurements.
- disadvantages / open questions
  - stability / long term operation
  - resolution achievable?
  - gas gain is smaller than in conventional wire chambers: might need two GEMS in series.
  - ion feedback suppression not large enough? Needs experimental verification.

plot of radiation length vs. theta:



Conclusions

- TPC a central part of the ECFA / DESY detector design for TESLA
- Operating a TPC in this environment should be possible and should not present un-surmountable problems.
- Occupancy on average is expected to be below 1%
- Large redundancy and large number of space points are particular advantages of a TPC
- Possibility of dE/dx is interesting for some selected physics topics.
- TPC offers advantages for the material budget
- Ungated operation is needed to be able to handle TESLA bunch train structure without deadtime
- Ungated operation requires new readout technologies (e.g. GEM's instead of wire chambers.
- A solution for a GEM readout has been proposed and is under investigation