A high precision time projection chamber for ILD: optimization strategies

J. Kaminski
for the LCTPC-collaboration

ILD meeting
Cracow
24th-26th September 2013

Content of Presentation

Reminder: Arguments why we want a high precision TPC for ILD

Optimization process
(which goal? Physics performance, price?)

'External' parameters	Influ-ence →	'Internal' parameters
radius, length, B		gas, pad size, gas amplification technology

Reminder of former studies and current status

Discussion

Arguments why we want a high precision TPC for ILD

In the DBD, the advantages are written in a nutshell:

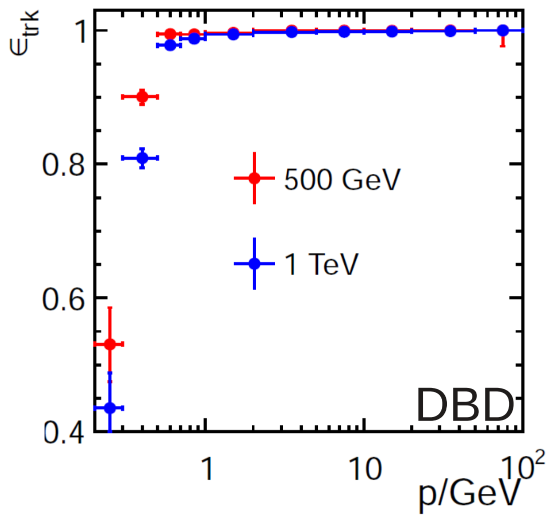
2.3 The ILD TPC system

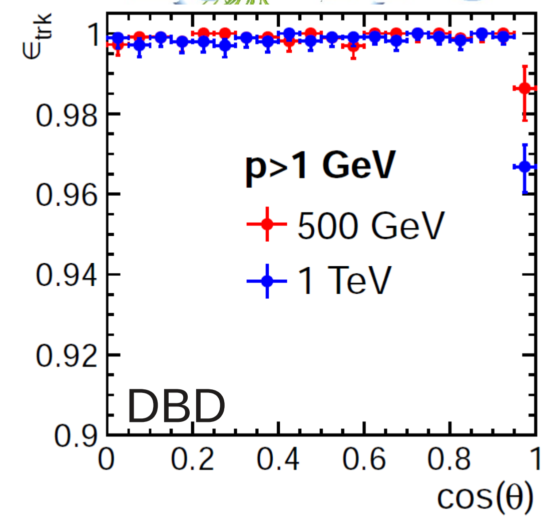
The central tracker of ILD is a Time Projection Chamber (TPC). A TPC tracker in a linear collider experiment offers several advantages. Tracks can be measured with a large number of three-dimensional (r, ϕ, z) space points. The point resolution, σ_{point}, and double-hit resolution, which are moderate when compared to silicon detectors, are compensated by 1 continuous tracking. The TPC presents a minimum 2 amount of material as required for the best calorimeter and PFA performance. A low material budget also minimises the effects due to the $\simeq 10^3$ beamstrahlung photons per bunch-crossing which traverse the barrel region [255]. 3 Topological time-stamping in conjunction with inner silicon detectors is an important tool that is explained in section 6.1.2.5. To obtain good momentum resolution and to suppress backgrounds, the detector will be situated in a strong magnetic field of 3.5 T. Under this condition a point resolution of better than $100\ \mu$m for the complete drift and a double hit resolution of < 2 mm are possible.

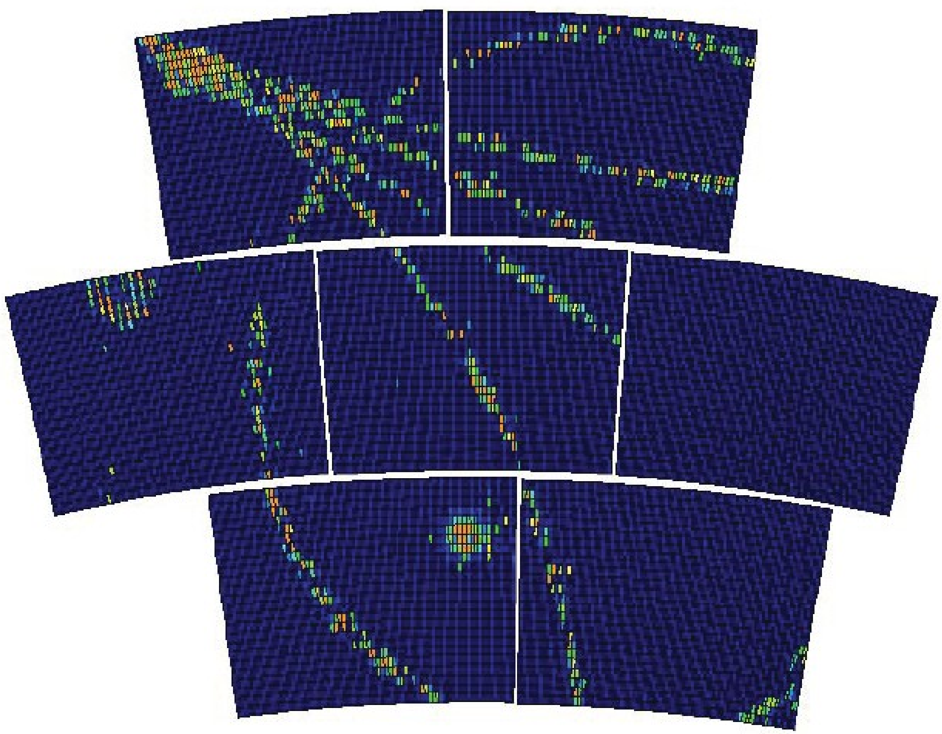
Continuous tracking facilitates the 4 reconstruction of non-pointing tracks which are significant for the particle-flow measurement and for the reconstruction of physics signatures in many scenarios. The TPC yields particle identification via the specific energy loss dE/dx which is valuable for many physics analyses. 5

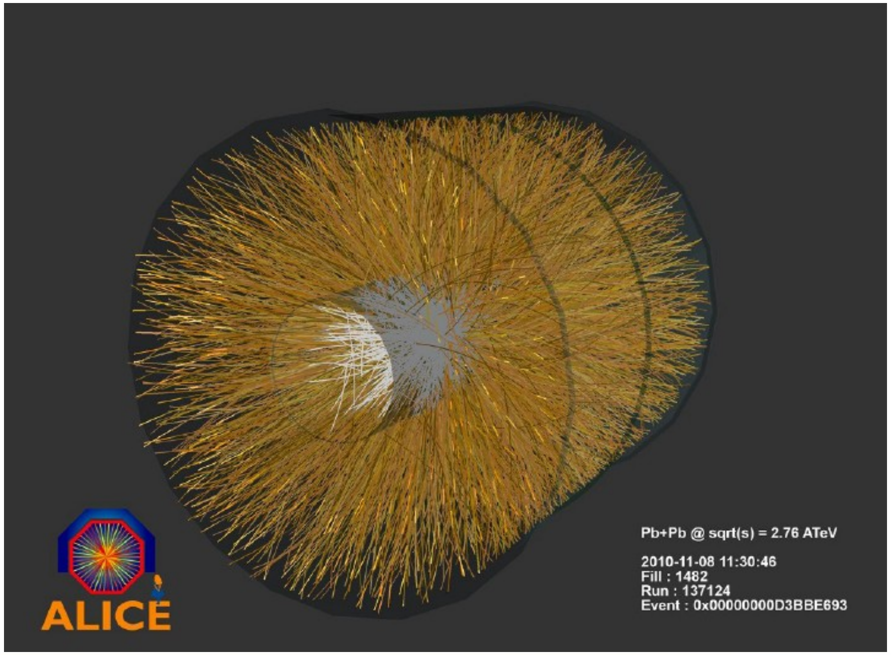
1. Continuous Tracking

- Large number of track points
- High granularity (~10^9 voxels)
- Truly 3D points
  facilitates track finding
  and background rejection
  (s. next transparency)



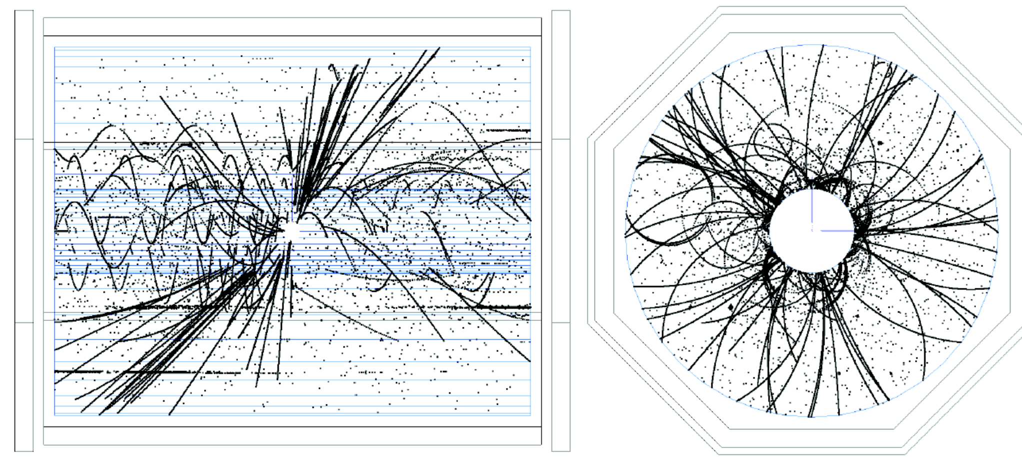




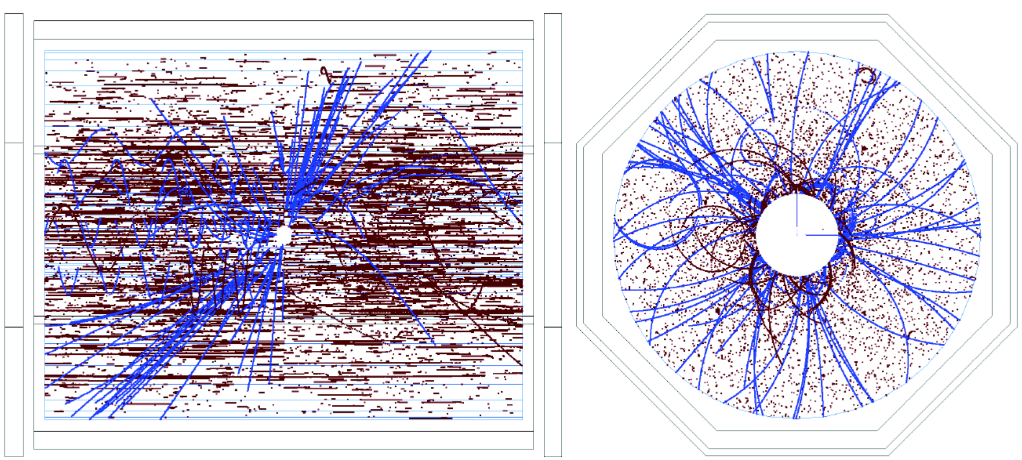


Background Suppression - LOI

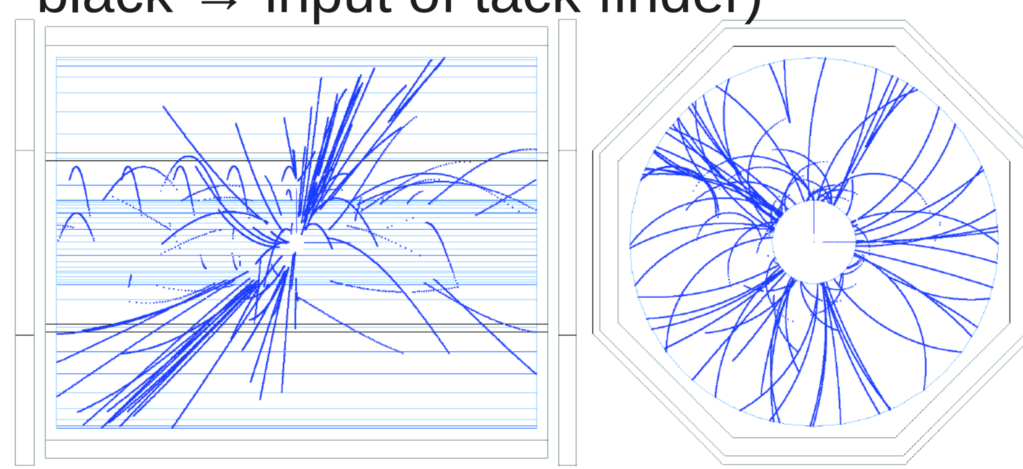
TPC integrates over 150 bunch crossings. Also the machine background is integrated. To verify that tracking still works in these conditions, $t\bar{t} \rightarrow$ 6 jets events with all backgrounds were simulated.
The microcurlers from low energy γ-conversions could easily be removed.



Microcurlers removed:
black $\rightarrow$ input of tack finder)



Original events: (blue $\rightarrow$ physics
red $\rightarrow$ machine background)



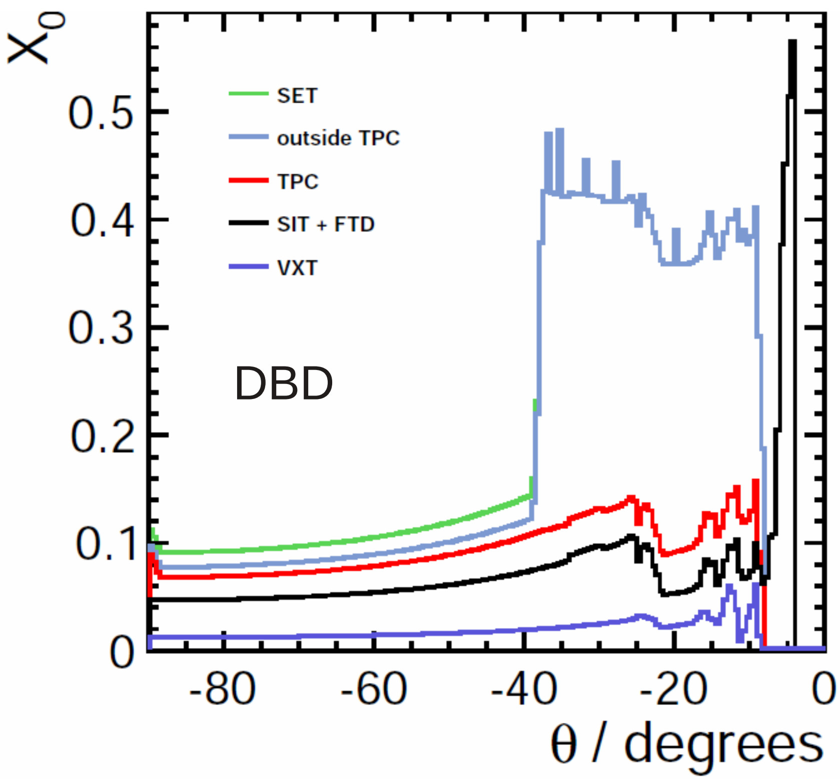
Reconstructed TPC tracks.

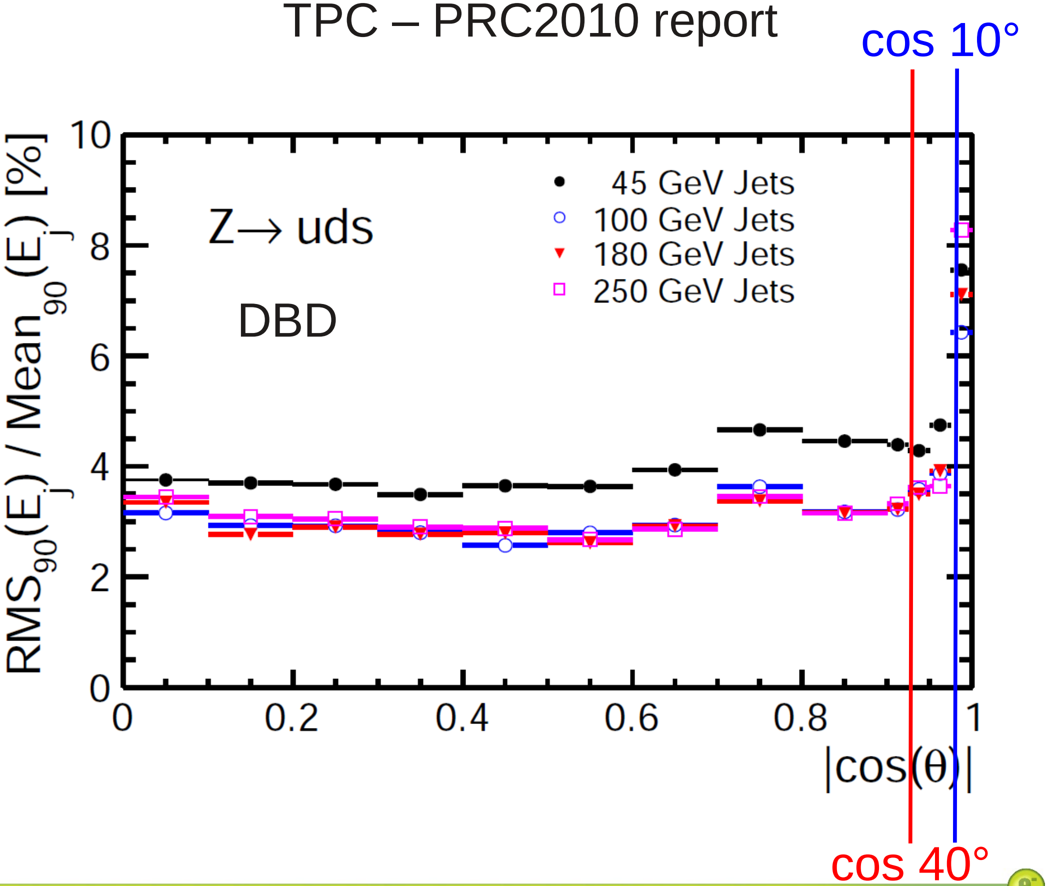
2. Minimum Amount of Material

Low material budget
Homogeneously distributed
Also the end plate with 0.25 X_0 has no significant impact.

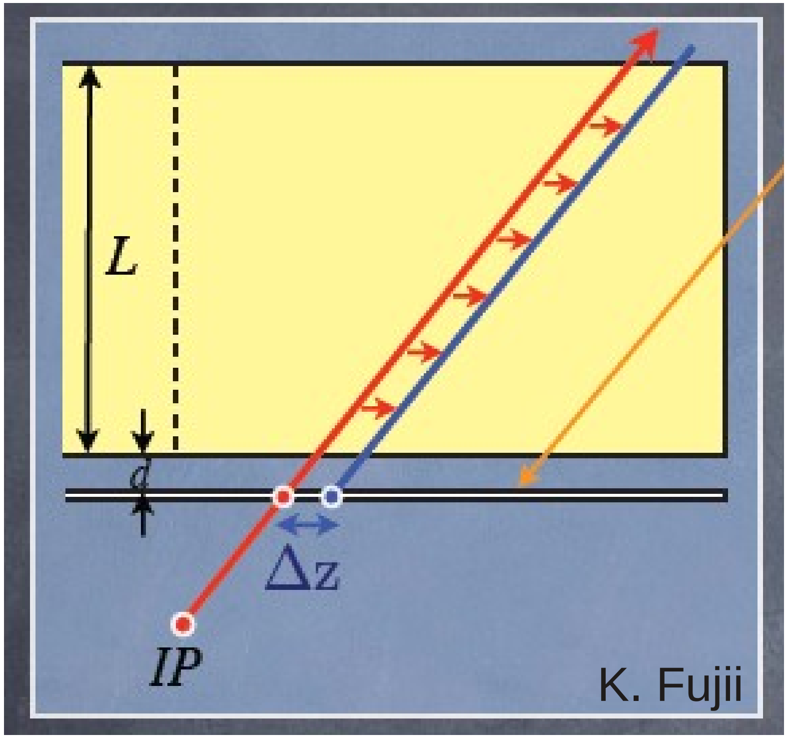
	45 GeV	100 GeV	250 GeV
$15\%X_0$	0.28 ± 0.01	0.32 ± 0.01	0.47 ± 0.02
$30\%X_0$	0.30 ± 0.01	0.31 ± 0.01	0.47 ± 0.02
$45\%X_0$	0.30 ± 0.01	0.32 ± 0.01	0.52 ± 0.02
$60\%X_0$	0.32 ± 0.01	0.33 ± 0.01	

TPC – PRC2010 report





3. Topolgical Time-stamping

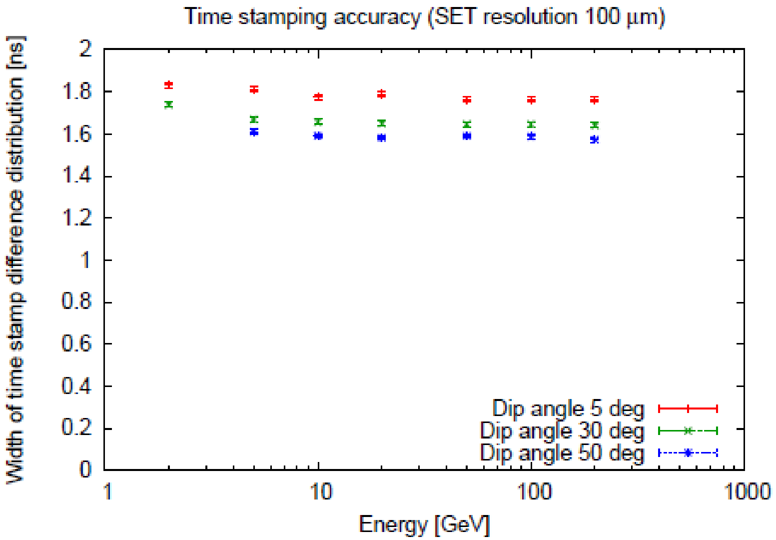


External detector

Distance is measured by drift time to endcap and then converted:

$z = v\, t_{drift}$

Precision of drift time measurement



M. Killenberg for muons at CLIC

Important for removal of beam background (muon halo), cosmics, etc. and for hooking up correct tracks to the ECAL and silicon detectors external to the TPC.

4. Reconstruction of non-pointing tracks

Expecting
the unexpected

and the usual
stuff (K_L)

hep-ex/0203024v2

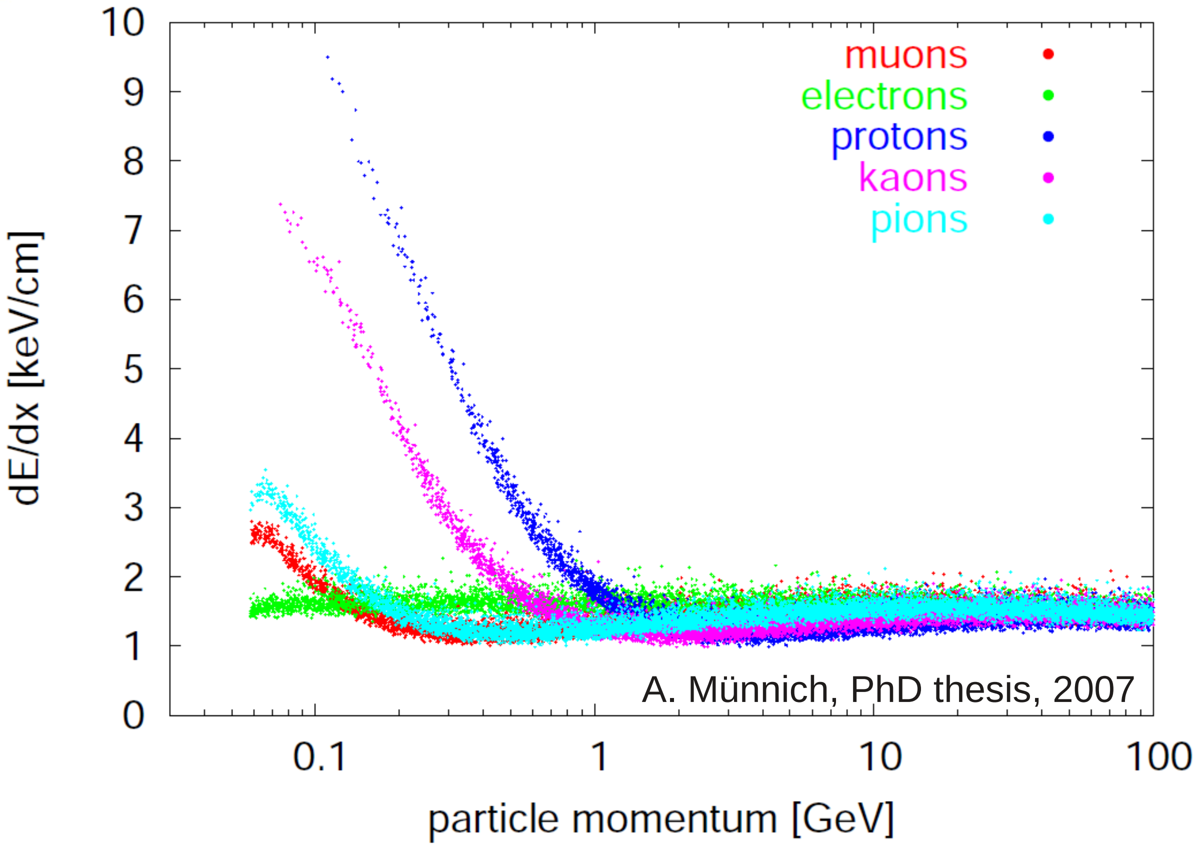
Search for gauge mediated SUSY breaking topologies in e^+e^- collisions at centre–of–mass energies up to 209 GeV

The ALEPH Collaboration *)

Abstract

A total of 628 pb^{-1} of data collected with the ALEPH detector at centre-of-mass energies from 189 to 209 GeV is analysed in the search for gauge mediated SUSY breaking (GMSB) topologies. These topologies include two acoplanar photons, non-pointing single photons, acoplanar leptons, large impact parameter leptons, detached slepton decay vertices, heavy stable charged sleptons and multi-leptons plus missing energy final states. No evidence is found for new phenomena, and lower limits on masses of supersymmetric particles are derived. A scan of a minimal GMSB parameter space is performed and lower limits are set for the next-to-lightest supersymmetric particle (NLSP) mass at 54 GeV/c^2 and for the mass scale parameter Λ at 10 TeV/c^2, independently of the NLSP lifetime. Including the results from the neutral Higgs boson searches, a NLSP mass limit of 77 GeV/c^2 is obtained and values of Λ up to 16 TeV/c^2 are excluded.

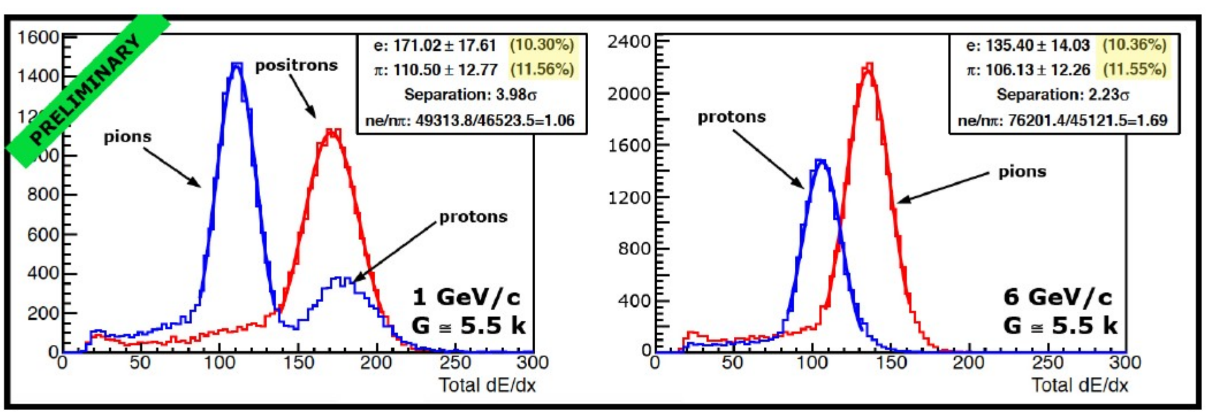
5. dE/dx

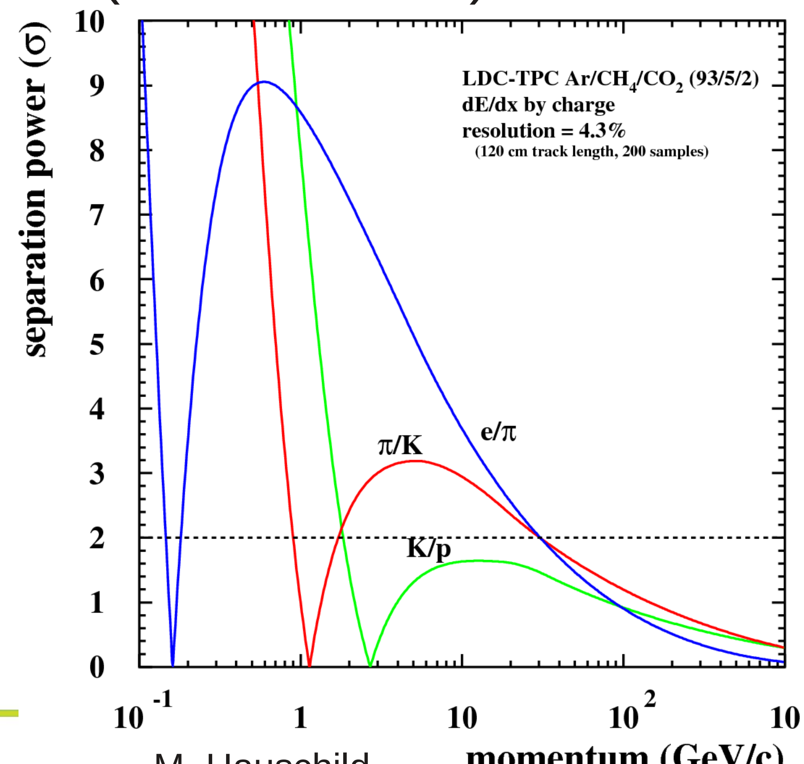


Important for many analysis

Examples:

- ALICE test detector at PS with triple GEM stack Preliminary online analysis (no calibration)





M. Hauschild

'External' Parameters

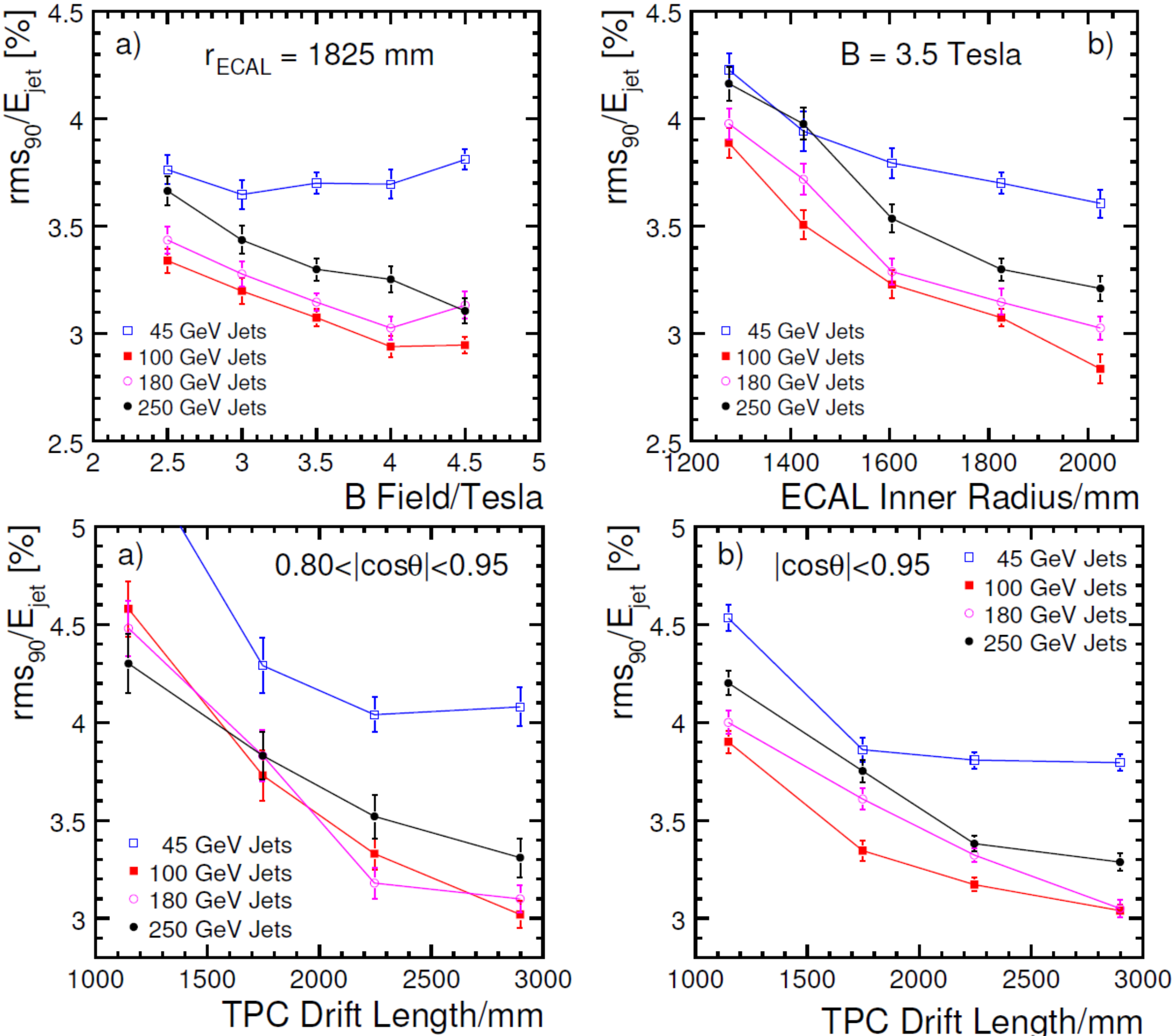
'External' parameters depend on the overall detector design.
Parameters are determined by detector-optimization group.

Extensive study: when GLD and LDC were joined to ILD - see ILD LOI

Radius, magnetic field, length, pad rows

Model Name		GLD	GLD′	GLD4LDC	LDC4GLD	LDC′	LDC	ILD
Simulator		Jupiter			Mokka			Mokka
B field (T)		3.0	3.5	4.0	3.0	3.5	4.0	3.5
TPC drift region	R_{min}	437	435	371	371			395
	R_{max}	1978	1740	1520	1931	1733	1511	1739
	z_{max}	2600	2350	2160	2498	2248	2186	2247.5
TPC pad rows		256	217	196	260	227	190	224

LOI study



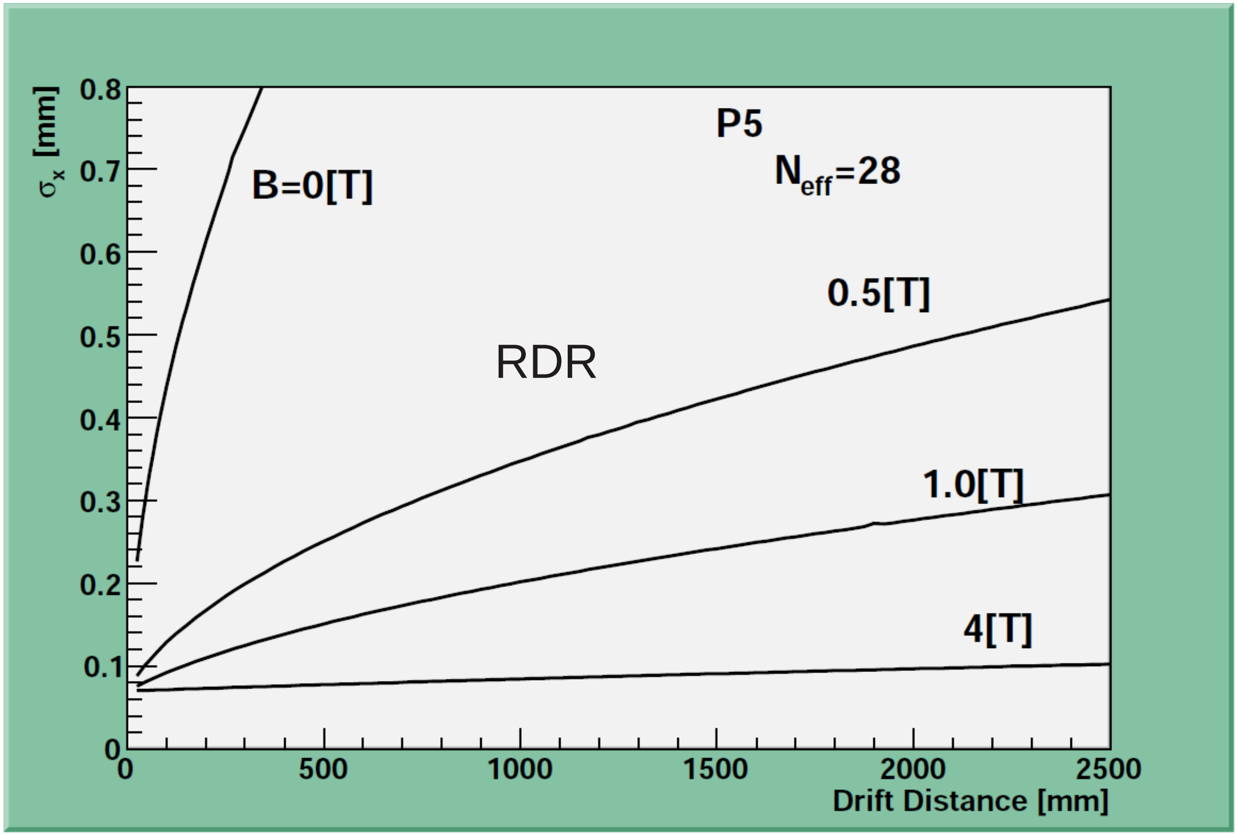
Conclusion in LOI:
It can be concluded that for the range of *B* and *R* spanned by the LDC and GLD detector concepts, the differences in impact parameter and momentum resolution are relatively small. It is also concluded that the tracking resolutions depend much more strongly on the sub-detector technologies and tracking system layout than on the global parameters (*B* and *R*) of the detector.

Choice:
Length: 2350 mm
Radius = 1808 mm

Influence of external parameters on performance

Magnetic field influences:

- transverse diffusion → spatial resolution
- ion backdrift → gating device has to be reevaluated
- E×B effects



Total length influences:

- total drift time
- number of bunch crossing which are integrated
- total charge because of ions

'Internal' Parameters

Parameters have no direct influence on other subdetectors.

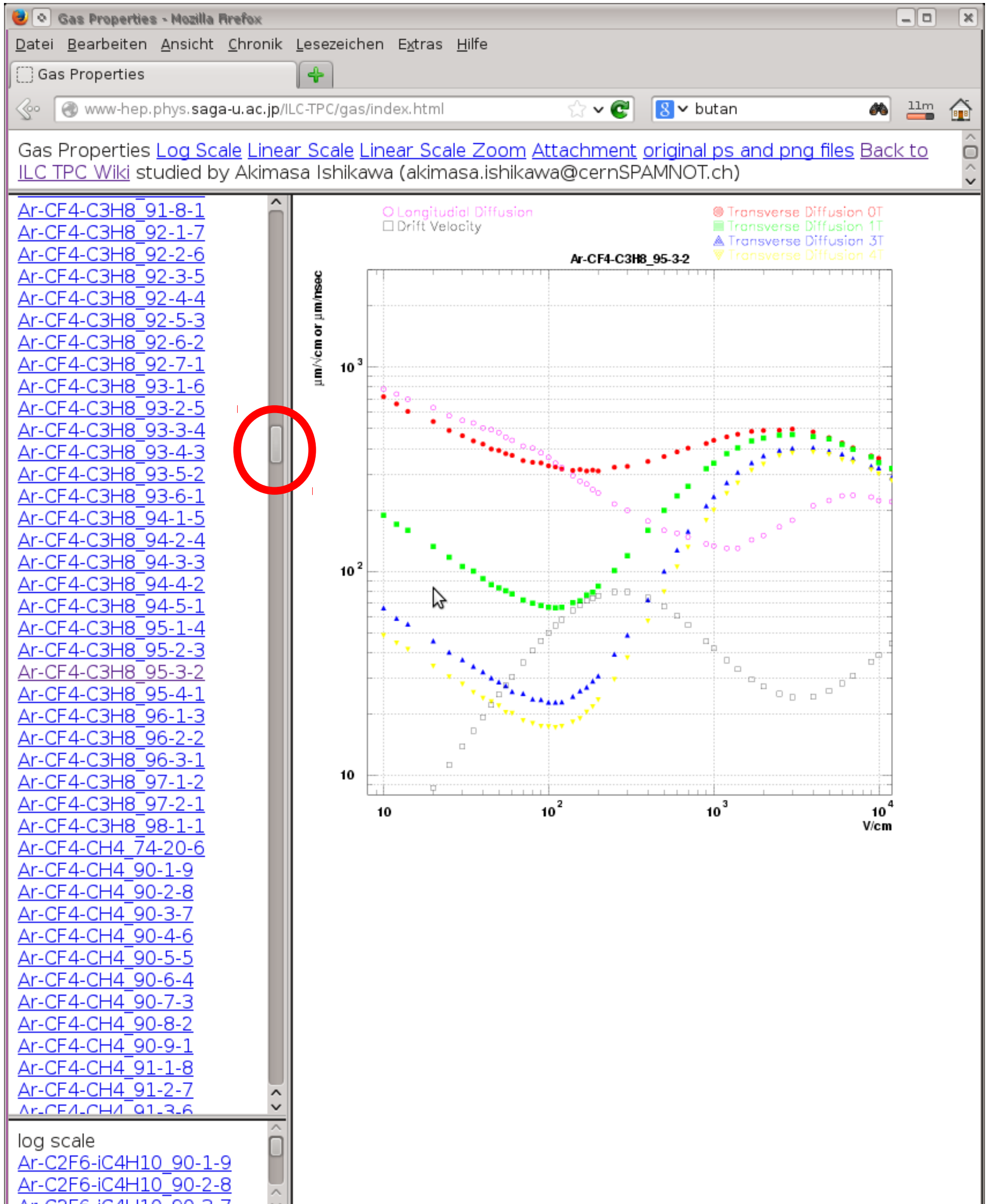
Gas choice

Gas amplification technique

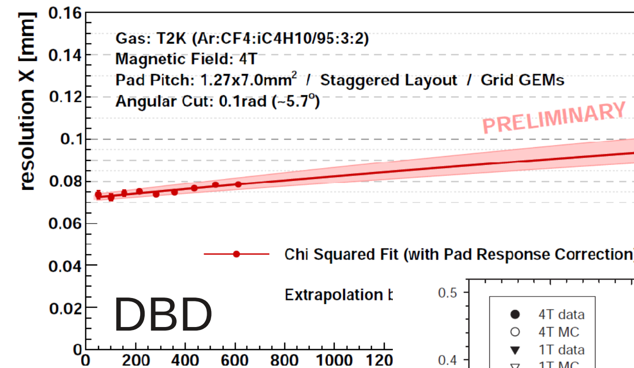
Pad size

Modules sizes

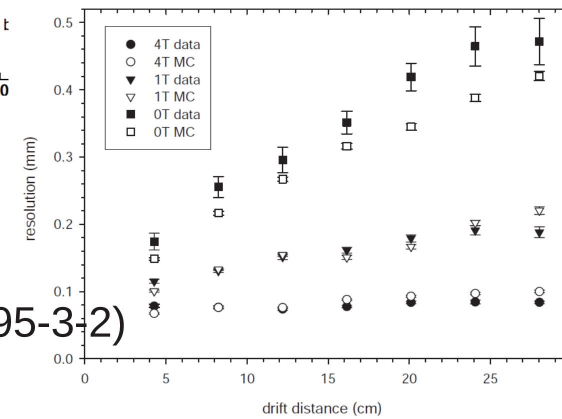
Gas Choice



A lot of gas mixtures have been looked at with MC. A few promising ones have been tested.



DBD



LOI
$ArCH_4CO_2$ (95-3-2)

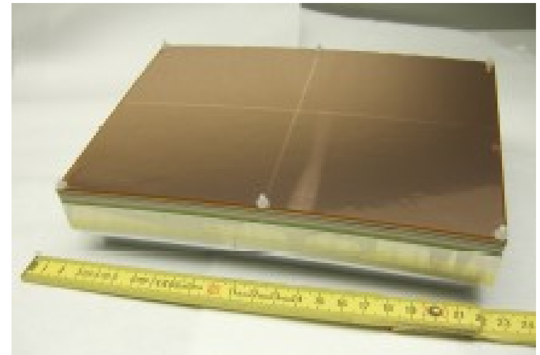
It's magic!

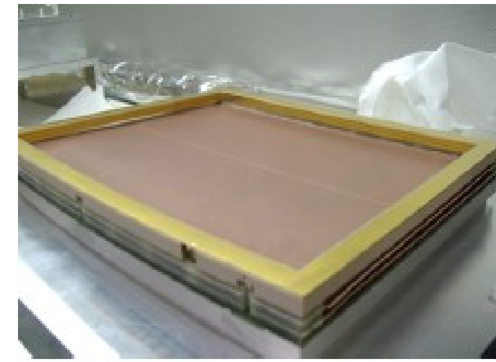
We have found a mixture which can fulfill the requirements, but needs to be tested for aging, etc.

Gas amplification stage

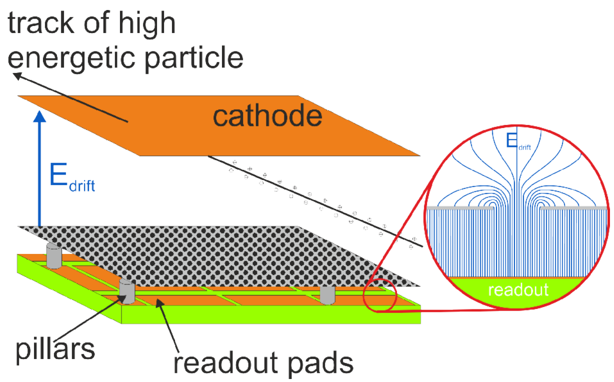
Three different approaches are under study

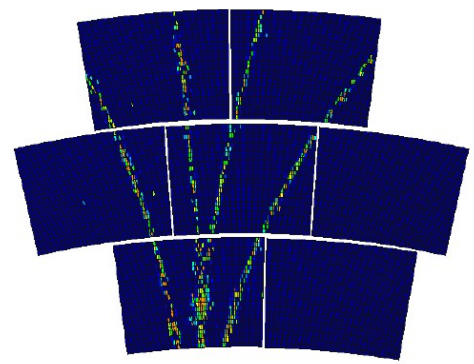
GEMs



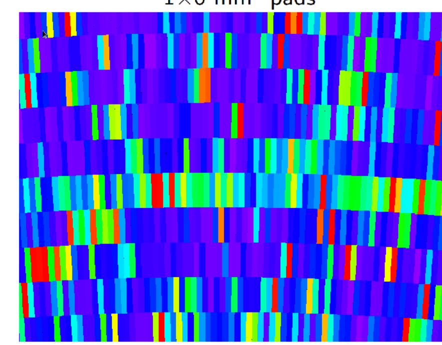


Micromegas

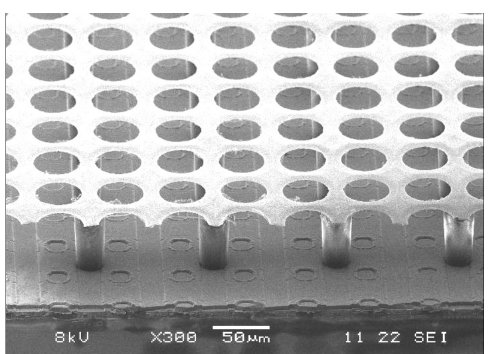


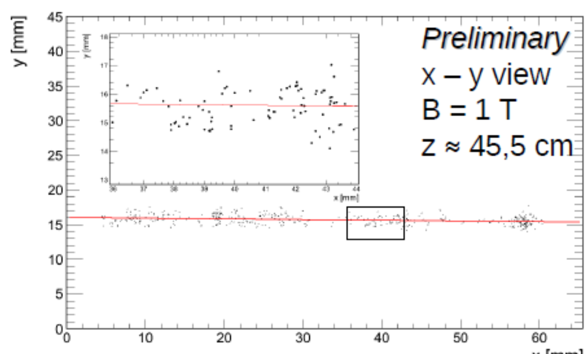


1×6 mm^2 pads

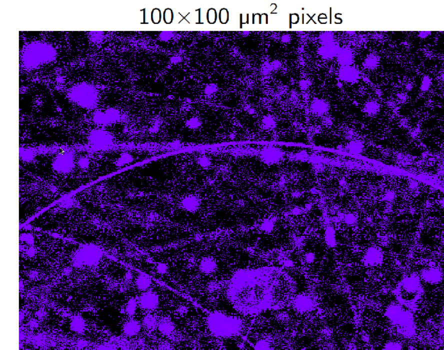


InGrids

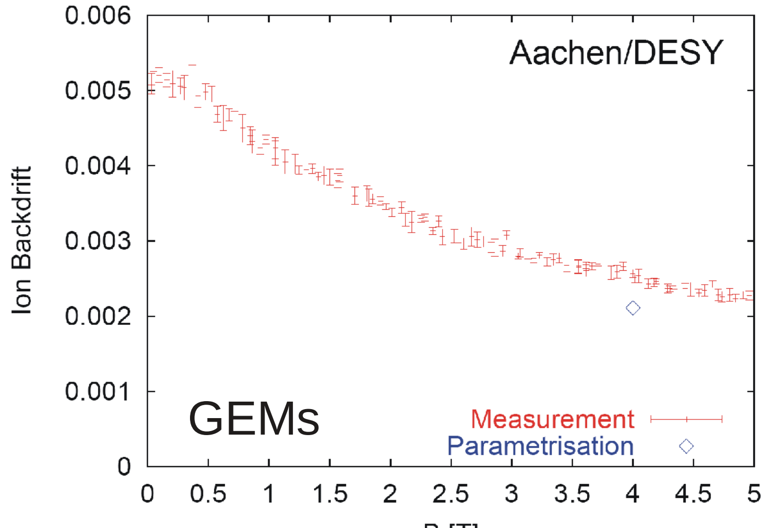




100×100 μm^2 pixels

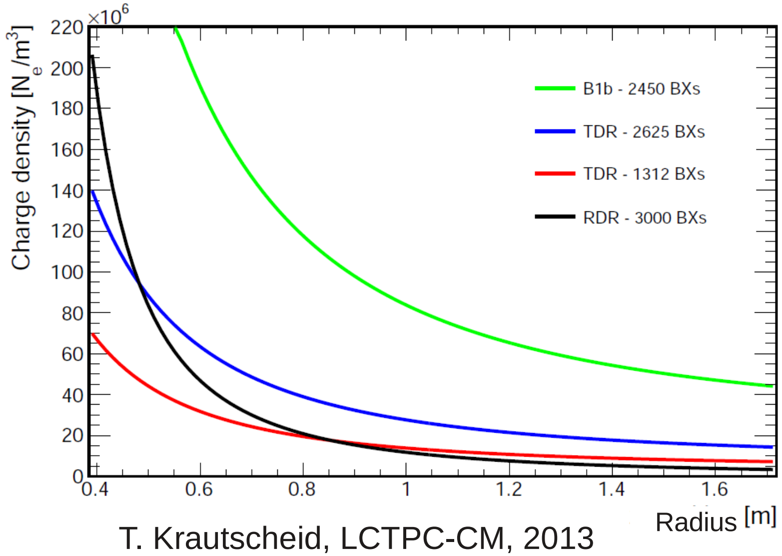


Ions, Gate, etc.

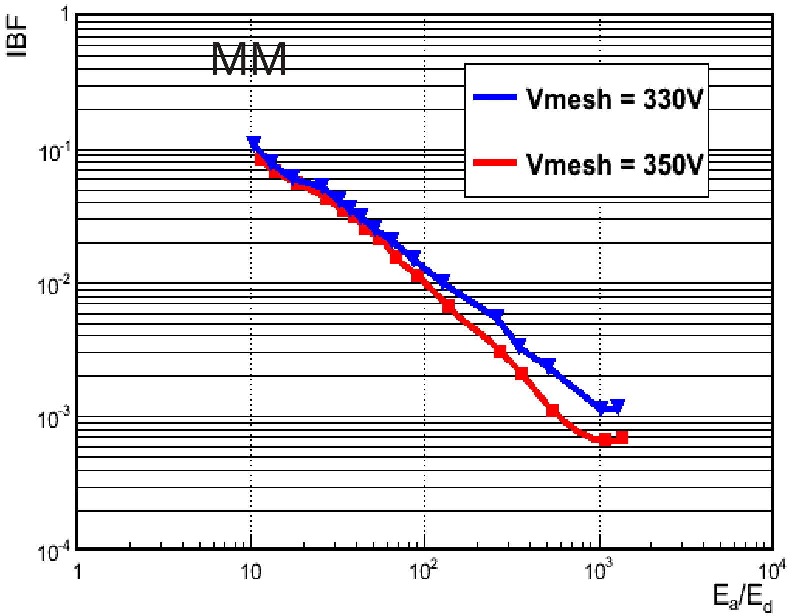


NIM A530 (2004) 251

Studies show, that the ion backdrift is still too large and we need a gate.

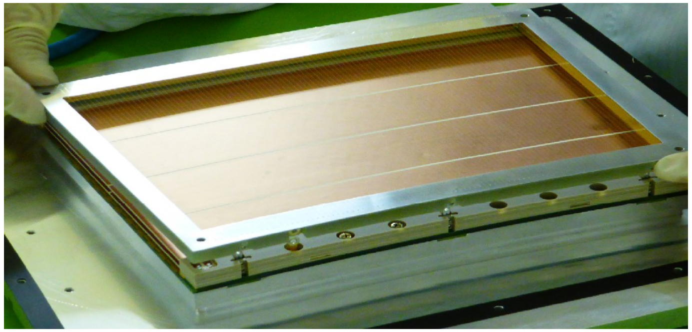


T. Krautscheid, LCTPC-CM, 2013



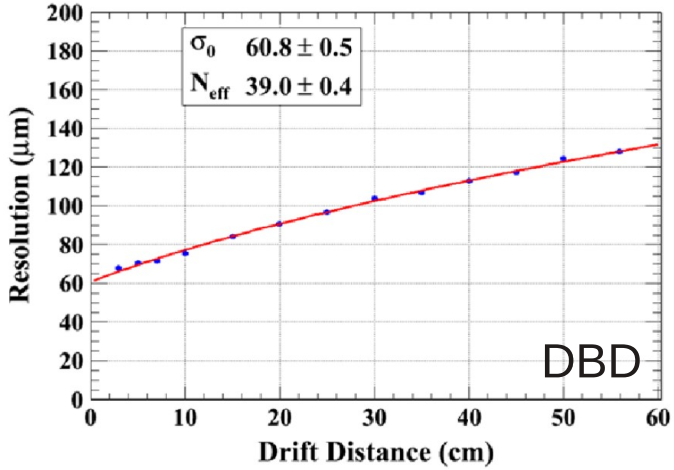
D. Attie, et al. LCTPC-CM 2013, B=0, T2K

First prototype of a wire gate has been tested.

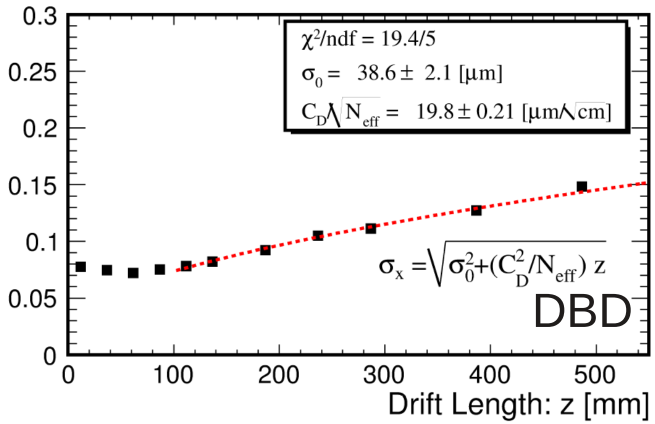


Performance

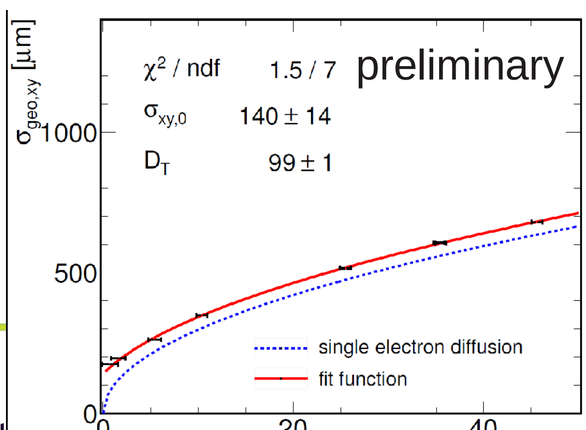
MM



GEMs



InGrids

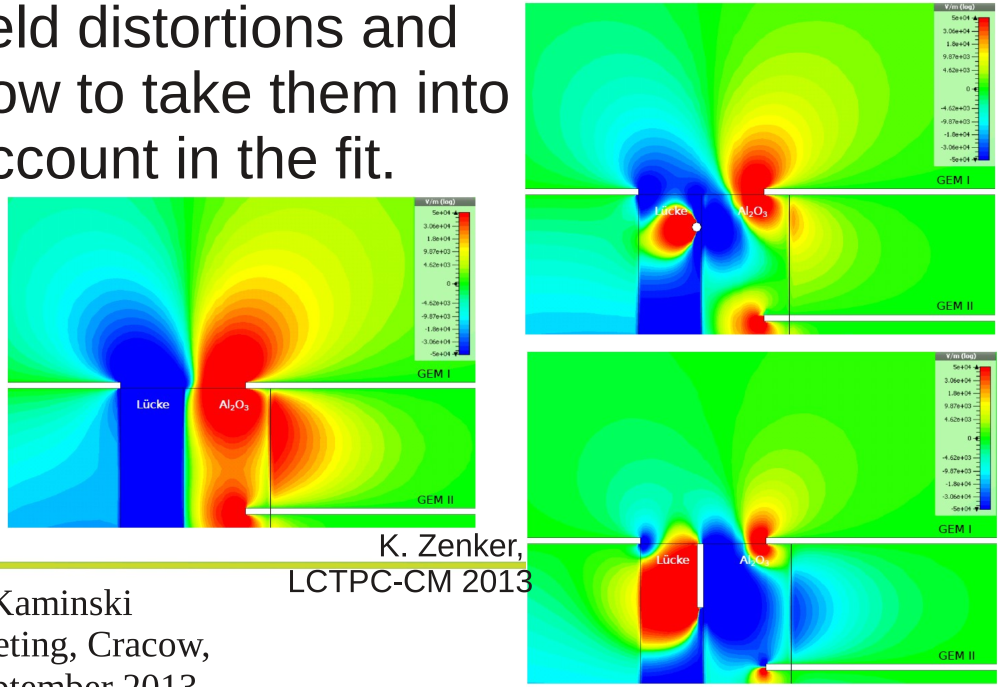


R. Menzen, Bonn

Performance of Micromegas and GEMs is very similar.

Comparison with InGrids is more difficult, since there N_{eff} = N = 1.

All candidates suffer from local field distortions at the end plate:
=> Study ongoing how to reduce these field distortions and how to take them into account in the fit.



K. Zenker, LCTPC-CM 2013

Pads, Electronics, etc

Development of a theoretical prediction of the spatial resolution
(R. Yonamine, K. Fujii, LCTPC-CM 2013)

$$\sigma_x^2(z; w, L\tan\phi, C_d, N_{eff}, \hat{N}_{eff}, [f]) = [A] + \frac{1}{N_{eff}}[B] + [C] + \frac{1}{\hat{N}_{eff}}[D]$$

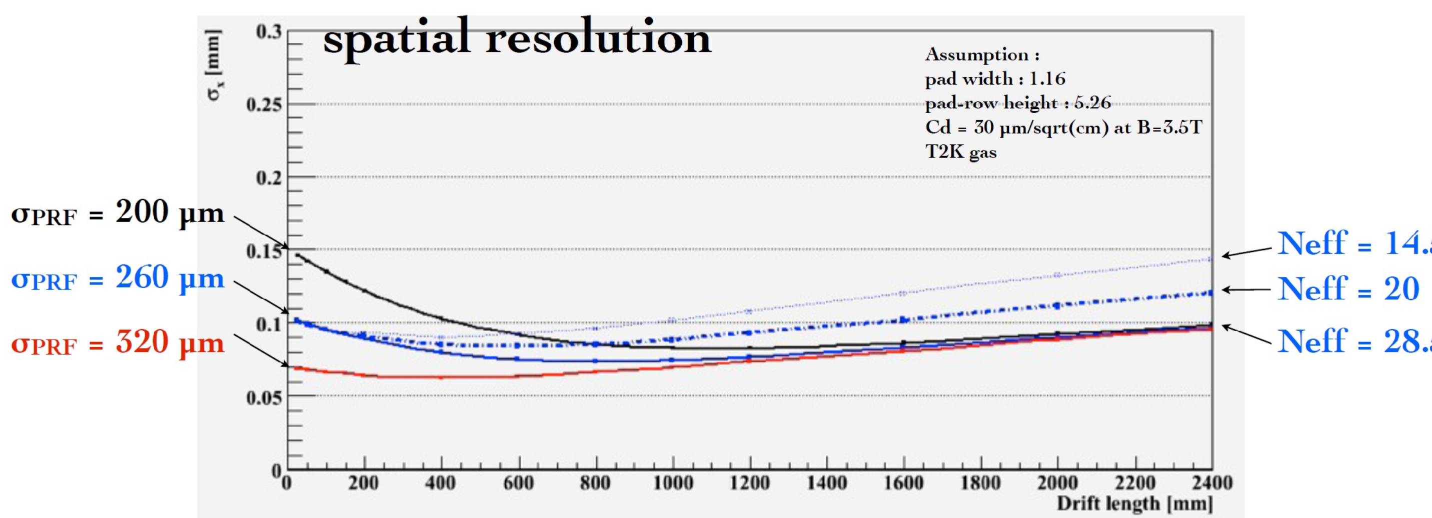
$$[A] := \int_{-1/2}^{+1/2} d\left(\frac{\tilde{x}}{w}\right) \Bigg(\underbrace{\underbrace{\sum_a (aw) \left\langle \langle F_a(\tilde{x} + y\tan\phi + \Delta x)\rangle_{\Delta x} \right\rangle_y}_{\text{diffusion-averaged \& cluster position average charge centroid}} - \tilde{x}}_{\text{systematics}} \Bigg)^2$$

$$[B] := \int_{-1/2}^{+1/2} d\left(\frac{\tilde{x}}{w}\right) \left\langle \Bigg(\underbrace{\sum_a (aw) F_a(\tilde{x} + \Delta x) - \underbrace{\sum_a (aw) \langle F_a(\tilde{x} + \Delta x)\rangle_{\Delta x}}_{\text{diffusion-averaged charge centroid}}}_{\text{displacement due to diffusion for a single electron}} \Bigg)^2 \right\rangle_{\Delta x}$$

$$\approx [A]_{z=0} + \sigma_d^2$$

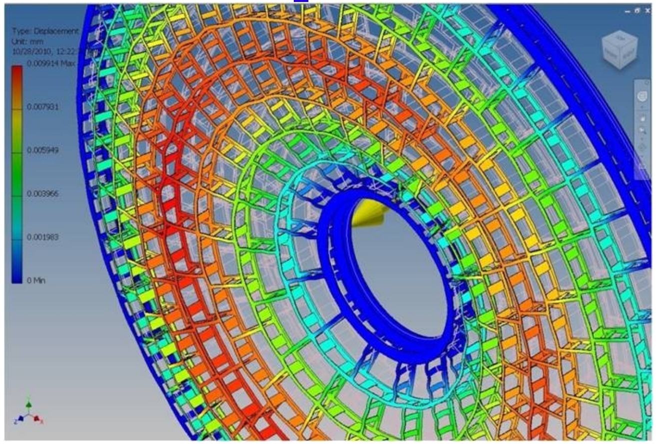
$$[C] := \left(\frac{\sigma_G}{\bar{G}}\right)^2 \left\langle \frac{1}{N^2} \right\rangle_N \sum_a (aw)^2$$

$$[D] := \boxed{\frac{L^2 \tan^2\phi}{12}}$$

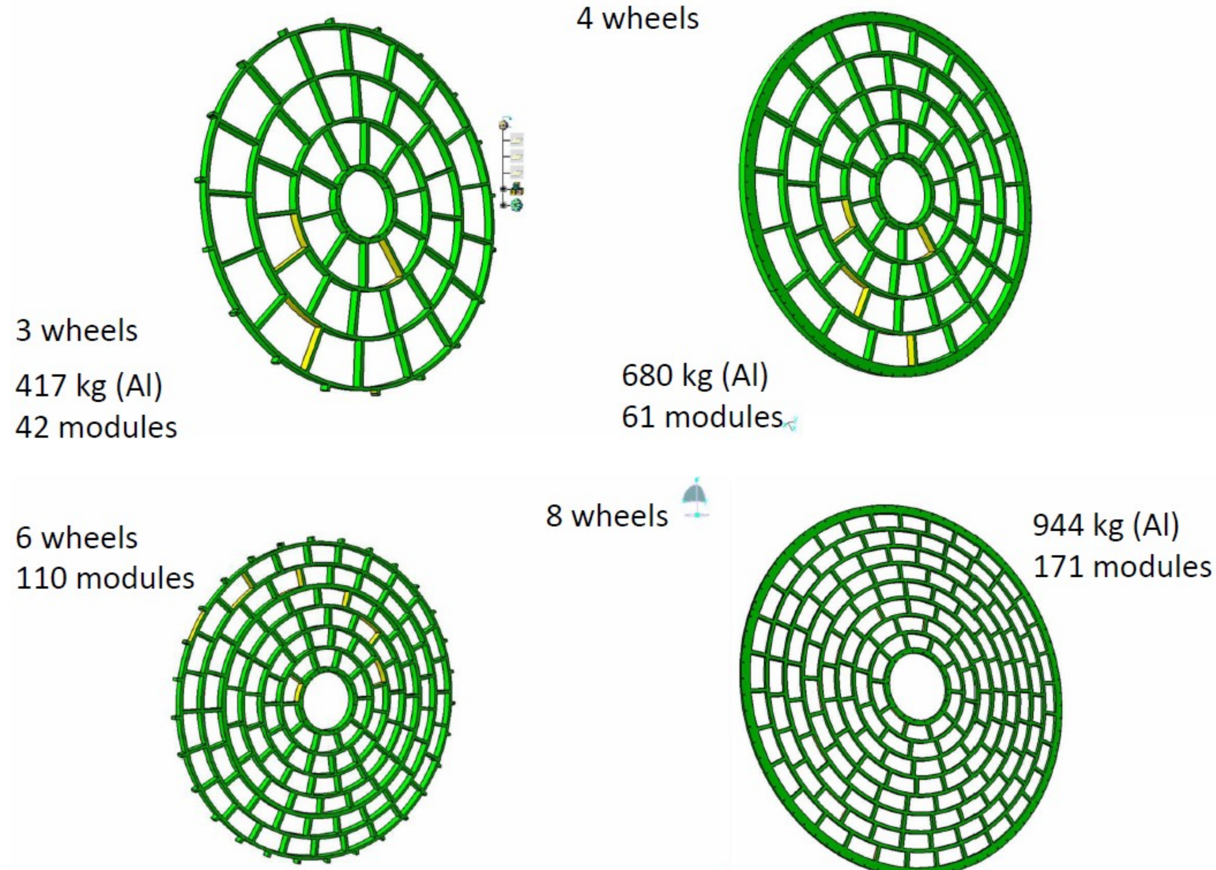


universitätbonn

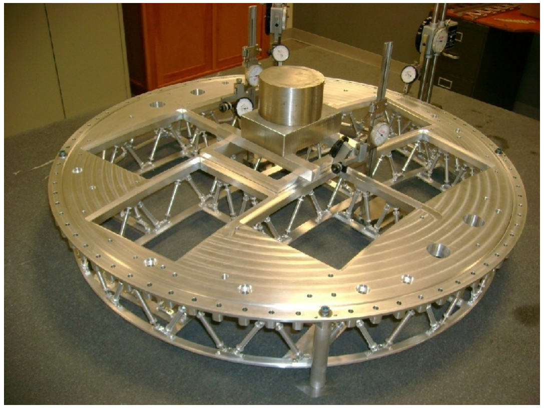
Endcap and Modules Size



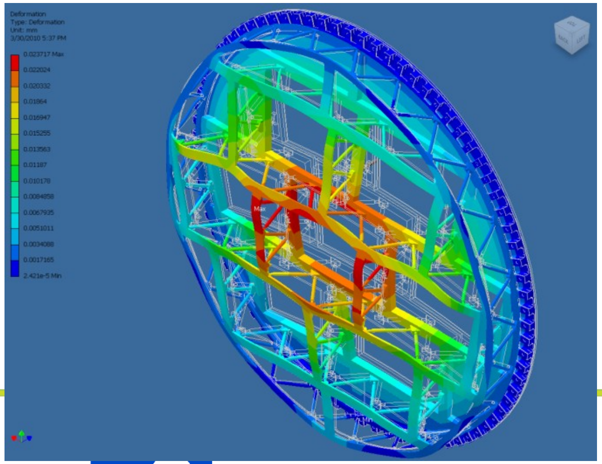
Detailed FEM model for endcap available. Verified with test setup (LP endplate). Different endcap layouts shall be studied.



P. Manil, Saclay, WP151



D. Peterson, Cornell, WP151



Summary

TPC has many interesting features and can add important information to physics analysis.

LCTPC is studying many 'internal' parameters. There are still a number of open questions, but no show stoppers.

We have not the capacity to make optimization studies of external parameters, but extensive studies have been performed by the detector optimization group for the LOI.

What have we forgotten and what are possible changes?

We are looking forward for the discussion!