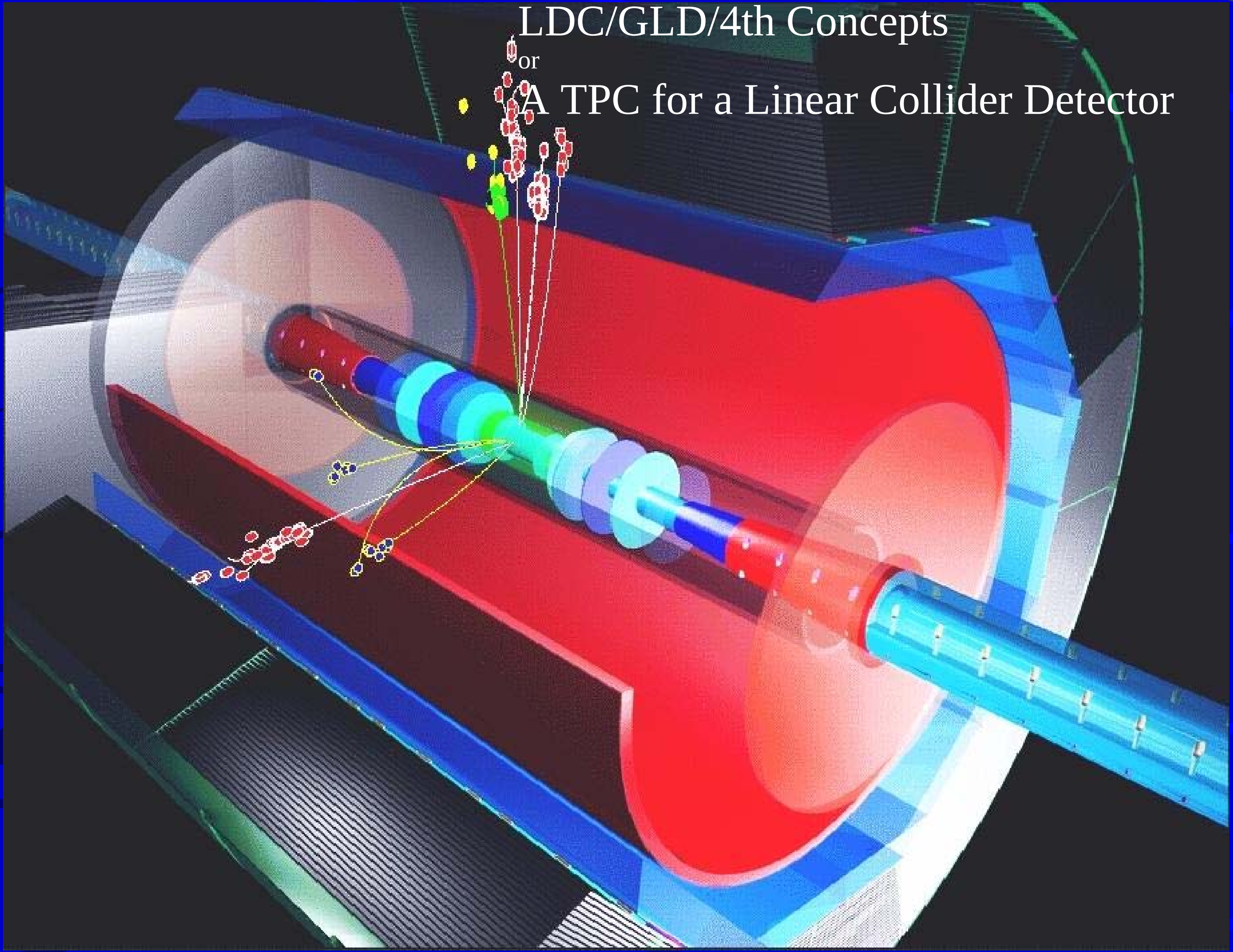
Issues for the LCTPC design and their feedback to the endcap and R&D program

OUTLINE of TALK

- Overview
- LCTPC Design Issues in the DODs
- Next steps:
    - More work with Small Prototypes (SP)
    - Build the Large Prototype (LP)
- LCTPC ⇒ **R&D plans**

LDC/GLD/4th Concepts
or
A TPC for a Linear Collider Detector



HISTORY

1992: *First discussions on detectors in Garmisch-Partenkirschen (LC92). Silicon? Gas?*
1996-1997: *TESLA Conceptual Design Report. Large wire TPC, 0.7Mchan.*
1/2001: *TESLA Technical Design Report. Micropattern (GEM, Micromegas) as a baseline, 1.5Mchan.*
5/2001: *Kick-off of Detector R&D*
11/2001: *DESY PRC proposal. for TPC R&D (European & North American teams)*
2002: *UCLC/LCRD proposals*
2004: *After ITRP,*
WWS R&D panel

Europe
Chris Damerell (Rutherford Lab. UK)
Jean-Claude Brient (Ecole Polytechnique, France)
Wolfgang Lohmann (DESY-Zeuthen, Germany)

Asia
HongJoo Kim (Korean National U.)
Tohru Takeshita (Shinsu U., Japan)
Yasuhiro Sugimoto (KEK, Japan)

North America
Dean Karlen (U Victoria, CAN)
Ray Frey (U. of Oregon, USA)
Harry Weerts (Fermilab, USA)

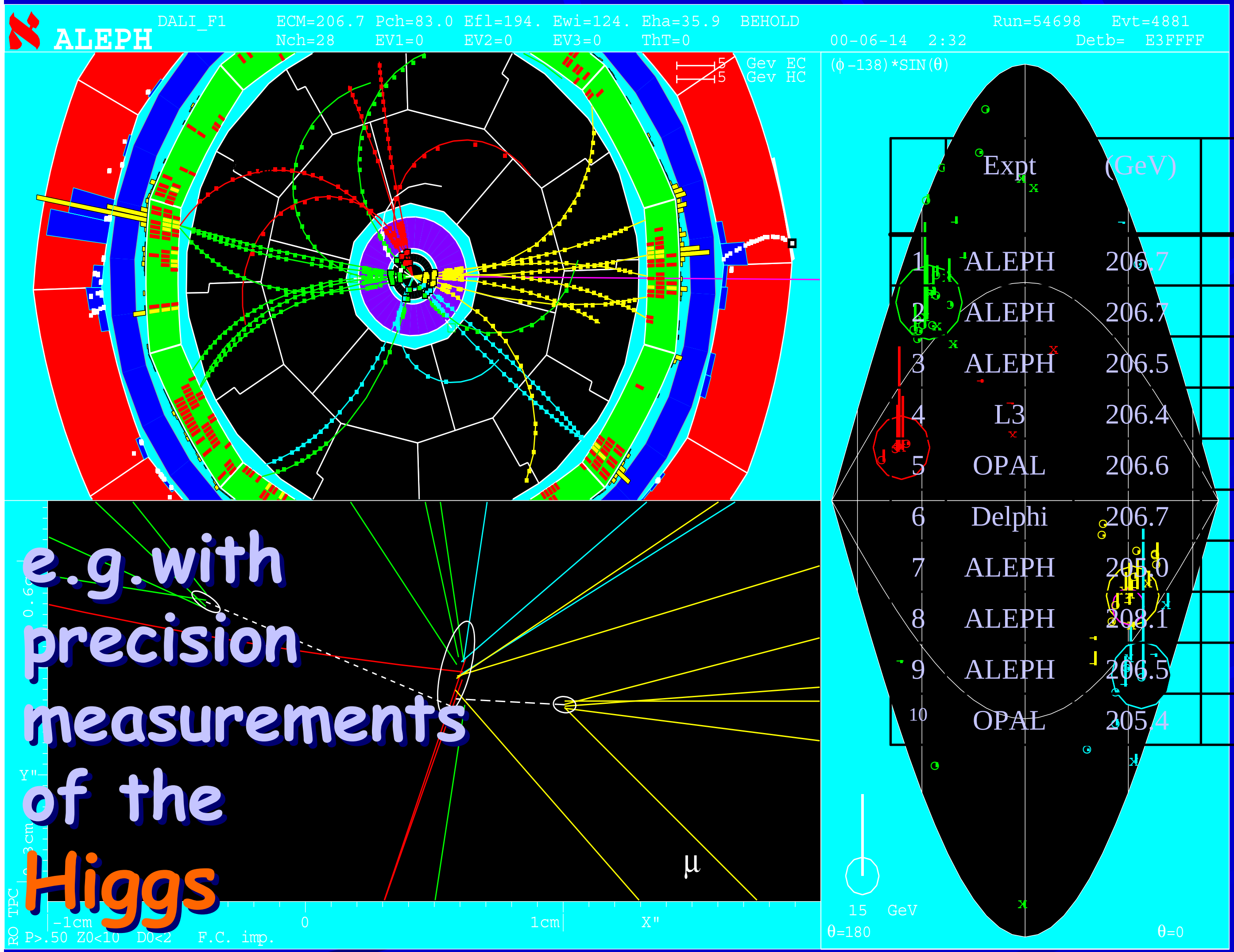
GOAL

To design and build an ultra-high performance

Time Projection Chamber

...as central tracker for the ILC detector, where excellent vertex, momentum and jet-energy precision are required

Goal: to revisit the Higgs…



e.g. with precision measurements of the Higgs

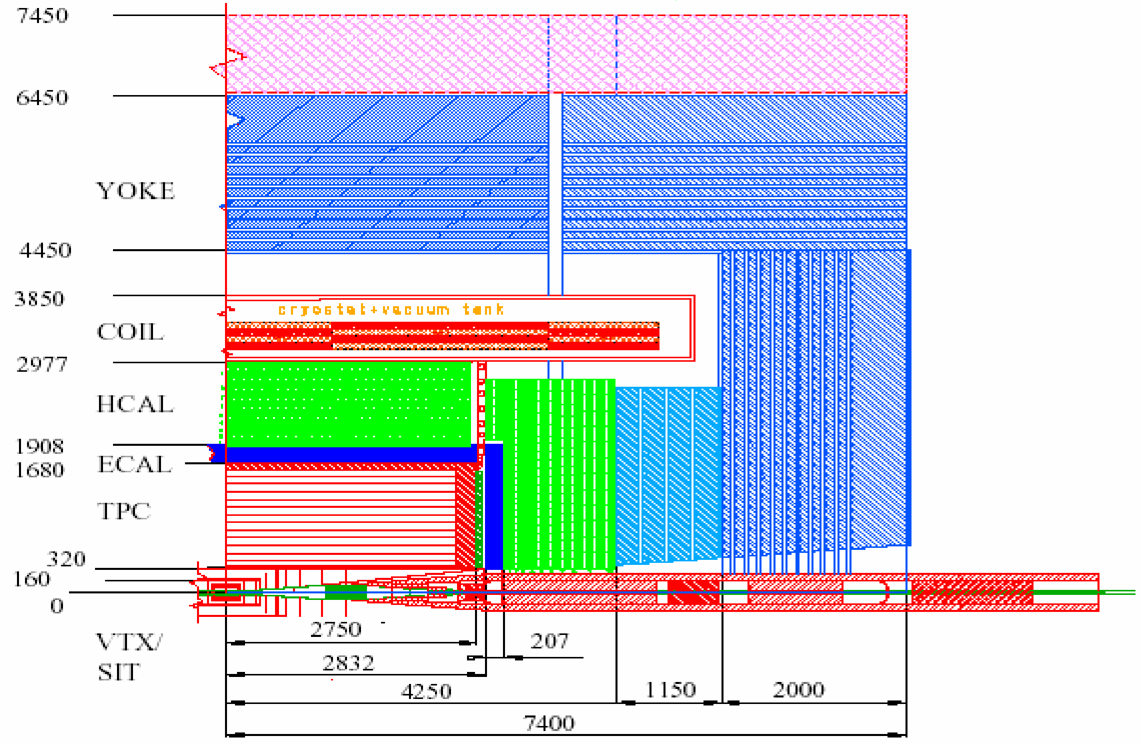
	Expt	(GeV)	Decay Channel	(GeV/c²)	ln(1+s/b) 115 GeV/c²
1	ALEPH	206.7	4-jet	114.3	1.73
2	ALEPH	206.7	4-jet	112.9	1.21
3	ALEPH	206.5	4-jet	110.0	0.64
4	L3	206.4	E-miss	115.0	0.53
5	OPAL	206.6	4-jet	110.7	0.53
6	Delphi	206.7	4-jet	114.3	0.49
7	ALEPH	206.0	Lept	118.1	0.47
8	ALEPH	208.1	Tau	115.4	0.41
9	ALEPH	206.5	4-jet	114.5	0.40
10	OPAL	205.4	4-jet	112.6	0.40

Large Detector Concept example

- Flavor tag $\delta(\mathrm{IP}) \sim 5\mu\mathrm{m} \oplus \frac{10\mu m\ \mathrm{GeV}/c}{p \sin^{3/2}\theta}$
- Track momentum $\delta(1/p_t) \sim 3\mathrm{x}10^{-5}\ \mathrm{GeV}/c^{-1}$
- **Particle Flow** $\delta E/E \sim .30/\sqrt{E}$

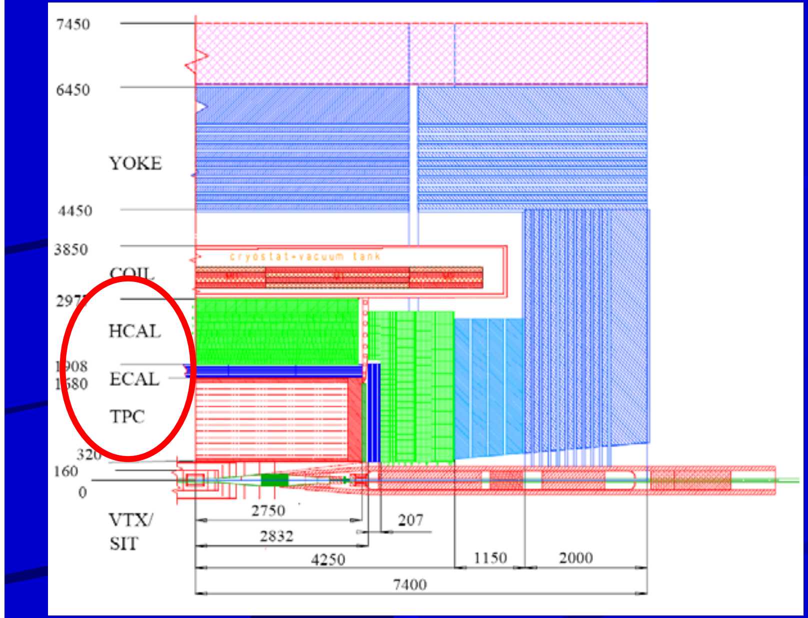
Energy flow
– granularity
– hermeticity
– min. material inside calos
– calos inside 4 T coil

(N.B. below are TDR dimensions, which have changed for latest LDC iteration)

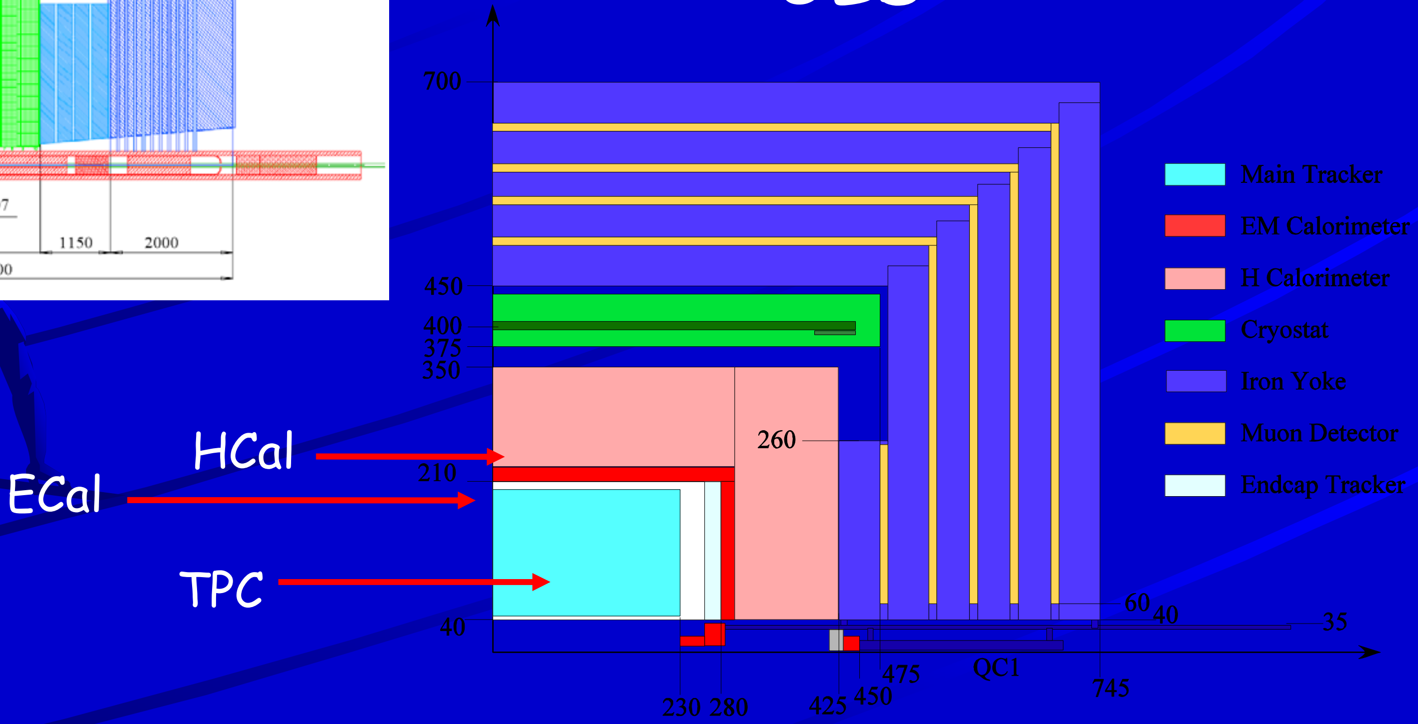


LDC

4th (not shown)



GLD



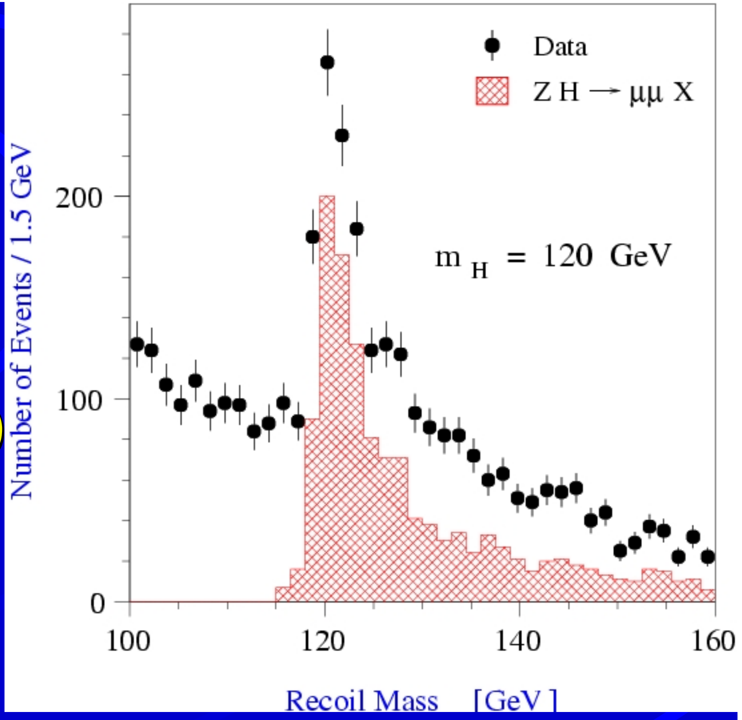
Physics determines detector design

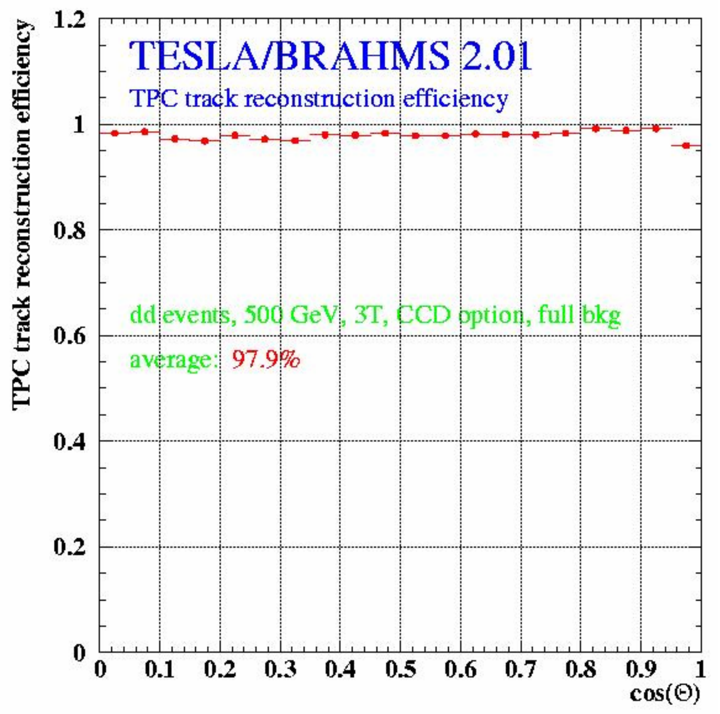
- ★ **momentum: $d(1/p) \sim 10^{-4}$/GeV(TPC only)**
  $\sim 0.6\times10^{-4}$/GeV(w/vertex)
  (1/10xLEP)

$e^+e^-\rightarrow ZH\rightarrow ll\ X$ goal: $\delta M_{\mu\mu} < 0.1\times\Gamma_Z$
→ δM_H dominated by beamstrahlung

- ★ **tracking efficiency: 99% (overall)**

excellent and robust tracking efficiency by combining vertex detector and TPC, each with excellent tracking efficiency





R&D Planning

- 1) Demonstration phase
  - Continue work with small prototypes on mapping out parameter space, understanding resolution, etc, to prove feasibility of an MPGD TPC. For CMOS-based pixel TPC ideas this will include proof-of-principle tests.
- 2) Consolidation phase
  - Build and operate the Large Prototype (LP), Ø ~ 80cm, drift ~ 60cm, with EUDET infrastructure as basis, to test manufacturing techniques for MPGD endplates, fieldcage and electronics. LP design is starting → building and testing will take another ~ 3-4 years.
- 3) Design phase
  - During phase 2, the decision as to which endplate technology to use for the LC TPC would be taken and final design started.

LCTPC/LP Groups (19Sept06)

Americas

Carleton
Montreal
Victoria
Cornell
Indiana
LBNL
Purdue (observer)

Asia

Tsinghua
CDC:
Hiroshima
KEK
Kinki U
Saga
Kogakuin
Tokyo UA&T
U Tokyo
U Tsukuba
Minadano SU-IIT

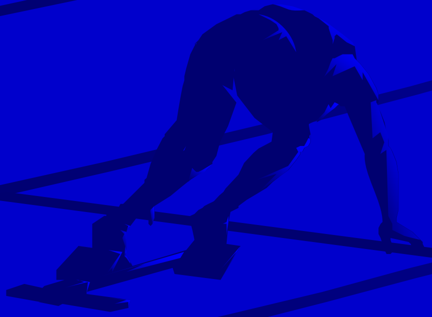
Europe

LAL Orsay
IPN Orsay
CEA Saclay
Aachen
Bonn
DESY
U Hamburg
Freiburg
MPI-Munich
TU Munich (observer)
Rostock
Siegen
NIKHEF
Novosibirsk
Lund
CERN

Other groups

MIT
MIT (LCRD)
Temple/Wayne State (UCLC)
Yale
Karlsruhe
UMM Krakow
Bucharest

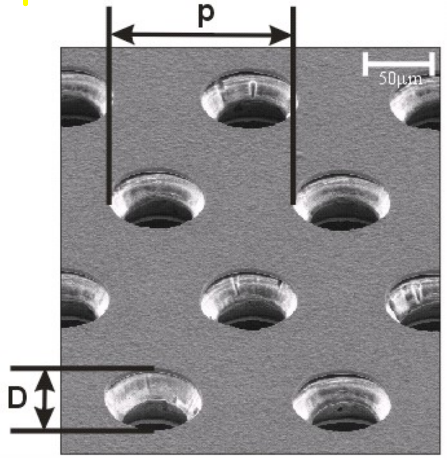
What have we been doing in Phase 1 ?



Gas-Amplification Systems: Wires & MPGDs→

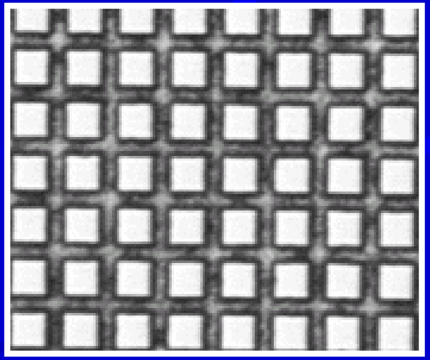
GEM: Two copper foils separated by kapton, multiplication takes place in holes, uses 2 or 3 stages

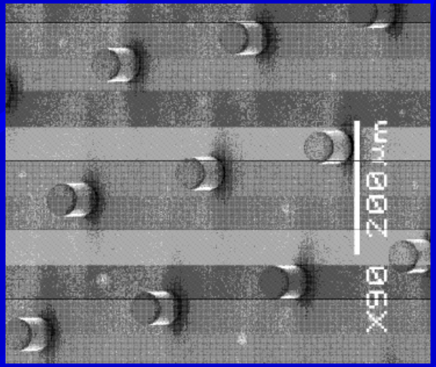
Micromegas: micromesh sustained by 50μm pillars, multiplication between anode and mesh, one stage



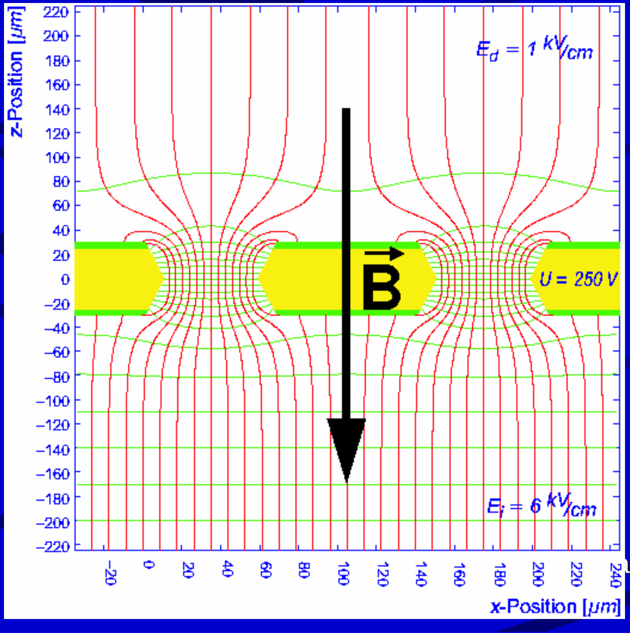
P~140 μm

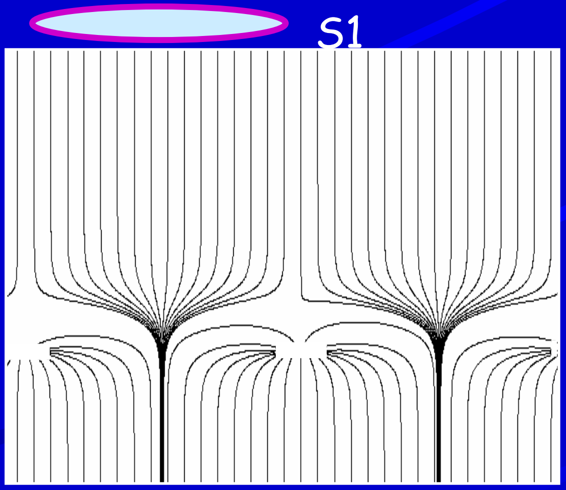
D~60 μm





S1/S2 ~ Eamplif / Edrift

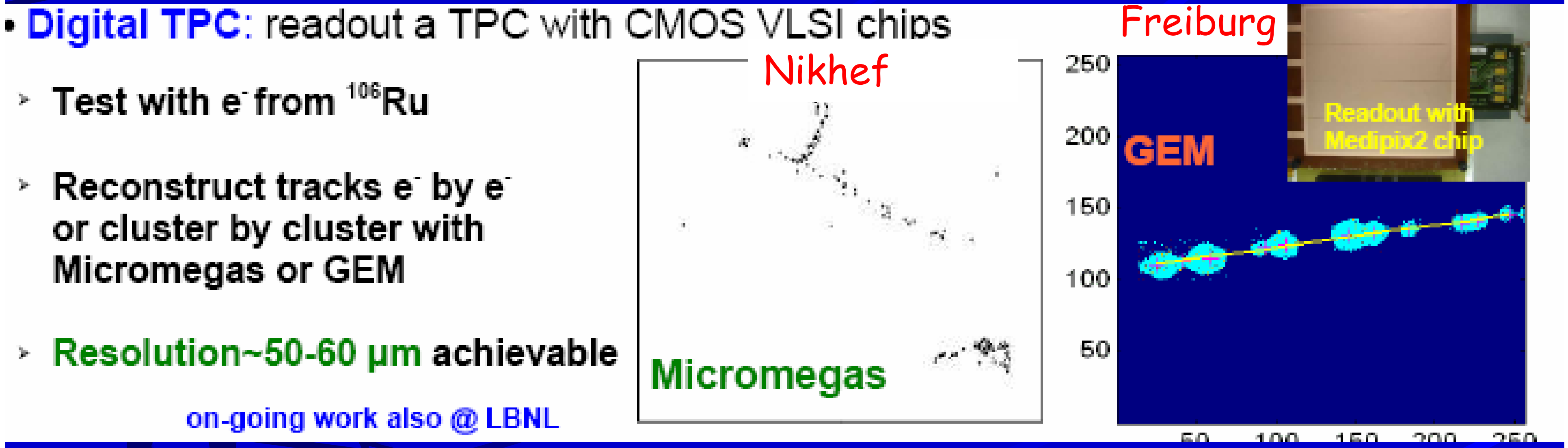




S1

S2

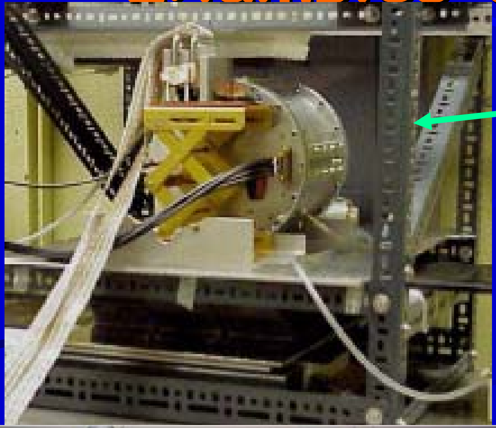
Pixel TPC Development



- **Digital TPC**: readout a TPC with CMOS VLSI chips
  - Test with e⁻ from ^{106}Ru
  - Reconstruct tracks e⁻ by e⁻ or cluster by cluster with Micromegas or GEM
  - Resolution~50-60 µm achievable

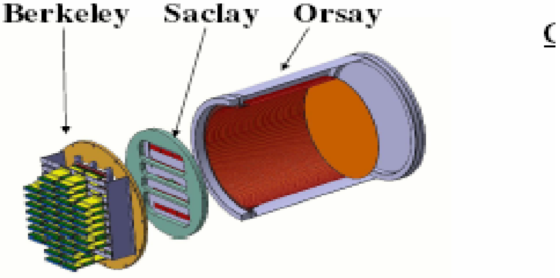
on-going work also @ LBNL

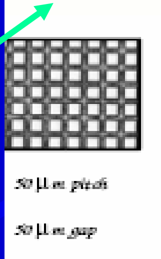
Examples of Prototype TPCs

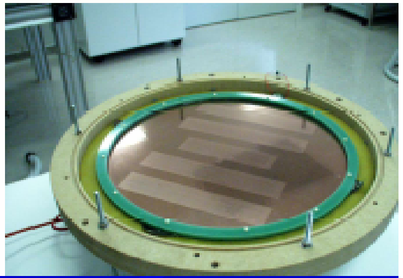


Carleton, Aachen, Cornell/Purdue, Desy(n.s.) for B=0or1T studies

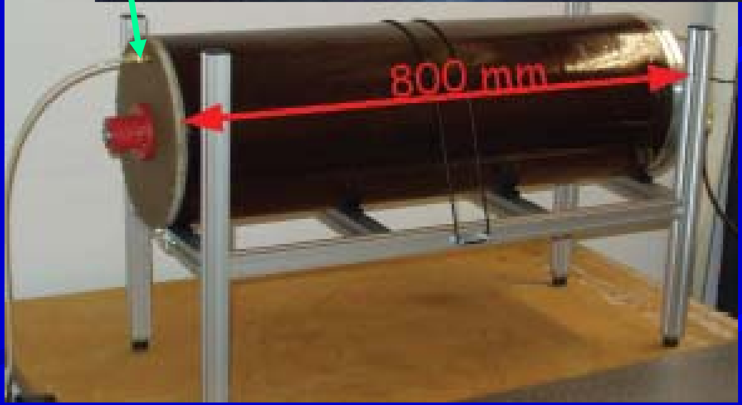
Saclay, Victoria, Desy (fit in 2-5T magnets)





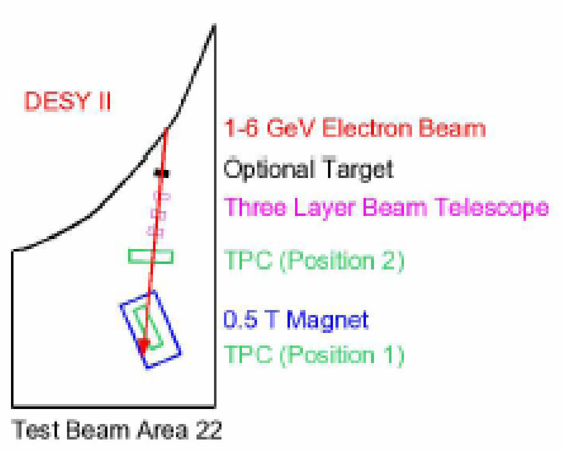


Karlsruhe, MPI/Asia, Aachen built test TPCs for magnets (not shown), other groups built small special-study chambers

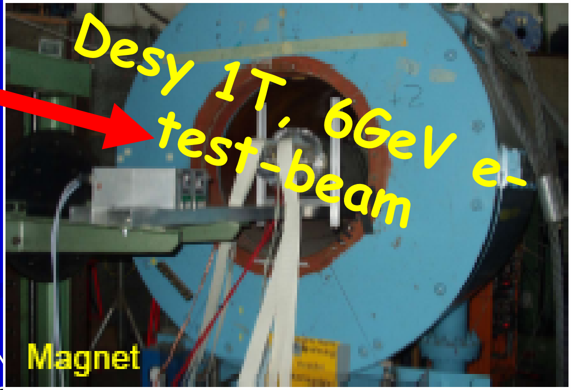


Facilities

Cern test-
beam (not
shown)



EUDET



TPC R&D summary to date

- Now 4 years of MPGD experience gathered
- Gas properties rather well understood
- Limit of resolution being understood
- Resistive foil charge-spreading demonstrated
- CMOS RO demonstrated
- Work starting for the Large Prototype

Phase 2

- Basic Idea: LP should be a prototype for the LC TPC design and test as many of the issues as possible (like, e.g., TPC90 @ Aleph). This will take at least 2 iterations, we call them LP1 and LP2.

- The Eudet infrastructure gives us a starting basis for the LP work

- The general LCTPC/LP R&D issues and been divided up into workpackages (WP) →more later…

Excerpts from DODs for GLD and LDC used here as examples

DESIGN ISSUES for the LCTPC

- Performance
- Endplate
- Electronics
- Chamber gas
- Fieldcage
- Effect of non-uniform field
- Calibration and alignment
- Backgrounds and robustness

Performance

- Momentum precision needed for overall tracking?
- Momentum precision needed for the TPC?
- Good dE/dx resolution, V° detection
- Requirements for
  - 2-track resolution (in rφ and z)?
  - track-gamma separation (in rφ and z)?
- Tolerance on the maximum endplate thickness?
- Tracking configuration
  - Calorimeter diameter
  - TPC
  - Other tracking detectors
- TPC OD/ID/length

LCTPC resolution in the DODs

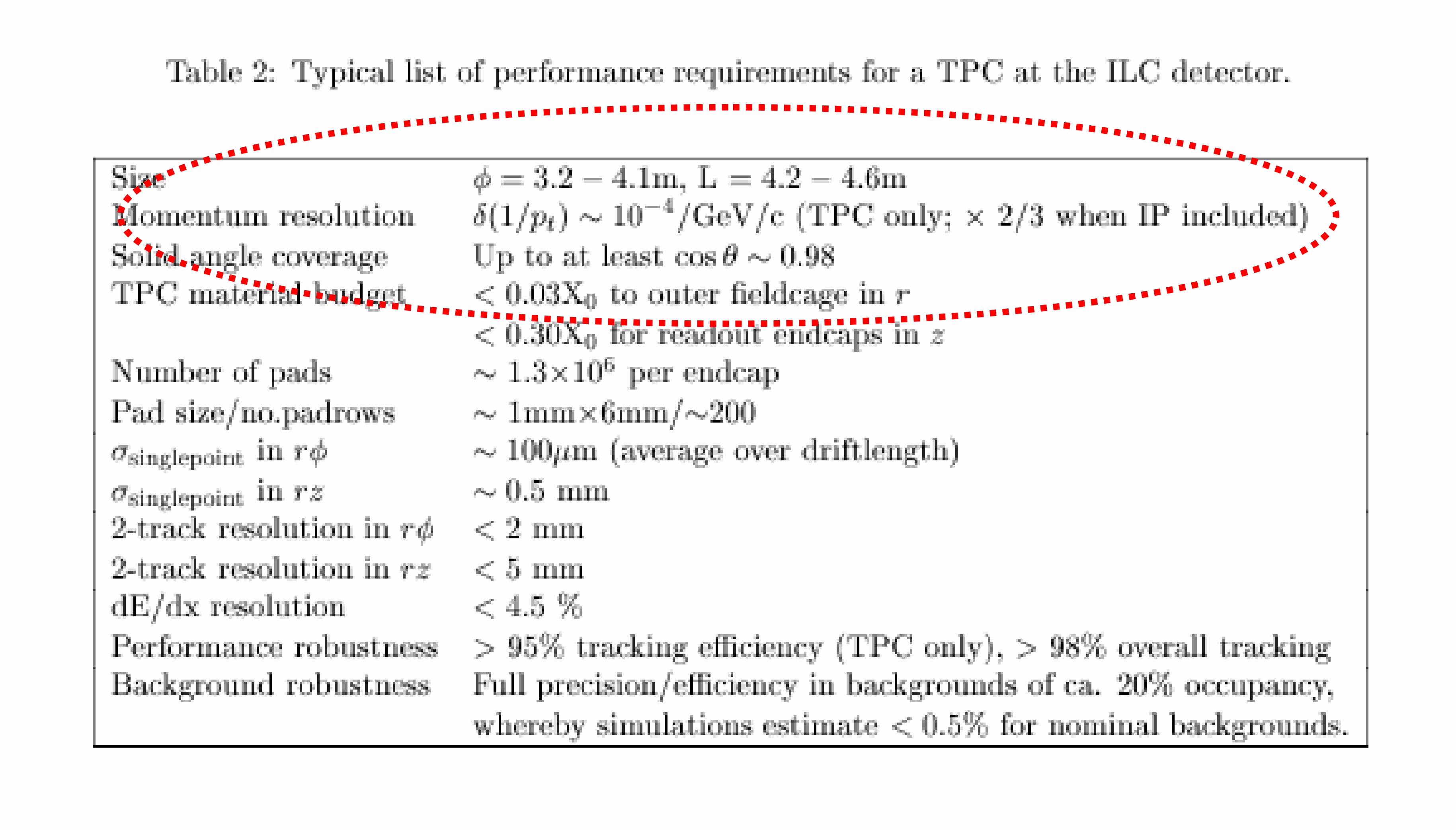


Table 2: Typical list of performance requirements for a TPC at the ILC detector.

Size	$\phi = 3.2 - 4.1\text{m}$, $\text{L} = 4.2 - 4.6\text{m}$
Momentum resolution	$\delta(1/p_t) \sim 10^{-4}/\text{GeV/c}$ (TPC only; × 2/3 when IP included)
Solid angle coverage	Up to at least $\cos\theta \sim 0.98$
TPC material budget	$< 0.03\text{X}_0$ to outer fieldcage in r $< 0.30\text{X}_0$ for readout endcaps in z
Number of pads	$\sim 1.3\times10^6$ per endcap
Pad size/no.padrows	$\sim$ 1mm×6mm/$\sim$200
$\sigma_{\text{singlepoint}}$ in $r\phi$	$\sim 100\mu\text{m}$ (average over driftlength)
$\sigma_{\text{singlepoint}}$ in rz	~ 0.5 mm
2-track resolution in $r\phi$	< 2 mm
2-track resolution in rz	< 5 mm
dE/dx resolution	< 4.5 %
Performance robustness	$> 95\%$ tracking efficiency (TPC only), $> 98\%$ overall tracking
Background robustness	Full precision/efficiency in backgrounds of ca. 20% occupancy, whereby simulations estimate $< 0.5\%$ for nominal backgrounds.

A Study of Tracker Performance with Jupiter

Atsushi Yamaguchi Tsukuba Univ.
Keisuke Fujii KEK
Akiya Miyamoto KEK
Tomoaki Fujikawa Tohoku Univ.
Kotoyo Hoshina Wisconsin Univ.
Yuzo Asano Tsukuba Univ.
other acfa-sim-j members, cdc group

ACFA8--July2005

Tracker parameters used in this study

TPC

- lever arm = 155 [cm] (Rmin = 44cm)
- half length = 255 [cm]
- N_{sample} = 200
- sigma$_{r\varphi}^2$ = $55^2 + 55^2/28 \times Z_{drift}$ [μm^2]
- sigma$_z$ = 600 [μm]

(measured for a GEM-TPC with P5 gas --> K. Ikematsu's talk)

IT

- N_{layer} = 4 (R_{min} = 9cm, R_{step} = 7cm)
- thick = 560 [μm] (silicon)
- sigma$_{r\varphi, z}$ = 10 [μm]

VTX

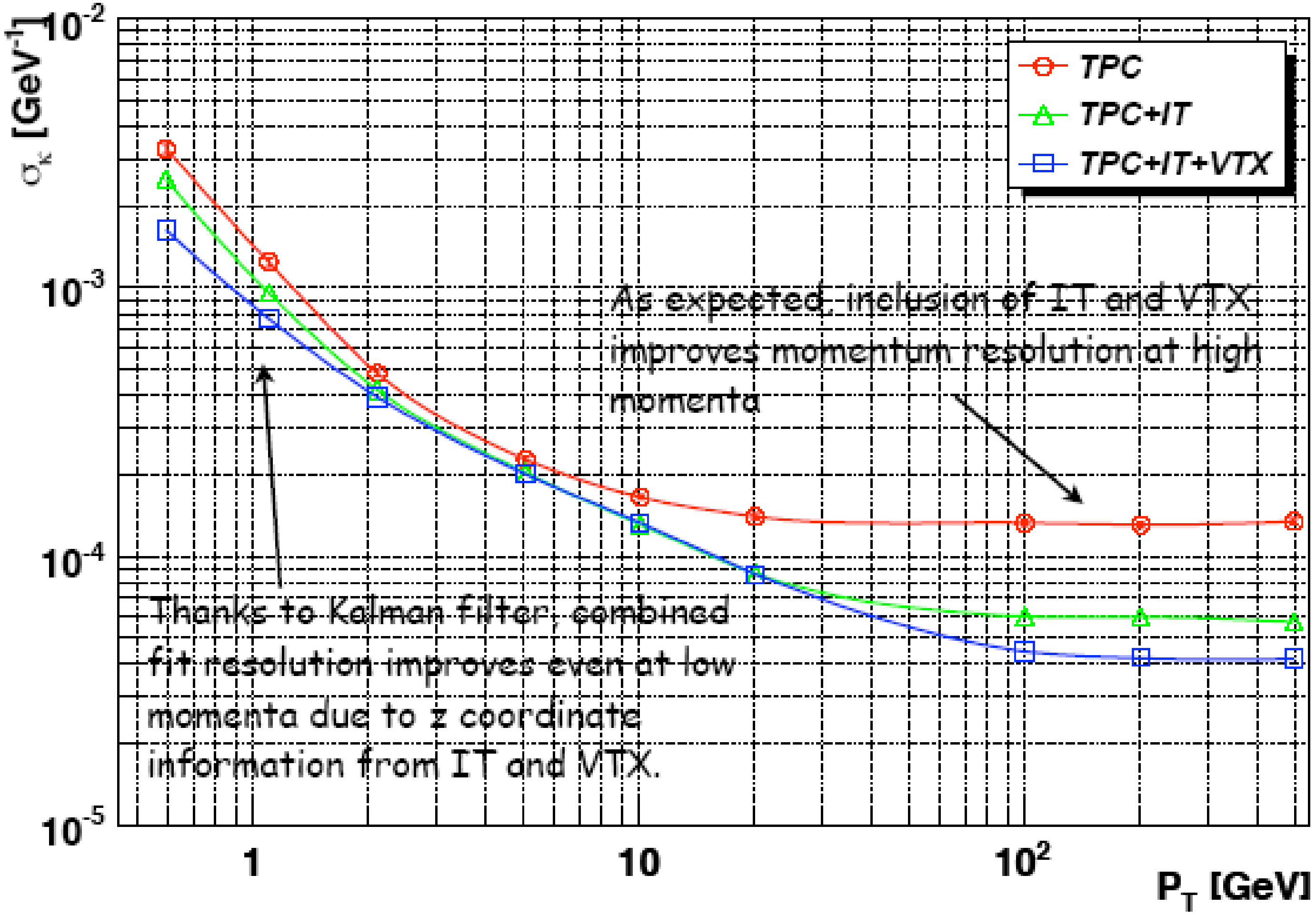
- N_{layer} = 4 (R_{min} = 2.4cm, R_{step} = 1.2cm)
- thickness = 330 [μm] (silicon)
- sigma$_{r\varphi, z}$ = 4 [μm]

09/11/2006

Ro
Valenc
De

Momentum resolution vs transverse momentum

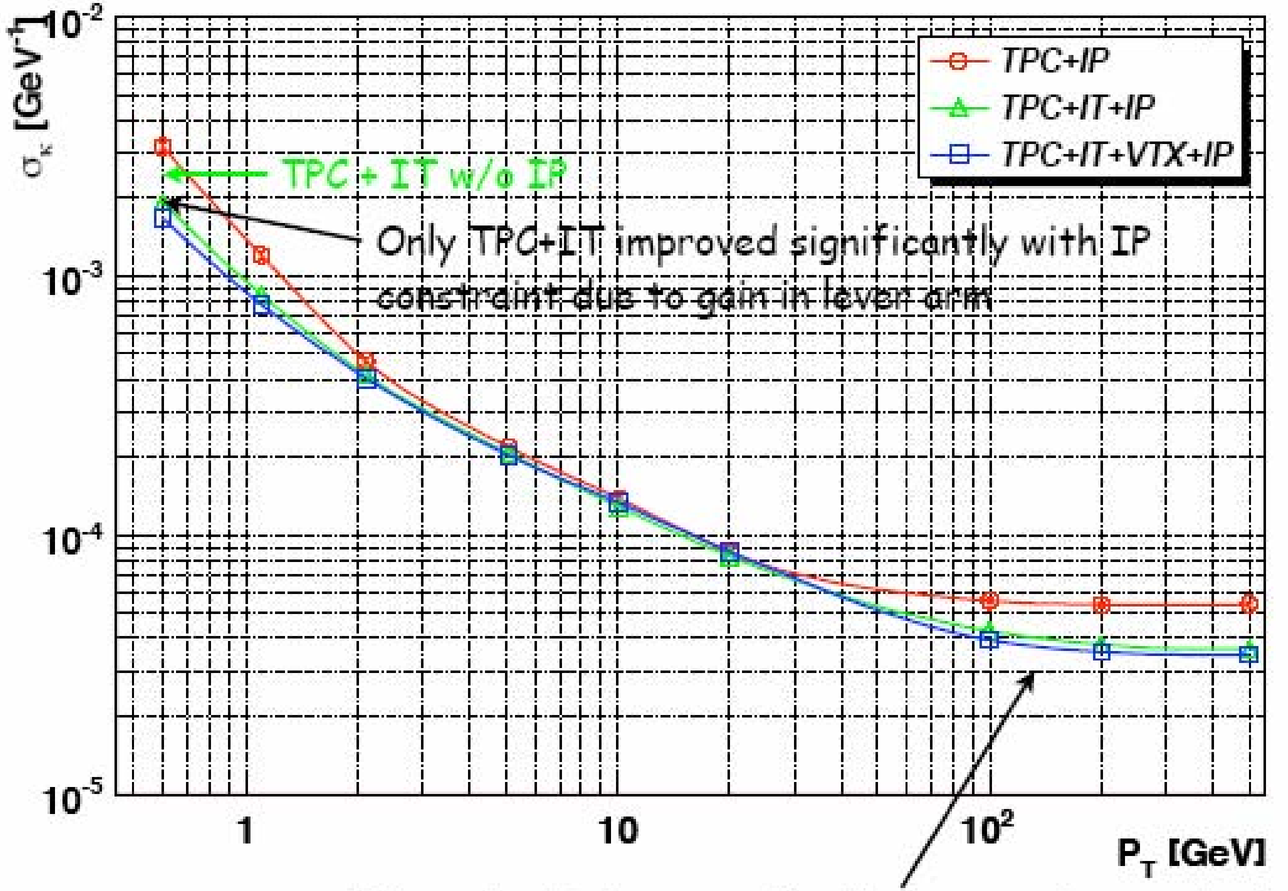
(|cos| < 0.7)



As expected, inclusion of IT and VTX improves momentum resolution at high momenta

Thanks to Kalman filter, combined fit resolution improves even at low momenta due to z coordinate information from IT and VTX.

Momentum resolution vs transverse momentum with IP constraint



TPC + IT w/o IP

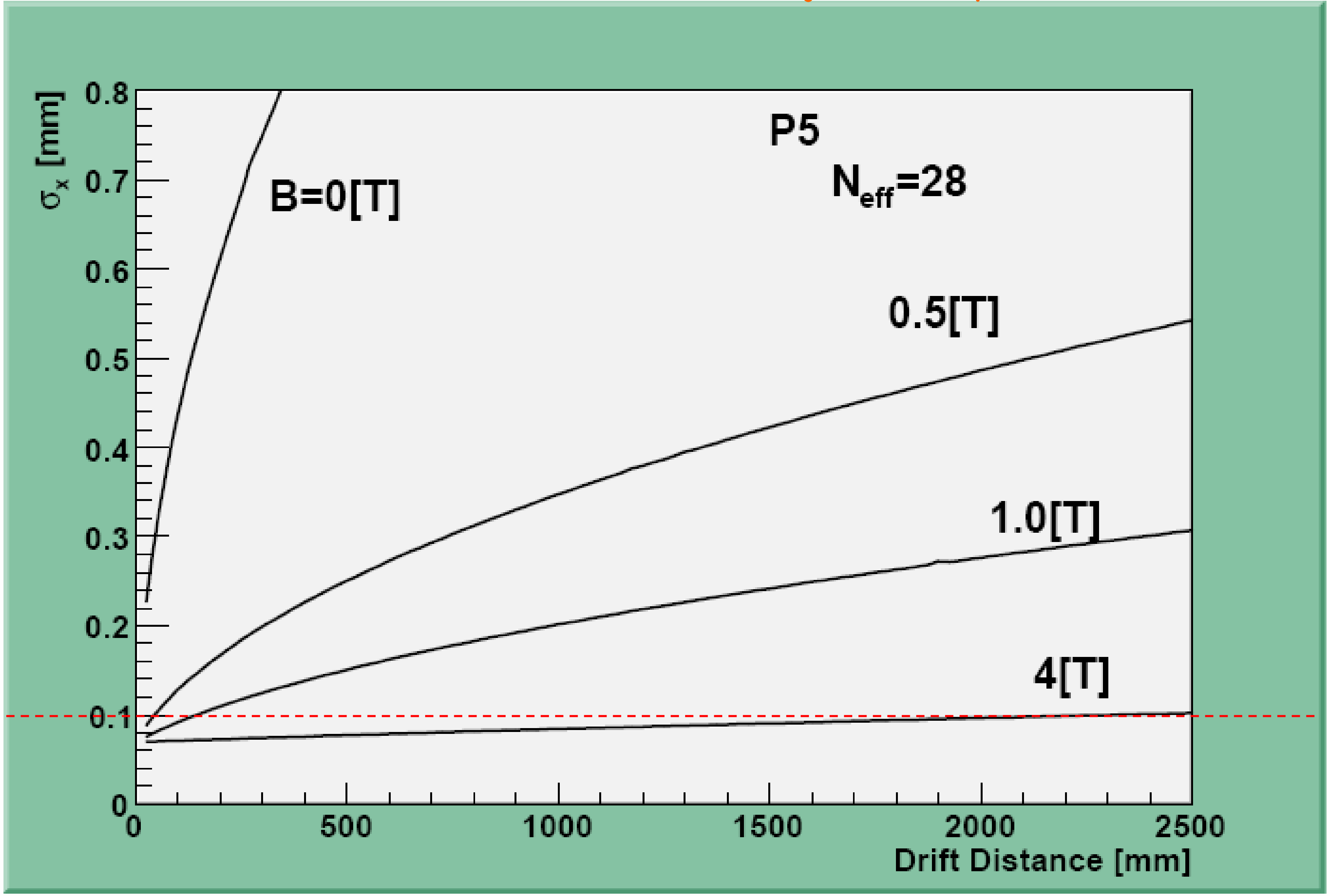
Only TPC+IT improved significantly with IP constraint due to gain in lever arm

IP constraint improves the high momentum region in particular for the TPC-only and TPC+IT cases.

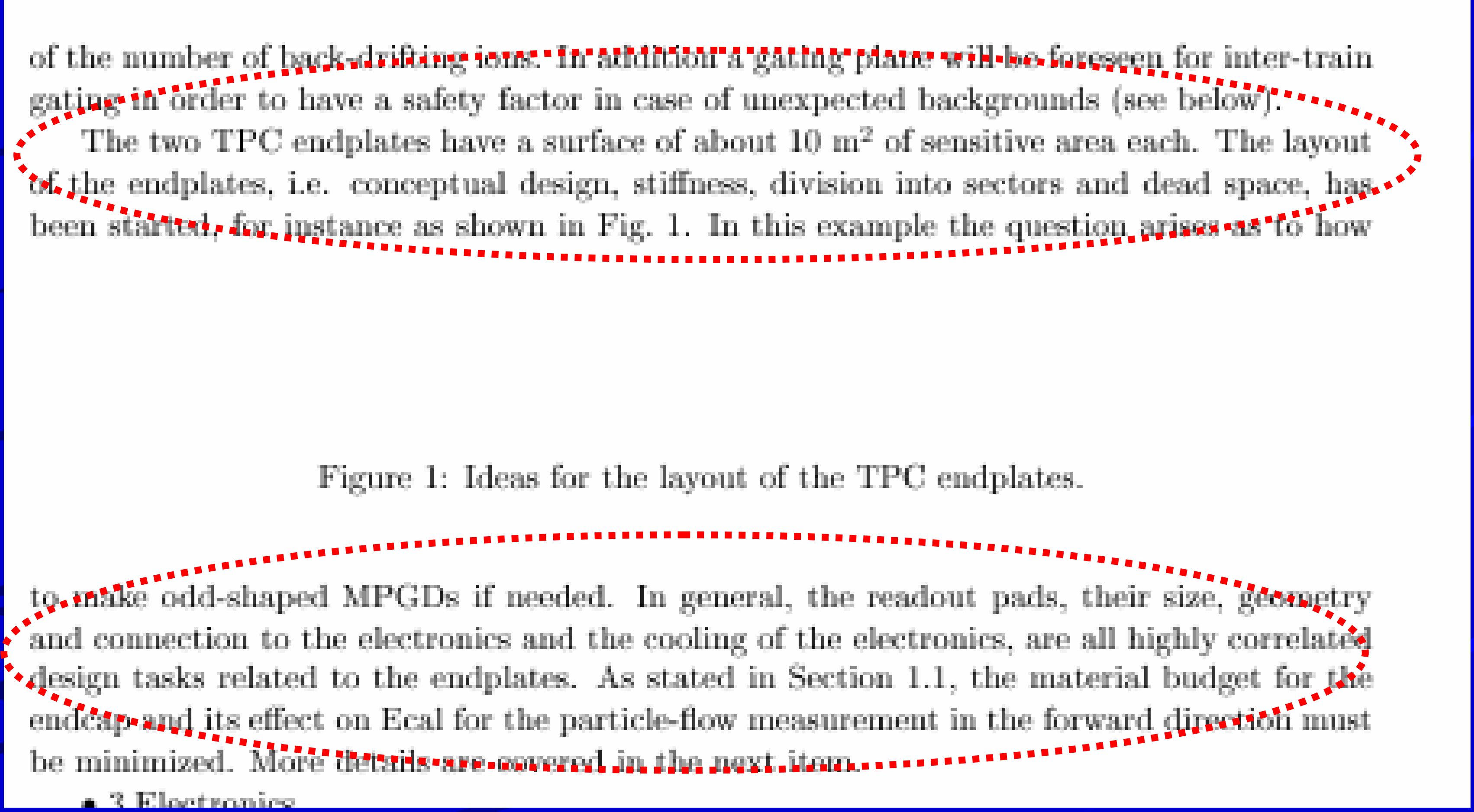
Performance

- Momentum precision needed for the TPC→
- What is the best we can do?

Keisuke Fujii, PRC report



LC TPC Endcaps



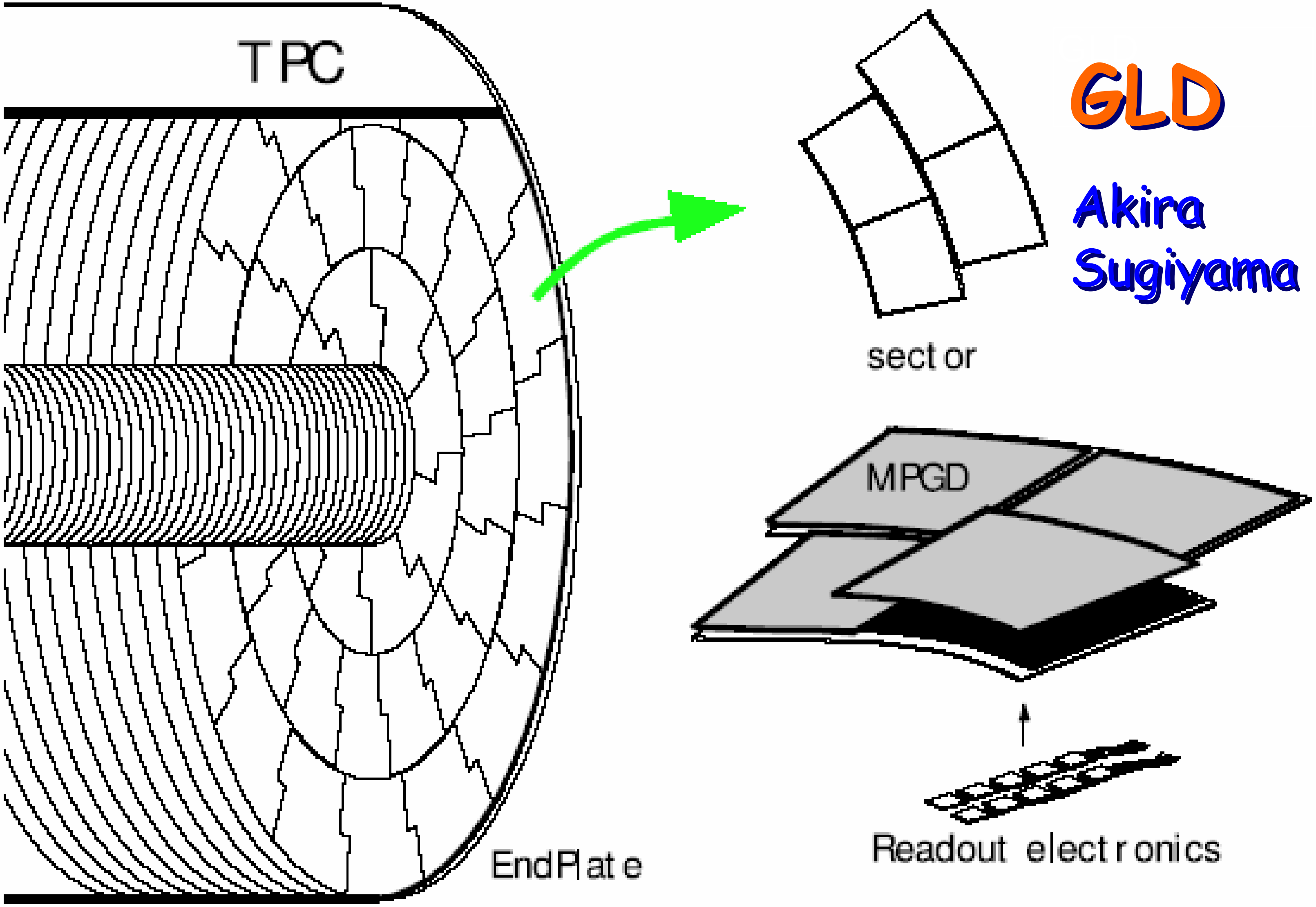
of the number of back-drifting ions. In addition a gating plane will be foreseen for inter-train gating in order to have a safety factor in case of unexpected backgrounds (see below).

The two TPC endplates have a surface of about 10 m^2 of sensitive area each. The layout of the endplates, i.e. conceptual design, stiffness, division into sectors and dead space, has been started, for instance as shown in Fig. 1. In this example the question arises as to how

Figure 1: Ideas for the layout of the TPC endplates.

to make odd-shaped MPGDs if needed. In general, the readout pads, their size, geometry and connection to the electronics and the cooling of the electronics, are all highly correlated design tasks related to the endplates. As stated in Section 1.1, the material budget for the endcap and its effect on Ecal for the particle-flow measurement in the forward direction must be minimized. More details are covered in the next item.

- 3 Electronics



GLD

Akira Sugiyama

Arrangements of detectors on the active area of the end cap (2/2)
Trapezoidal shapes assembled in iris shape

LDC

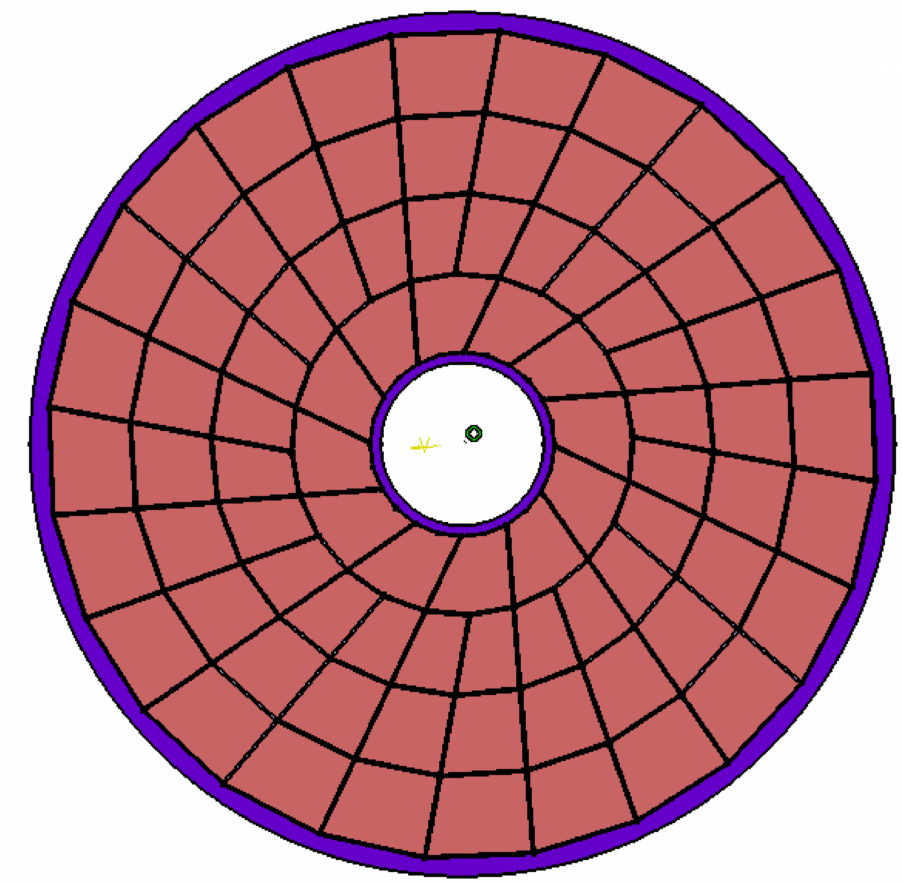
Annotations: Px is the type number of PADS boards or frames

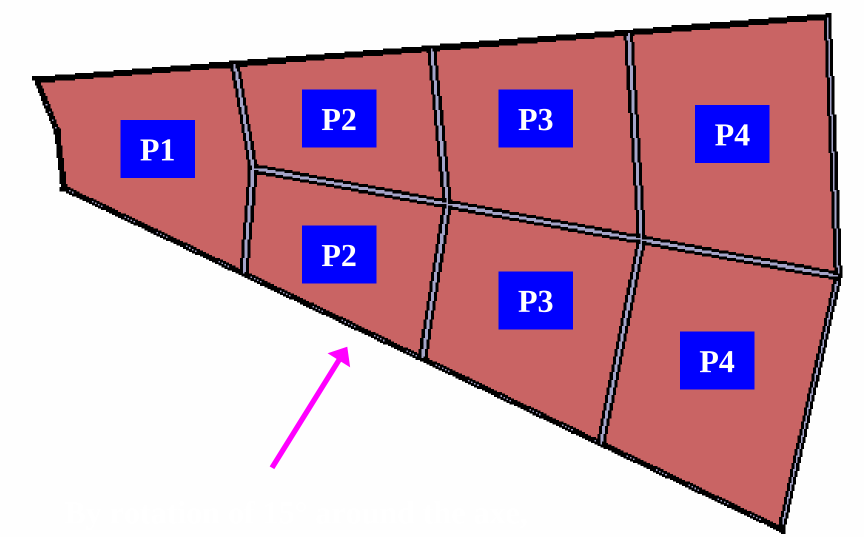
RS/Joel Pouthas/Philippe Rosier

12 sectors (30° each) as super modules are defined

On each, 7 modules are fixed

he sizes of detectors are varying from 180 to 420 mm



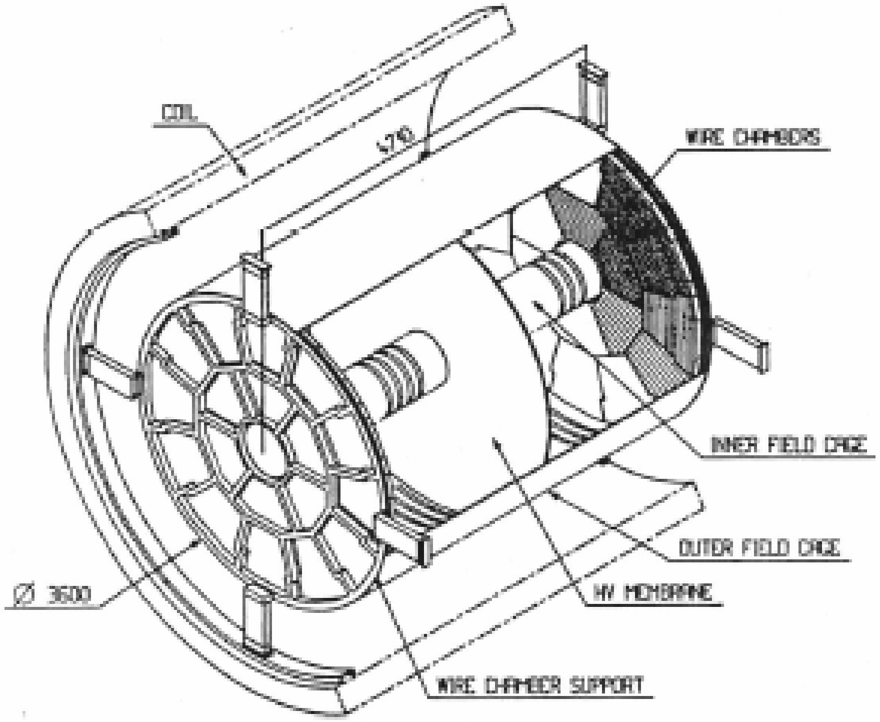


By rotation of 15° around the axis,
these frames are the same

These arrangement seems to be the best as only 4 different PADS are necessary

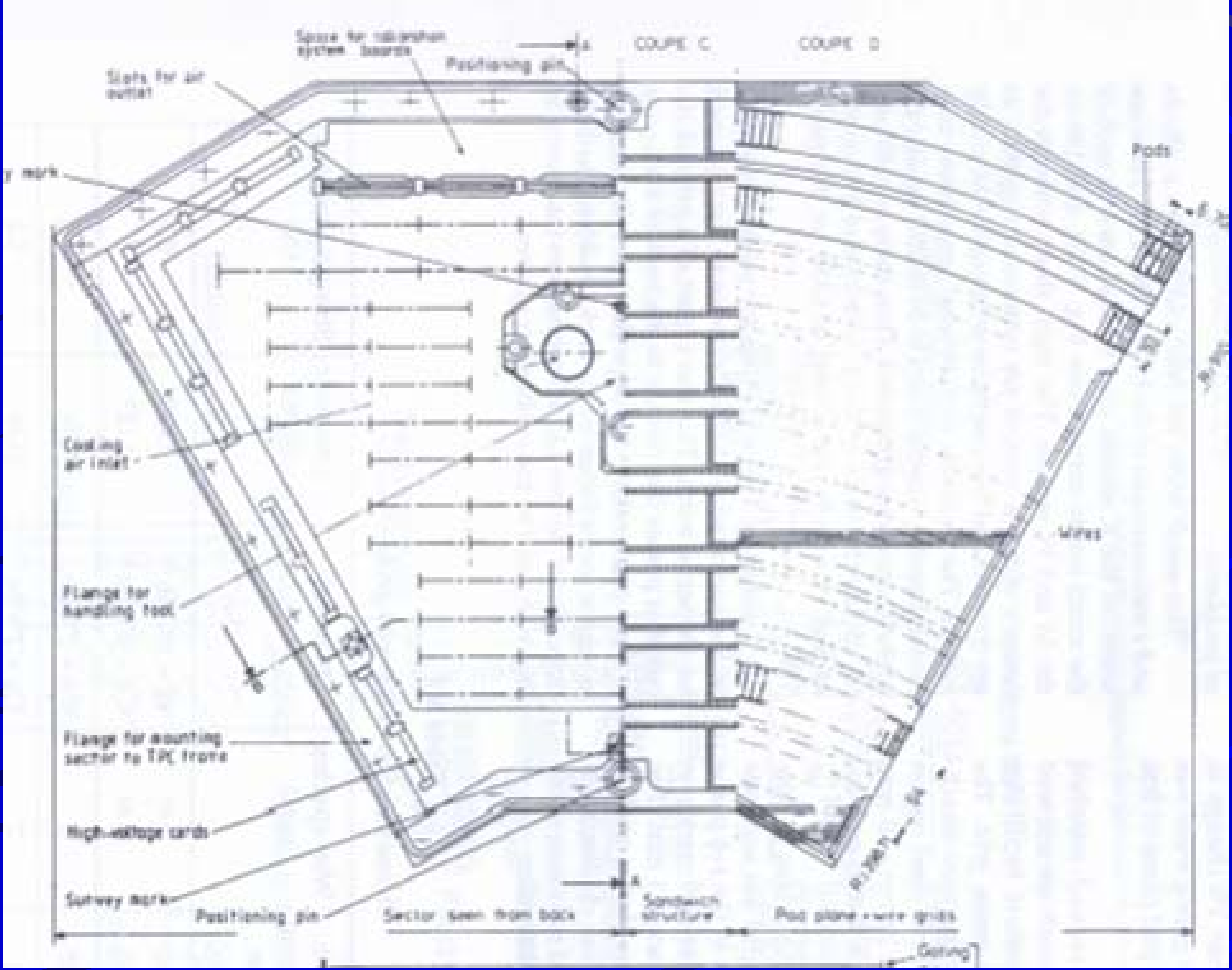
TPC

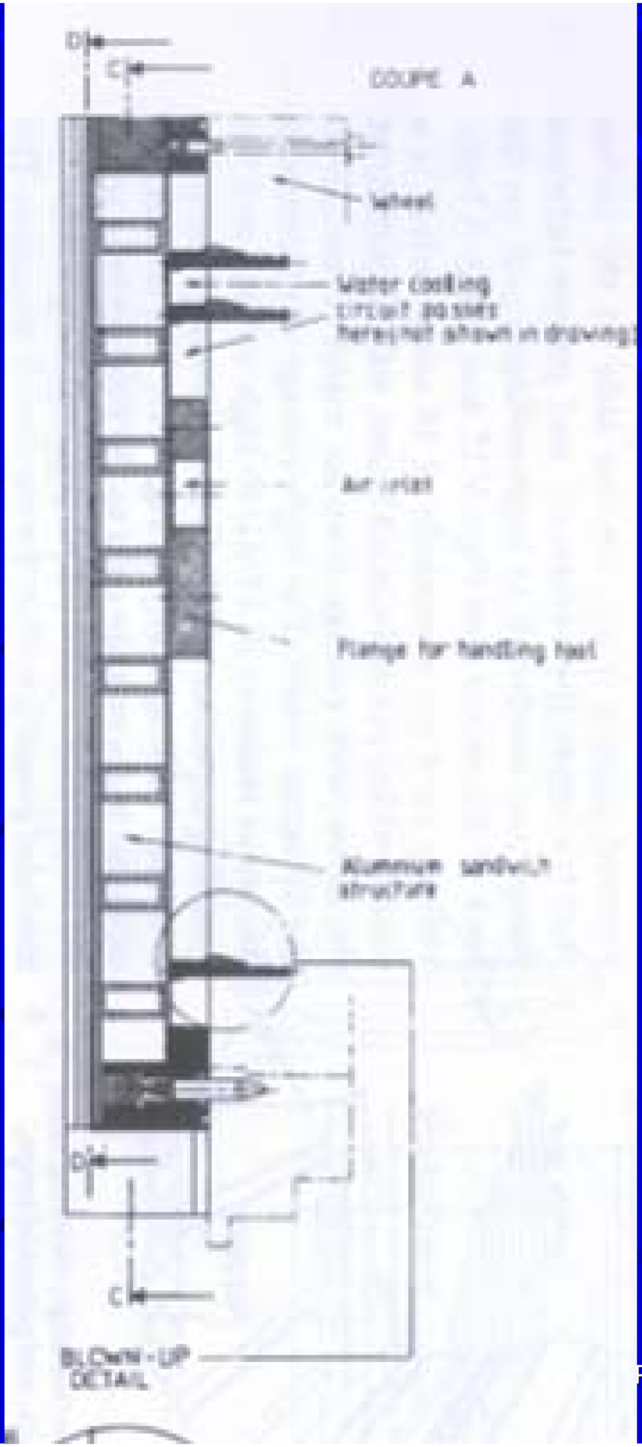
Aleph endplate



- rφ from pad position
- z from drift time (pads + wires)
- dE/dx from wires and pads

- Length = 4.7 m
- Outer radius = 1.8 m
- Total weight = 3.6 t
- Drift length 2 × 2.2m
- Up to 21 space points / track
- 18 wire chambers / endplate
- 47340 channels in total
- B = 15 kG
- HV (Membrane) = −27.5 kV
- Gas
  - Volume 43 m^3
  - Argon/Methan (91:9) at atmospheric pressure
- Angular coverage
  - 2π in φ
  - 21 pad rows hit for $|\cos\Theta| \leq 0.8$
  - At least 3 pad rows for $|\cos\Theta| \leq 0.97$


Space for calibration system boards
COUPE C
COUPE D
Positioning pin
Slots for air outlet
y mark
Pads
Cooling air inlet
Wires
Flange for handling tool
Flange for mounting sector to TPC frame
High-voltage cards
Survey mark
Positioning pin
Sector seen from back
Sandwich structure
Pad plane + wire grids
Gating


D
C
COUPE A
Wheel
Water cooling
circuit passes
here(not shown in drawing)
Air inlet
Flange for handling tool
Aluminum sandwich
structure
D
C
BLOWN-UP
DETAIL

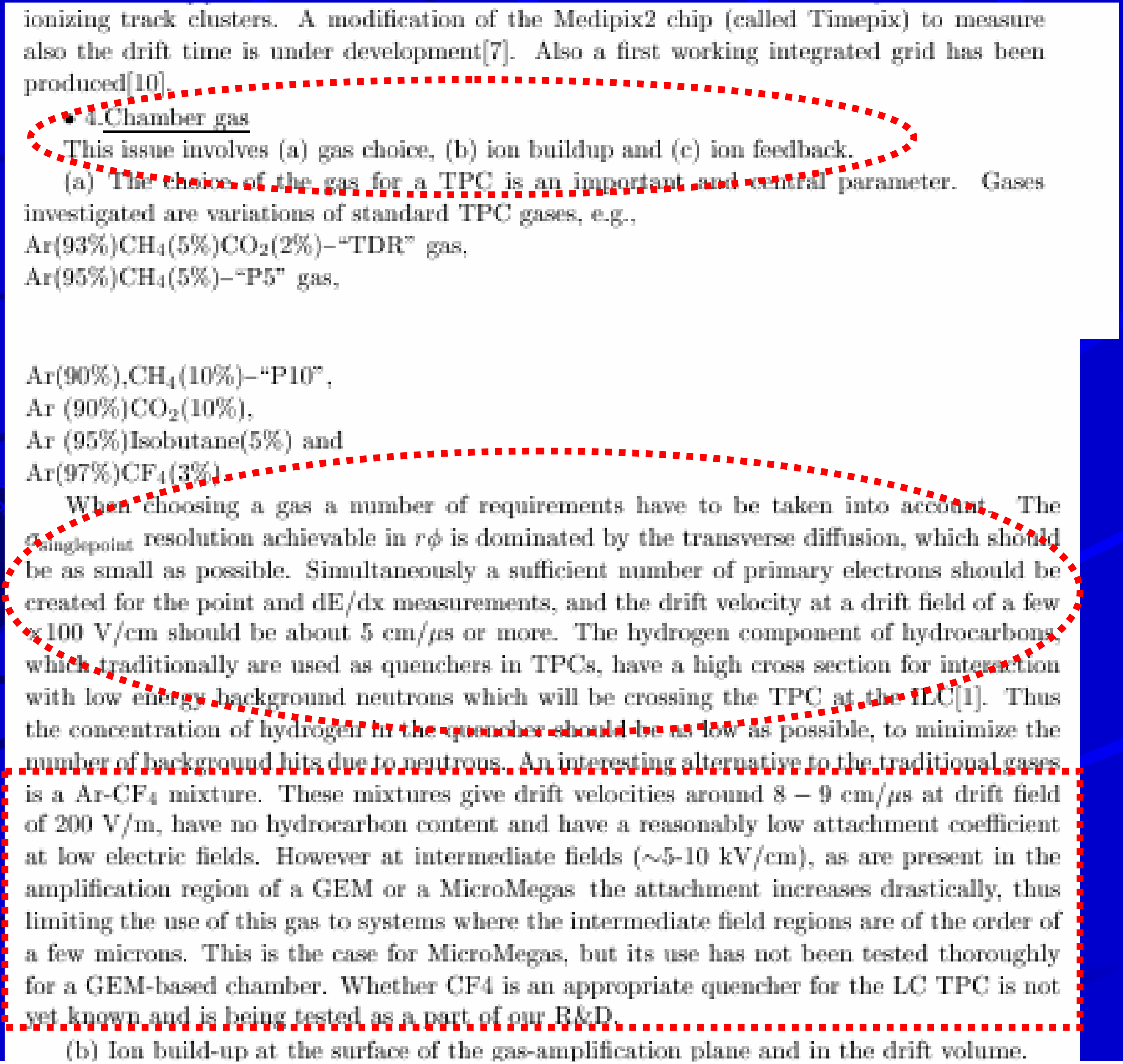
Some features

- Zigzag structure prevented loss of tracks > $\theta \sim 22^\circ$
- Sectors mounted from inside using a “handling tool” to minimize the dead space between sectors. This straight-forward operation which was performed at least 30 times during the lifetime of Aleph.
- Alu sandwich structure stiff, lightweight to
  - contain 7mb overpressure
  - provide forced-air thermal insulation between electronics and TPC volume
- Water cooling of 1kW electronics/side in addition
  - 22K channels per side
- Combination water/air cooling blocked all heat to TPC
- Overall thickness ~ 25%Xo (average) w/o cables
- Bending of endplate
  - 20 micrometers due to 7mb overpressure
  - 5 micrometers due to wire tension

Design

- Gas-amplification technology → input from R&D projects
- Chamber gas candidates: crucial decision!
- Electronics design: LP WP
  - Zeroth-order "conventional-RO" design
  - Is there an optimum pad size for momentum, dE/dx resolution and electronics packaging?
  - Silicon RO: proof-of-principle
- Endplate design LP WP
  - Mechanics
  - Minimize thickness
  - Cooling
- Field cage design LP WP

LC TPC Chamber gas
(a) gas choice



ionizing track clusters. A modification of the Medipix2 chip (called Timepix) to measure also the drift time is under development[7]. Also a first working integrated grid has been produced[10].

- 4.Chamber gas

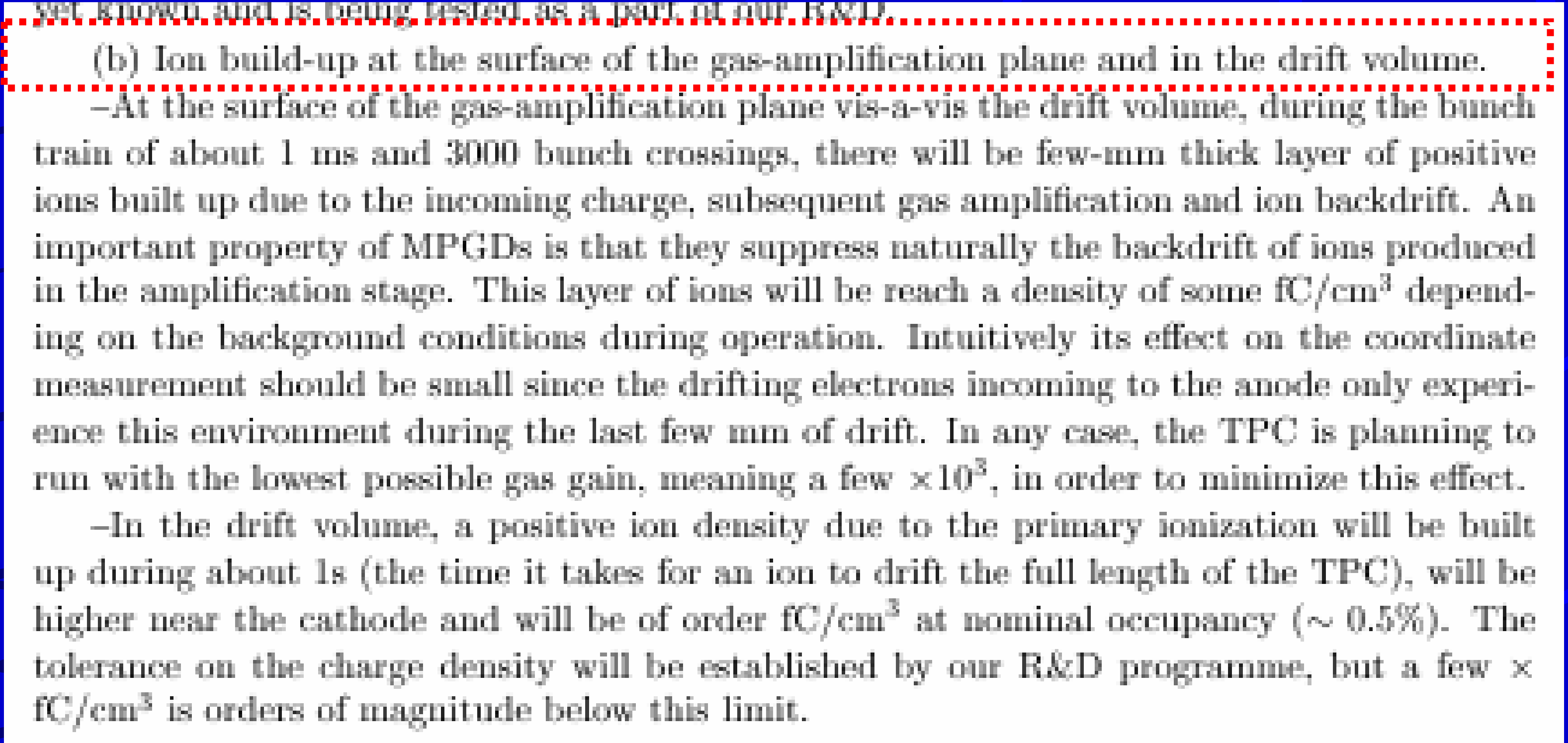
This issue involves (a) gas choice, (b) ion buildup and (c) ion feedback.

(a) The choice of the gas for a TPC is an important and central parameter. Gases investigated are variations of standard TPC gases, e.g.,
Ar(93%)CH_4(5%)CO_2(2%)–"TDR" gas,
Ar(95%)CH_4(5%)–"P5" gas,
Ar(90%),CH_4(10%)–"P10",
Ar (90%)CO_2(10%),
Ar (95%)Isobutane(5%) and
Ar(97%)CF_4(3%).

When choosing a gas a number of requirements have to be taken into account. The $\sigma_{singlepoint}$ resolution achievable in $r\phi$ is dominated by the transverse diffusion, which should be as small as possible. Simultaneously a sufficient number of primary electrons should be created for the point and dE/dx measurements, and the drift velocity at a drift field of a few $\times$100 V/cm should be about 5 cm/μs or more. The hydrogen component of hydrocarbons, which traditionally are used as quenchers in TPCs, have a high cross section for interaction with low energy background neutrons which will be crossing the TPC at the ILC[1]. Thus the concentration of hydrogen in the quencher should be as low as possible, to minimize the number of background hits due to neutrons. An interesting alternative to the traditional gases is a Ar-CF_4 mixture. These mixtures give drift velocities around $8-9$ cm/μs at drift field of 200 V/m, have no hydrocarbon content and have a reasonably low attachment coefficient at low electric fields. However at intermediate fields (∼5-10 kV/cm), as are present in the amplification region of a GEM or a MicroMegas the attachment increases drastically, thus limiting the use of this gas to systems where the intermediate field regions are of the order of a few microns. This is the case for MicroMegas, but its use has not been tested thoroughly for a GEM-based chamber. Whether CF4 is an appropriate quencher for the LC TPC is not yet known and is being tested as a part of our R&D.

(b) Ion build-up at the surface of the gas-amplification plane and in the drift volume.

LC TPC Chamber gas
(b) Ion buildup



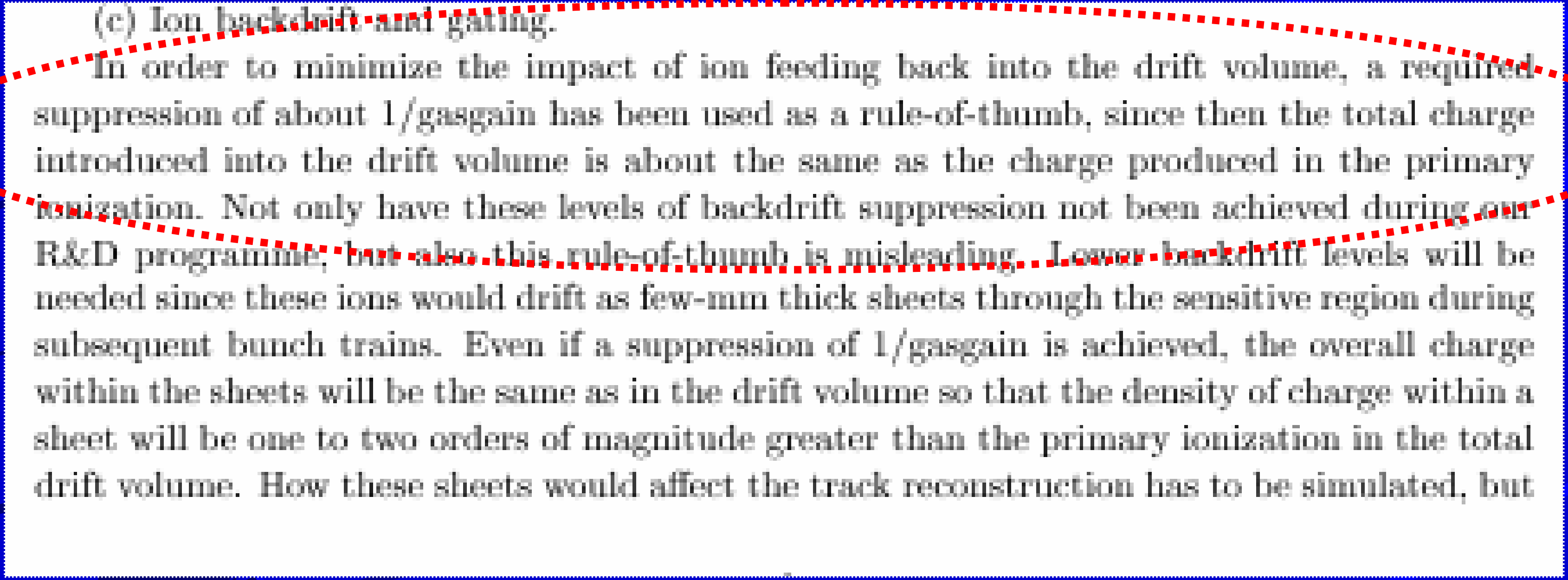
yet known and is being tested as a part of our R&D.

(b) Ion build-up at the surface of the gas-amplification plane and in the drift volume.

–At the surface of the gas-amplification plane vis-a-vis the drift volume, during the bunch train of about 1 ms and 3000 bunch crossings, there will be few-mm thick layer of positive ions built up due to the incoming charge, subsequent gas amplification and ion backdrift. An important property of MPGDs is that they suppress naturally the backdrift of ions produced in the amplification stage. This layer of ions will be reach a density of some fC/cm^3 depending on the background conditions during operation. Intuitively its effect on the coordinate measurement should be small since the drifting electrons incoming to the anode only experience this environment during the last few mm of drift. In any case, the TPC is planning to run with the lowest possible gas gain, meaning a few $\times 10^3$, in order to minimize this effect.

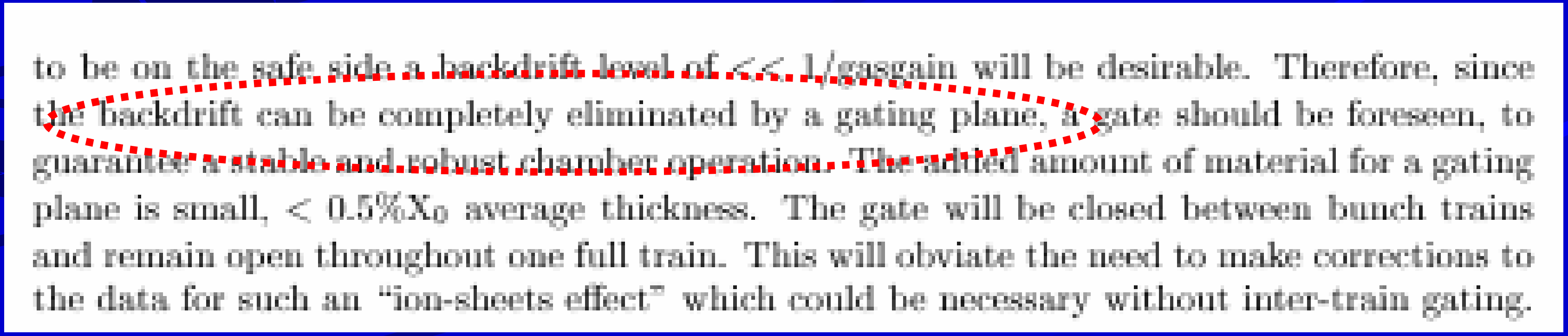
–In the drift volume, a positive ion density due to the primary ionization will be built up during about 1s (the time it takes for an ion to drift the full length of the TPC), will be higher near the cathode and will be of order fC/cm^3 at nominal occupancy ($\sim 0.5\%$). The tolerance on the charge density will be established by our R&D programme, but a few $\times$ fC/cm^3 is orders of magnitude below this limit.

LC TPC Chamber gas
(c) ion backdrift/gating



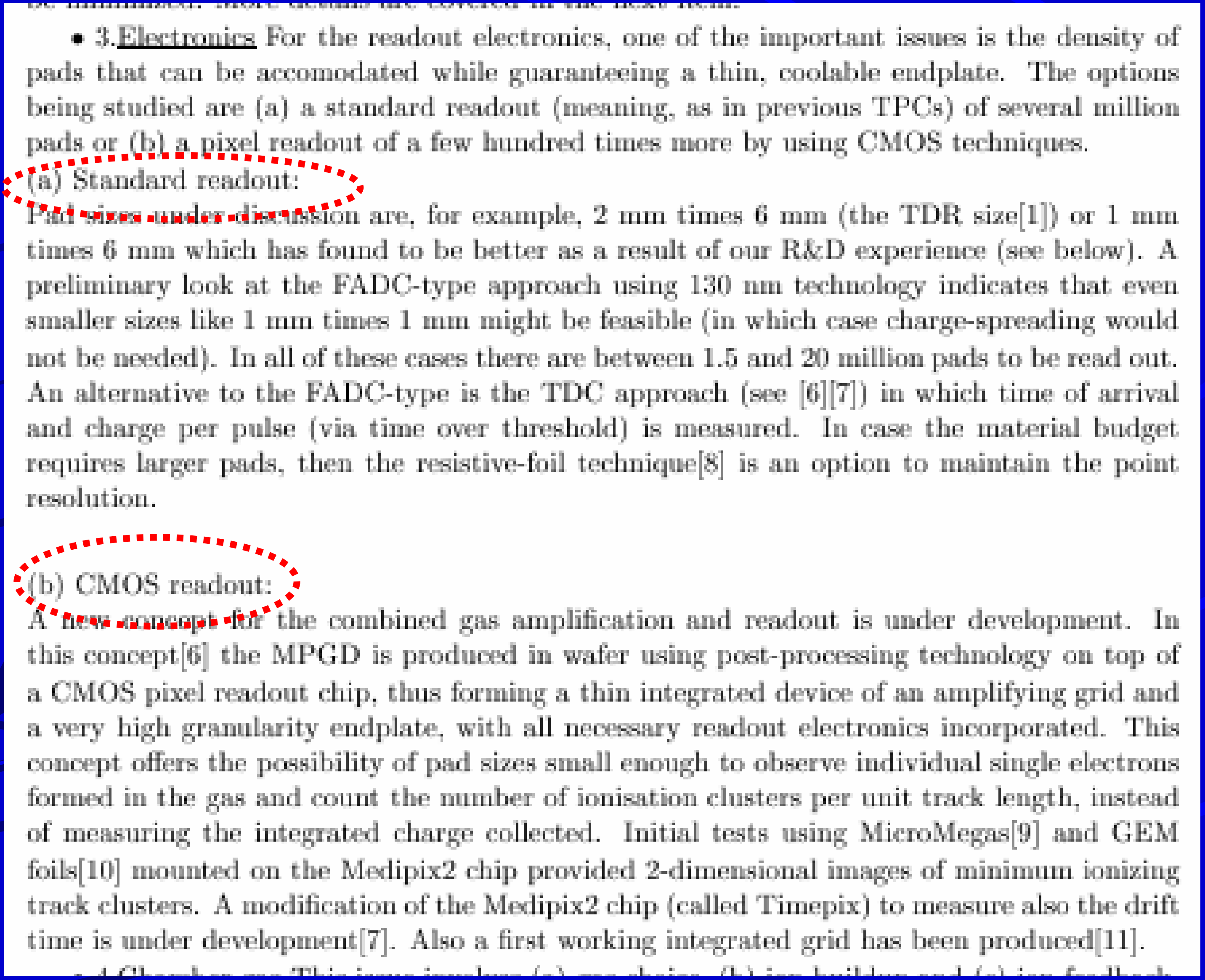
(c) Ion backdrift and gating.

In order to minimize the impact of ion feeding back into the drift volume, a required suppression of about 1/gasgain has been used as a rule-of-thumb, since then the total charge introduced into the drift volume is about the same as the charge produced in the primary ionization. Not only have these levels of backdrift suppression not been achieved during our R&D programme, but also this rule-of-thumb is misleading. Lower backdrift levels will be needed since these ions would drift as few-mm thick sheets through the sensitive region during subsequent bunch trains. Even if a suppression of 1/gasgain is achieved, the overall charge within the sheets will be the same as in the drift volume so that the density of charge within a sheet will be one to two orders of magnitude greater than the primary ionization in the total drift volume. How these sheets would affect the track reconstruction has to be simulated, but



to be on the safe side a backdrift level of $<< 1$/gasgain will be desirable. Therefore, since the backdrift can be completely eliminated by a gating plane, a gate should be foreseen, to guarantee a stable and robust chamber operation. The added amount of material for a gating plane is small, $< 0.5\%X_0$ average thickness. The gate will be closed between bunch trains and remain open throughout one full train. This will obviate the need to make corrections to the data for such an “ion-sheets effect” which could be necessary without inter-train gating.

LC TPC Electronics

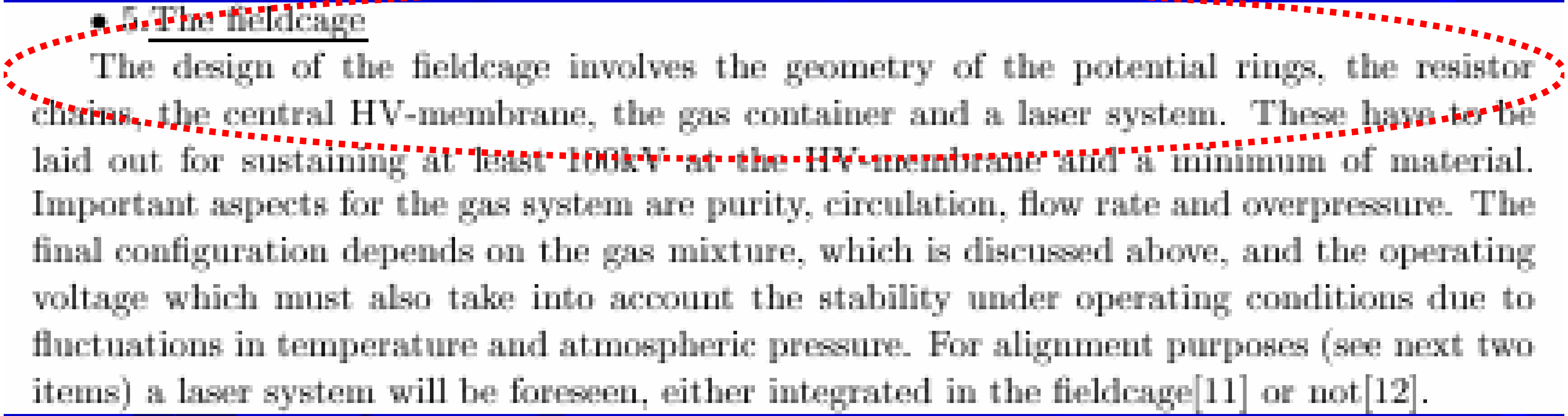


- 3.Electronics For the readout electronics, one of the important issues is the density of pads that can be accomodated while guaranteeing a thin, coolable endplate. The options being studied are (a) a standard readout (meaning, as in previous TPCs) of several million pads or (b) a pixel readout of a few hundred times more by using CMOS techniques.

(a) Standard readout:
Pad sizes under discussion are, for example, 2 mm times 6 mm (the TDR size[1]) or 1 mm times 6 mm which has found to be better as a result of our R&D experience (see below). A preliminary look at the FADC-type approach using 130 nm technology indicates that even smaller sizes like 1 mm times 1 mm might be feasible (in which case charge-spreading would not be needed). In all of these cases there are between 1.5 and 20 million pads to be read out. An alternative to the FADC-type is the TDC approach (see [6][7]) in which time of arrival and charge per pulse (via time over threshold) is measured. In case the material budget requires larger pads, then the resistive-foil technique[8] is an option to maintain the point resolution.

(b) CMOS readout:
A new concept for the combined gas amplification and readout is under development. In this concept[6] the MPGD is produced in wafer using post-processing technology on top of a CMOS pixel readout chip, thus forming a thin integrated device of an amplifying grid and a very high granularity endplate, with all necessary readout electronics incorporated. This concept offers the possibility of pad sizes small enough to observe individual single electrons formed in the gas and count the number of ionisation clusters per unit track length, instead of measuring the integrated charge collected. Initial tests using MicroMegas[9] and GEM foils[10] mounted on the Medipix2 chip provided 2-dimensional images of minimum ionizing track clusters. A modification of the Medipix2 chip (called Timepix) to measure also the drift time is under development[7]. Also a first working integrated grid has been produced[11].

LC TPC Fieldcage



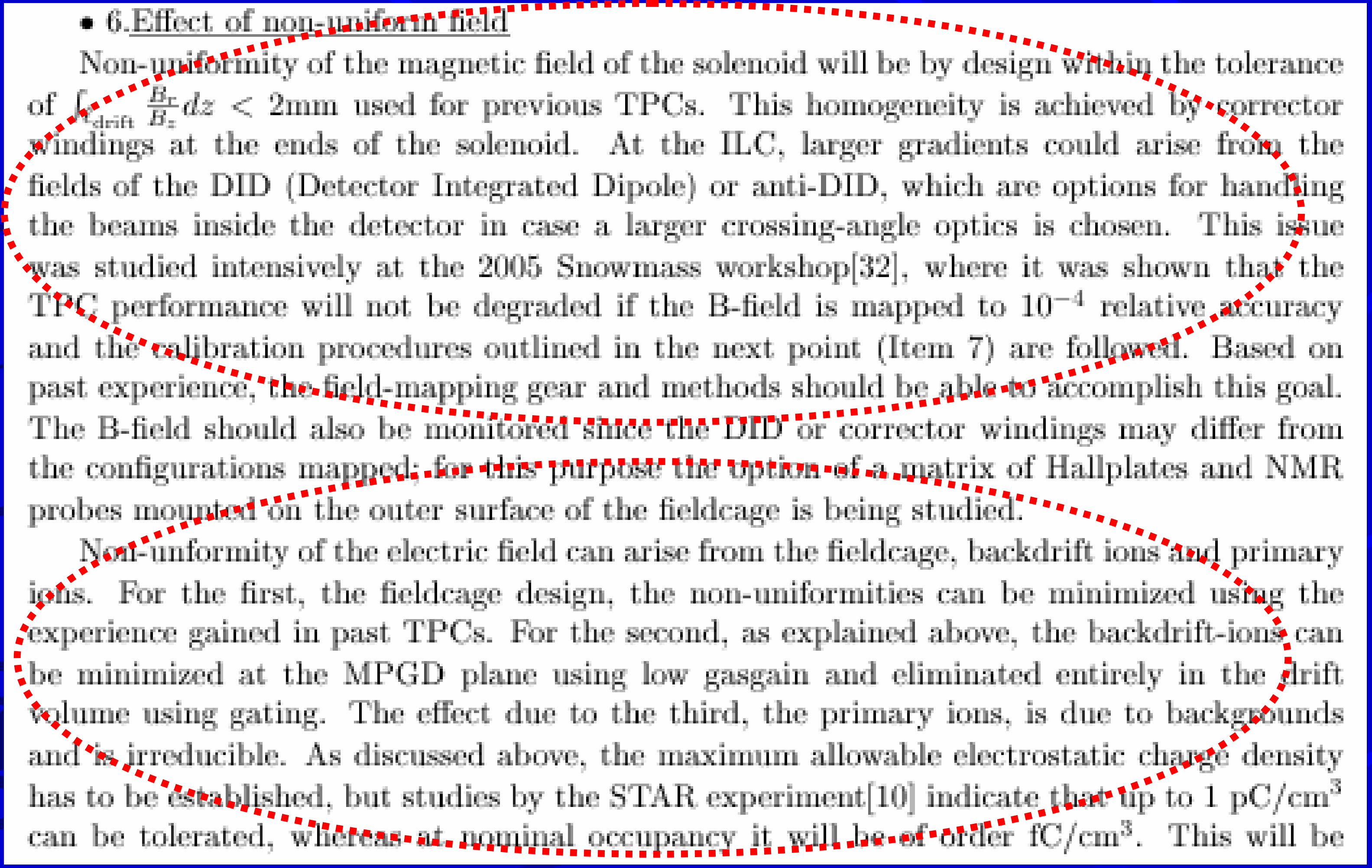
- 5. The fieldcage

The design of the fieldcage involves the geometry of the potential rings, the resistor chains, the central HV-membrane, the gas container and a laser system. These have to be laid out for sustaining at least 100kV at the HV-membrane and a minimum of material. Important aspects for the gas system are purity, circulation, flow rate and overpressure. The final configuration depends on the gas mixture, which is discussed above, and the operating voltage which must also take into account the stability under operating conditions due to fluctuations in temperature and atmospheric pressure. For alignment purposes (see next two items) a laser system will be foreseen, either integrated in the fieldcage[11] or not[12].

Backgrounds/alignment/distortion-correction

- **Revisit expected backgrounds**
- **Maximum positive-ion buildup tolerable**
- **Maximum occupancy tolerable**
- **Effect of positive-ion backdrift: gating plane**
- **Tools for correcting inhomogeneous B-field or space charge effects in bad backgrounds**

LC TPC Non-uniform fields

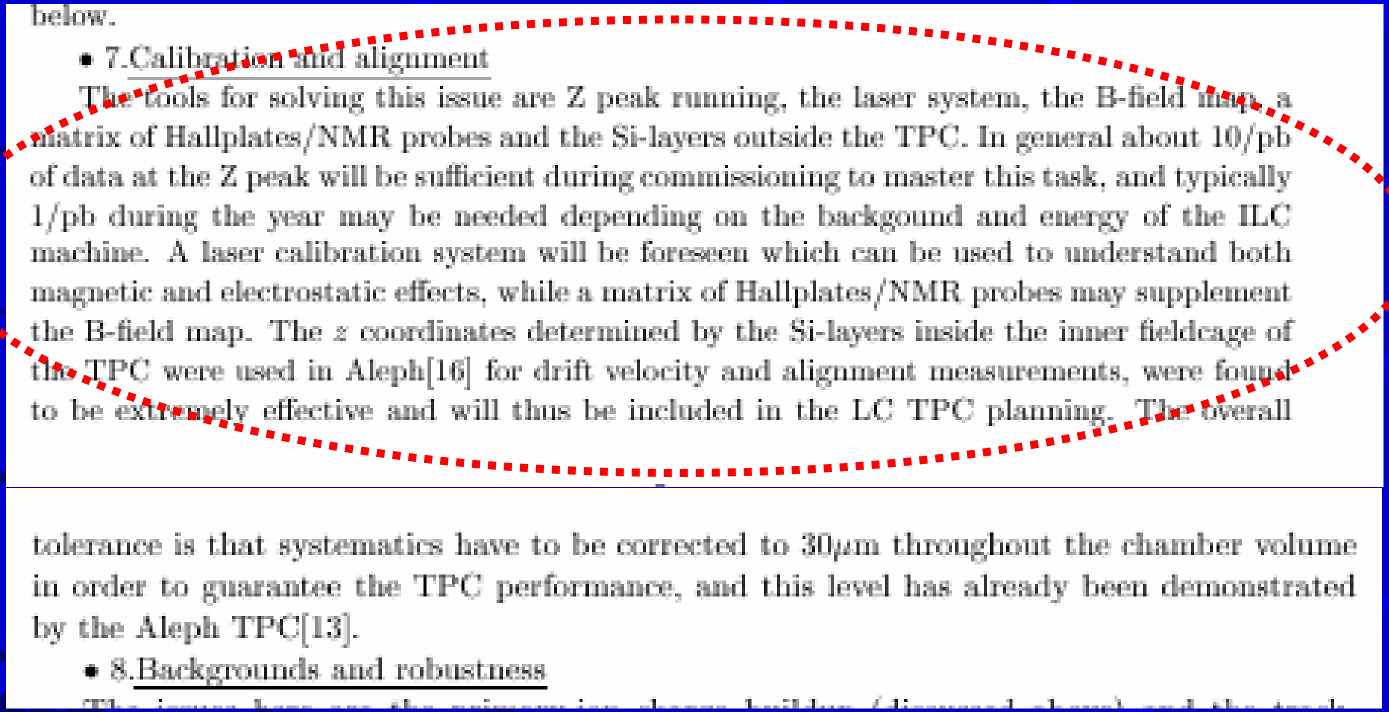


- 6.Effect of non-uniform field

Non-uniformity of the magnetic field of the solenoid will be by design within the tolerance of $\int_{\text{drift}} \frac{B_r}{B_z} dz < 2$mm used for previous TPCs. This homogeneity is achieved by corrector windings at the ends of the solenoid. At the ILC, larger gradients could arise from the fields of the DID (Detector Integrated Dipole) or anti-DID, which are options for handling the beams inside the detector in case a larger crossing-angle optics is chosen. This issue was studied intensively at the 2005 Snowmass workshop[32], where it was shown that the TPC performance will not be degraded if the B-field is mapped to 10^{-4} relative accuracy and the calibration procedures outlined in the next point (Item 7) are followed. Based on past experience, the field-mapping gear and methods should be able to accomplish this goal. The B-field should also be monitored since the DID or corrector windings may differ from the configurations mapped; for this purpose the option of a matrix of Hallplates and NMR probes mounted on the outer surface of the fieldcage is being studied.

Non-unformity of the electric field can arise from the fieldcage, backdrift ions and primary ions. For the first, the fieldcage design, the non-uniformities can be minimized using the experience gained in past TPCs. For the second, as explained above, the backdrift-ions can be minimized at the MPGD plane using low gasgain and eliminated entirely in the drift volume using gating. The effect due to the third, the primary ions, is due to backgrounds and is irreducible. As discussed above, the maximum allowable electrostatic charge density has to be established, but studies by the STAR experiment[10] indicate that up to 1 pC/cm^3 can be tolerated, whereas at nominal occupancy it will be of order fC/cm^3. This will be

LC TPC Calibration/alignment



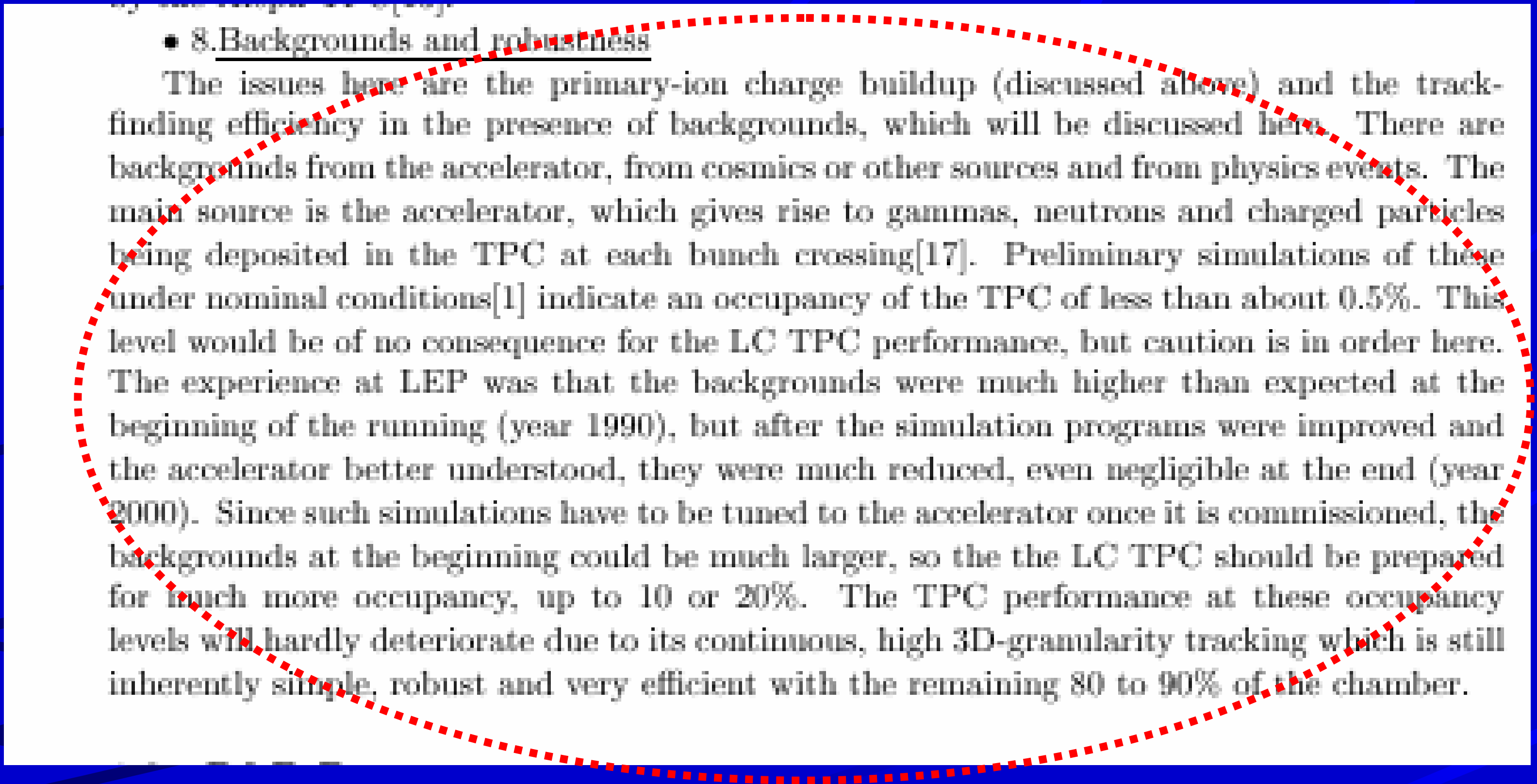
below.

- 7.Calibration and alignment

The tools for solving this issue are Z peak running, the laser system, the B-field map, a matrix of Hallplates/NMR probes and the Si-layers outside the TPC. In general about 10/pb of data at the Z peak will be sufficient during commissioning to master this task, and typically 1/pb during the year may be needed depending on the backgound and energy of the ILC machine. A laser calibration system will be foreseen which can be used to understand both magnetic and electrostatic effects, while a matrix of Hallplates/NMR probes may supplement the B-field map. The z coordinates determined by the Si-layers inside the inner fieldcage of the TPC were used in Aleph[16] for drift velocity and alignment measurements, were found to be extremely effective and will thus be included in the LC TPC planning. The overall tolerance is that systematics have to be corrected to 30μm throughout the chamber volume in order to guarantee the TPC performance, and this level has already been demonstrated by the Aleph TPC[13].

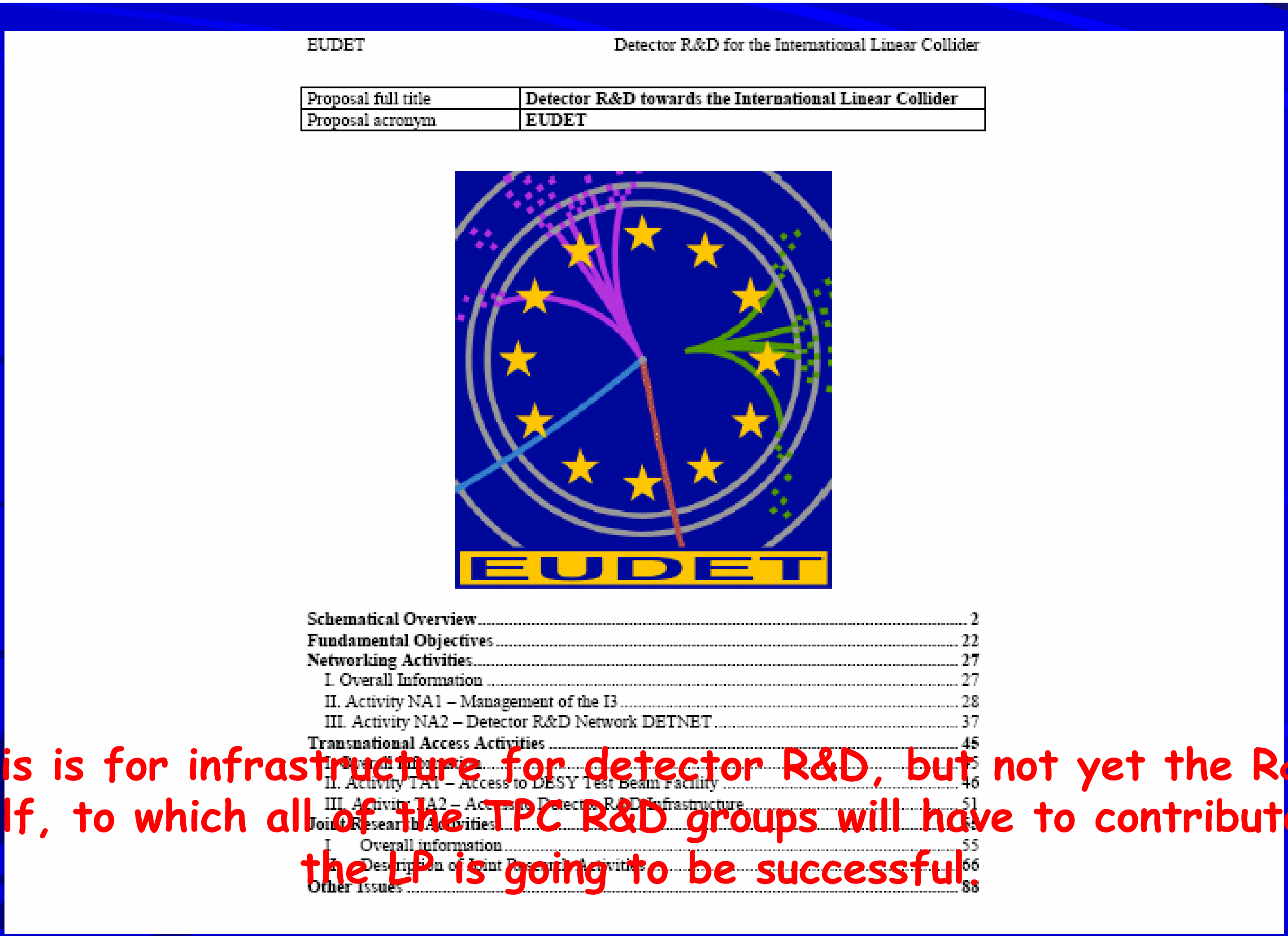
- 8.Backgrounds and robustness

LC TPC Backgrounds



- 8.Backgrounds and robustness

The issues here are the primary-ion charge buildup (discussed above) and the track-finding efficiency in the presence of backgrounds, which will be discussed here. There are backgrounds from the accelerator, from cosmics or other sources and from physics events. The main source is the accelerator, which gives rise to gammas, neutrons and charged particles being deposited in the TPC at each bunch crossing[17]. Preliminary simulations of these under nominal conditions[1] indicate an occupancy of the TPC of less than about 0.5%. This level would be of no consequence for the LC TPC performance, but caution is in order here. The experience at LEP was that the backgrounds were much higher than expected at the beginning of the running (year 1990), but after the simulation programs were improved and the accelerator better understood, they were much reduced, even negligible at the end (year 2000). Since such simulations have to be tuned to the accelerator once it is commissioned, the backgrounds at the beginning could be much larger, so the the LC TPC should be prepared for much more occupancy, up to 10 or 20%. The TPC performance at these occupancy levels will hardly deteriorate due to its continuous, high 3D-granularity tracking which is still inherently simple, robust and very efficient with the remaining 80 to 90% of the chamber.



EUDET Detector R&D for the International Linear Collider

Proposal full title	**Detector R&D towards the International Linear Collider**
Proposal acronym	**EUDET**

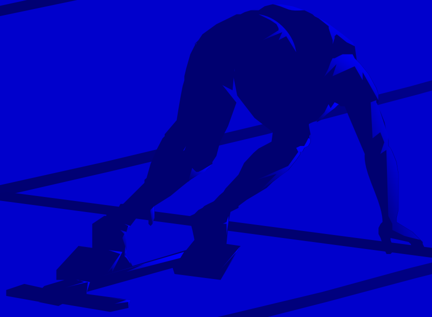
This is for infrastructure for detector R&D, but not yet the R&D itself, to which all of the TPC R&D groups will have to contribute if the LP is going to be successful.

This will provide a basis for the LC TPC groups to help get funding for the LP and other LC TPC work.

Work Packages for the LCTPC/LP

0) Workpackage: TPC R&D program/performance goals

To be worked out by the LCTPC collaboration



Work Packages for the LCTPC/LP

convener in
white color

1) Workpackage MECHANICS

Ron Settles

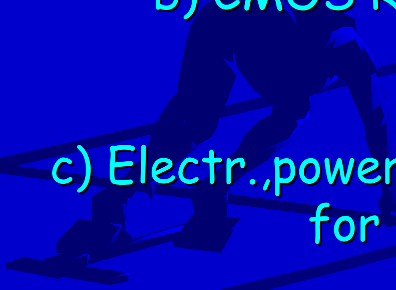
Work package	Convener	Groups expressing interest to date(others?)
a) LP design (incl. endplate structure)	Dan Peterson	Cornell, Desy, IPNOrsay, MPI, +contribution from Eudet
b) Fieldcage, laser, gas	Ties Behnke	Aachen, Desy, St.Petersburg, +contribution from Eudet
c) GEM panels for endplate	Akira Sugiyama	Aachen, Carleton, Cornell, Desy/HH, Karlsruhe, Kek/XCDC, Novosibirsk, Victoria
d) Micromegas panels for endplate	Paul Colas	Carleton, Cornell, Kek/XCDC, Saclay/Orsay
e) Pixel panels for endplate	Jan Timmermans	Cern,Freiburg,Nikhef,Saclay,Kek/XCDC, +contribution from Eudet
f) Resistive foil for endplate	Madhu Dixit	Carleton, Kek/XCDC, Saclay/Orsay

Work Packages for the LCTPC/LP

2) Workpackage ELECTRONICS

Leif Joennson

Groups expressing interest to date(others?)



a)"Standard" RO/DAQ for LP:
Leif Joennson + ?

Aachen, Desy/HH, Cern, Lund,
Rostock, Montreal, Tsinghua,
+contribution from Eudet

b) CMOS RO electronics:
Harry van der Graaf

Freiburg, Cern, Nikhef, Saclay,
+contribution from Eudet

c) Electr.,powerswitching,cooling
for LC TPC:

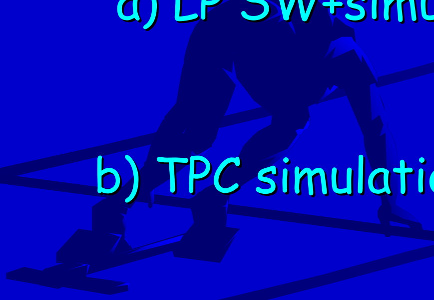
Luciano Musa

Aachen, Desy/HH, Cern, Lund,
Rostock, Montreal, St.Petersburg, Tsinghua,
+contribution from Eudet

Work Packages for the LCTPC/LP

3) Workpackage SOFTWARE

Peter Wienemann



	Groups expressing interest to date(others?)
a) LP SW+simul./reconstr.framework: Peter Wienemann	Desy/HH,Cern,Freiburg, Carleton, Victoria, +contribution from Eudet
b) TPC simulation, backgrounds Stefan Roth	Aachen, Carleton, Cornell, Desy/HH, Kek/XCDC, St.Petersburg,Victoria
c) Full detector simulation Keisuke Fujii	Desy/HH, Kek/XCDC, LBNL

Work Packages for the LCTPC/LP

4) Workpackage CALIBRATION

Dean Karlen

	Groups expressing interest to date(others?)
a) Fieldmap Lucie Linssen	Cern, +contribution from Eudet
b) Alignment Takeshi Matsuda	Kek/XCDC
c) Distortion correction Dean Karlen	Victoria
d) Rad.hardness of material Anatoliy Krivchitch	St.Petersburg
e) Gas/HV/Infrastructure Desy Postdoc	Desy, Victoria, +contribution from Eudet

Here are some ideas for the evolution up to the Design Phase 3 (under discussion with the collab.)

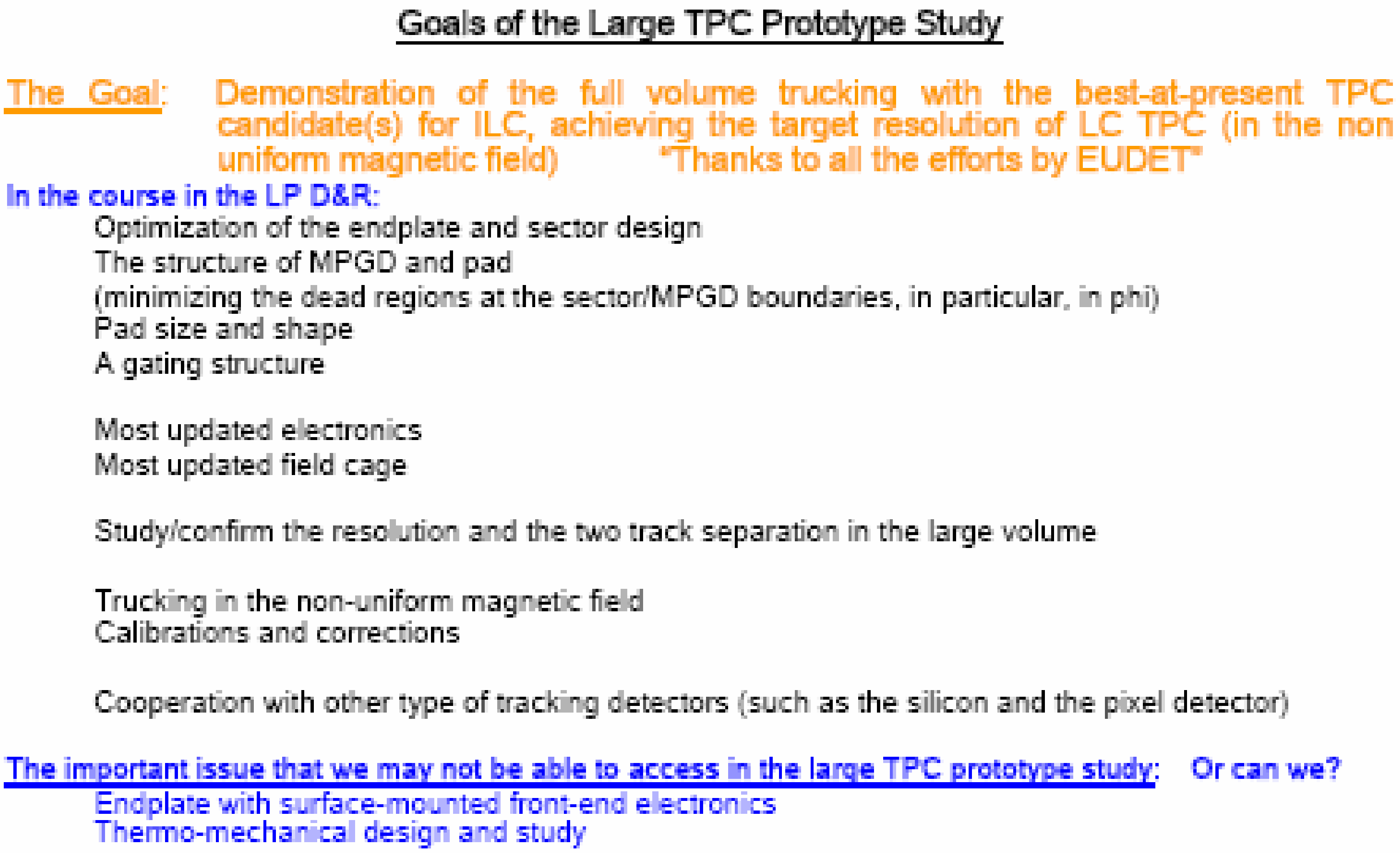
- 2006-09: SP (small prototype) tests,
  LP1 = two endplates: Gem+pixel,
  Microm.+pixel
  adiabatic developm. LP1->LP1.5->LP2
- 2010: LP2 = real LCTPC prototype endplate:
  Gem or µMegas + carbon-fibre
  sandwich,
  gating grid,
  sector/panel shape,
  LCTPC electronics,
  gas,
  etc

TPC R&D breakdown (prel.)

• Gem, Micromegas, Pixel	LP1@Desy
• Large, small, odd-shaped panels	LP1@Desy
• Endplate alignment and stability	LP1,LP2@Desy
• Fieldcage	LP1@Desy
• Sandwich structure	SP/LP2
• Gating/max. space charge ion feedback rate	SP/LP2
• Point/2-track resolution	LP1@Desy
• Momentum meas. in inhomog. B-field	LP1@Desy
• dE/dx measurement	LP1@Desy
• Gas studies	SP
• Pad shapes	Simulation→LP1,LP2
• Jet environment	SP@Cern/FermiLab
• Beams	
• 1-6 GeV/c electrons	LP1@Desy
• 1-20 GeV/c hadrons (+dE/dx)	LP2@Cern/FermiL
• 100 GeV hadrons (+jets)	LP2@Cern/FermiL

Some of the topics discussed at WP bi-weekly phonemeetings…

Takeshi Matsuda et al R&D “goals” discussion…



Goals of the Large TPC Prototype Study

The Goal: Demonstration of the full volume trucking with the best-at-present TPC candidate(s) for ILC, achieving the target resolution of LC TPC (in the non uniform magnetic field) "Thanks to all the efforts by EUDET"

In the course in the LP D&R:

Optimization of the endplate and sector design
The structure of MPGD and pad
(minimizing the dead regions at the sector/MPGD boundaries, in particular, in phi)
Pad size and shape
A gating structure

Most updated electronics
Most updated field cage

Study/confirm the resolution and the two track separation in the large volume

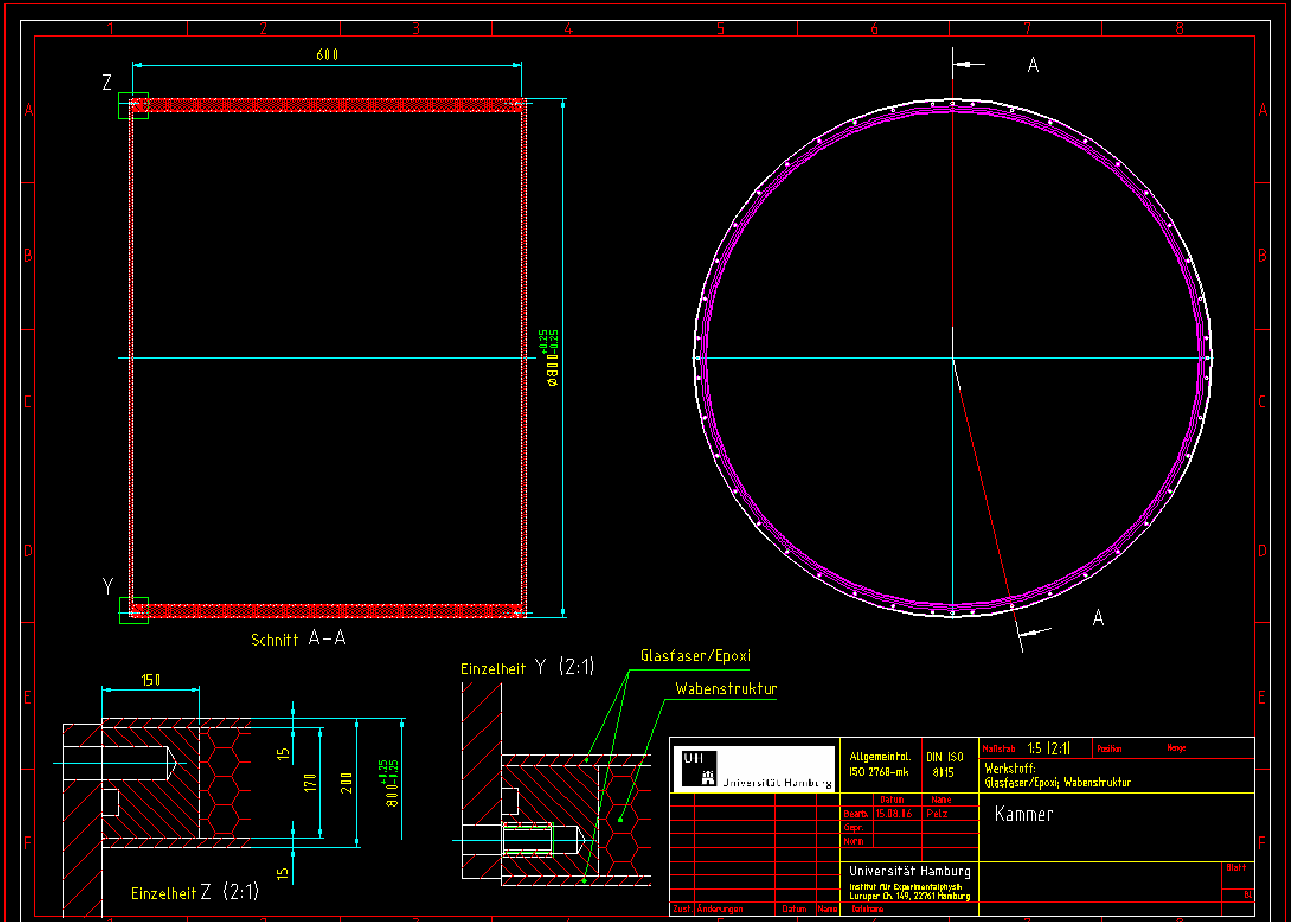
Trucking in the non-uniform magnetic field
Calibrations and corrections

Cooperation with other type of tracking detectors (such as the silicon and the pixel detector)

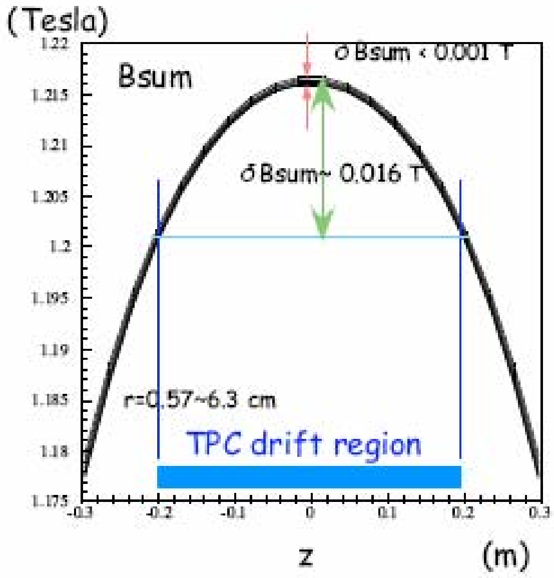
The important issue that we may not be able to access in the large TPC prototype study: Or can we?
Endplate with surface-mounted front-end electronics
Thermo-mechanical design and study

AGENDA

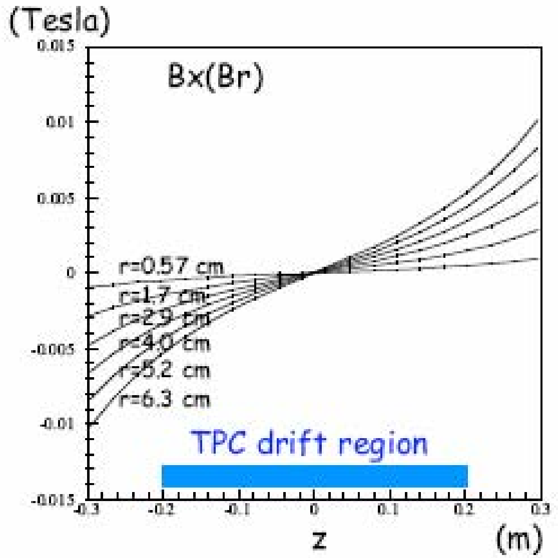
-Fieldcage for the LP (Ties Behnke, Peter Schade)



Magnetic field around TPC region



d|B| ~ 0.016 T (1.3 %)
if ceter is aligned



Max. |Br| < 0.005 T (0.4 %)
for TPC drift region
(40 cm)

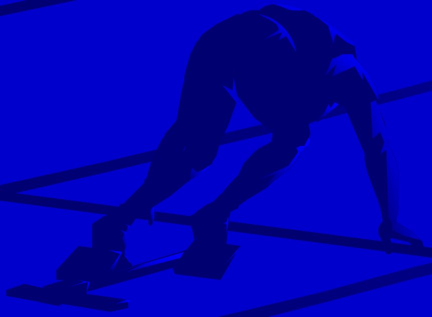
B = 1.216 T at r=0, z=0
dB ~ 1.3% z=20cm r=0~6cm

FC length ~ 60-80 cm

Madhu Dixit proposes for the LCTPC electronics:

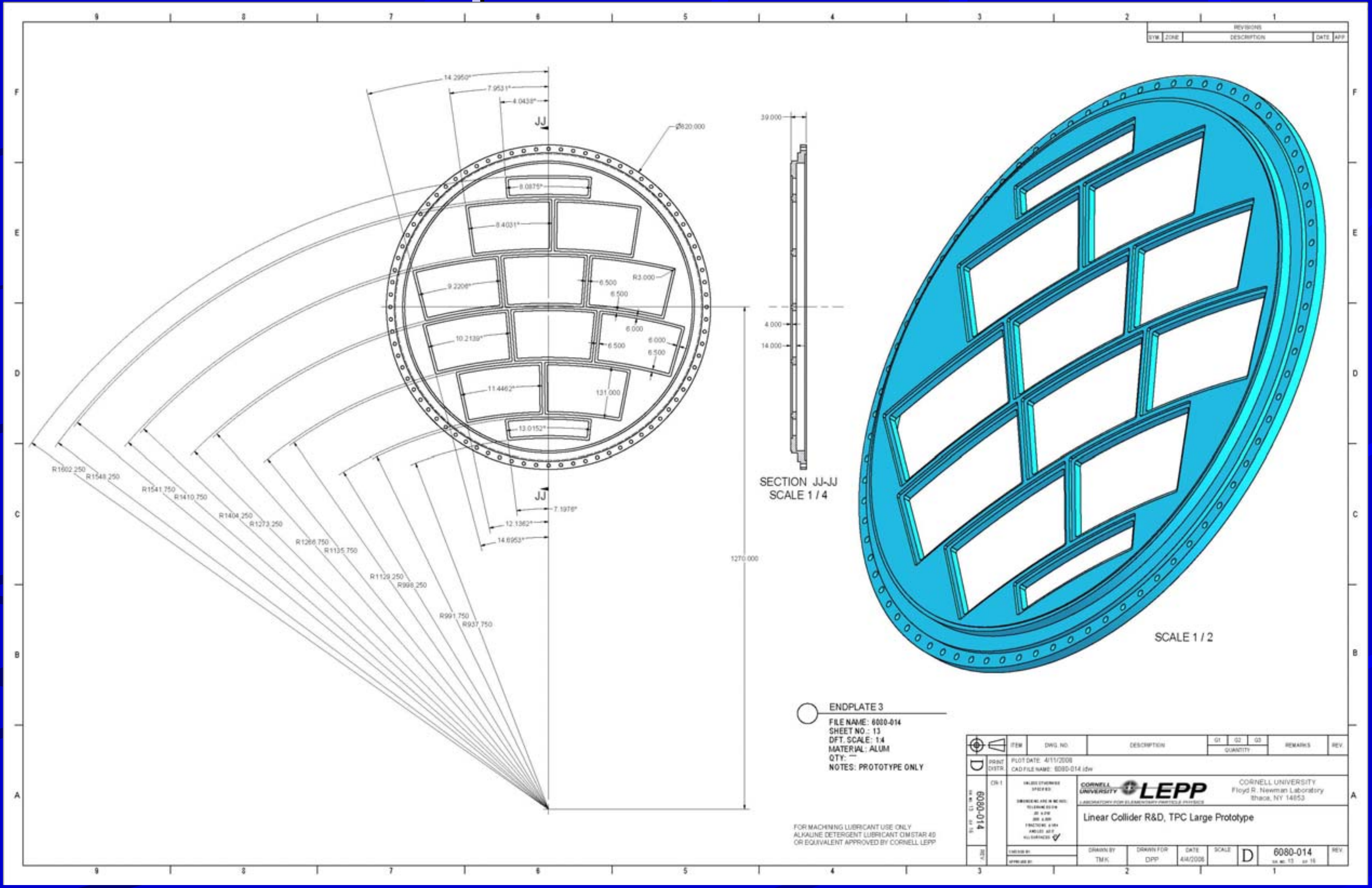
-preamp 25ns Trise (10%-90%)
-no shaper-integrator
-25MHz 10to12-bit FADC

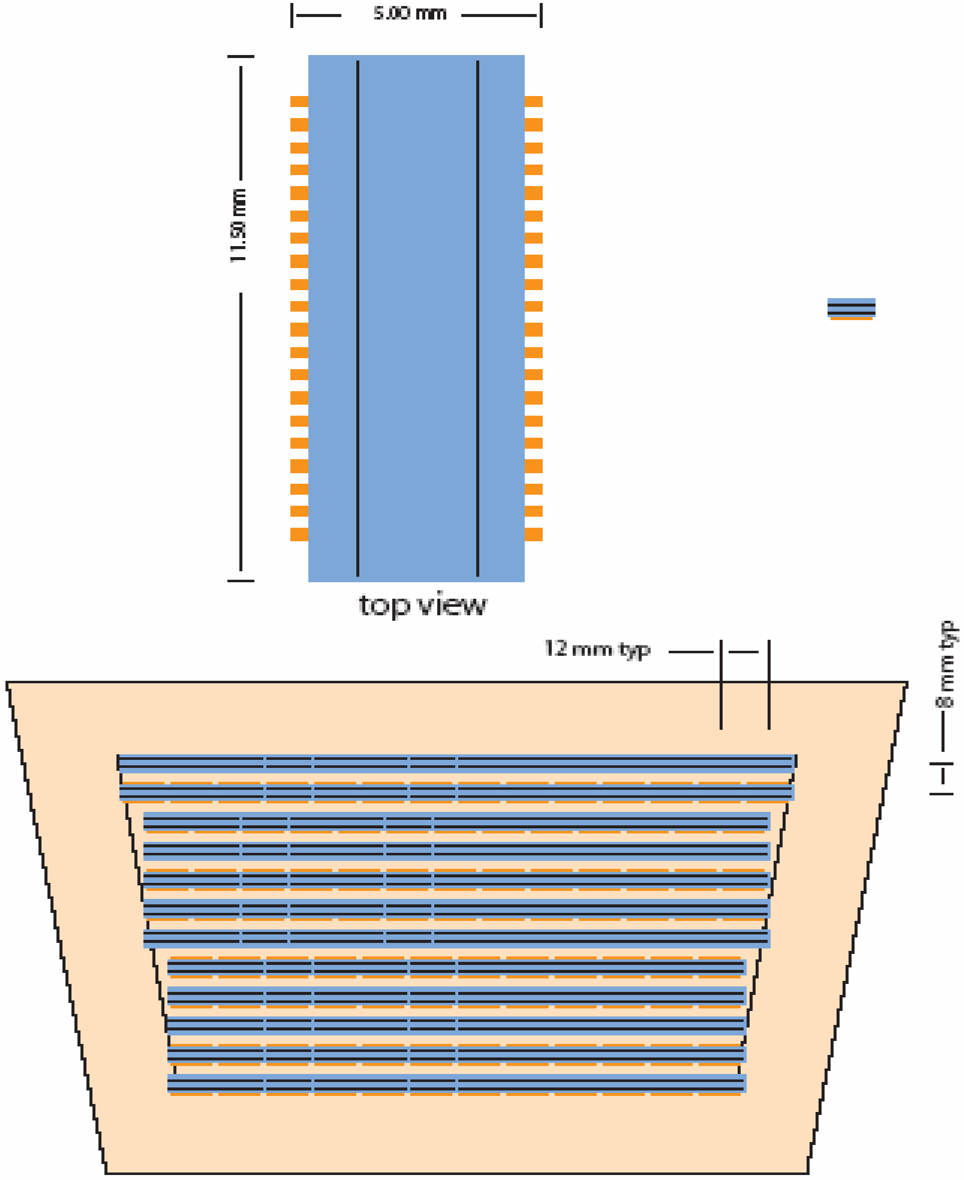
(2-track resolution can benefit from the somewhat faster Trise if the noise is still acceptable)



Dan Peterson

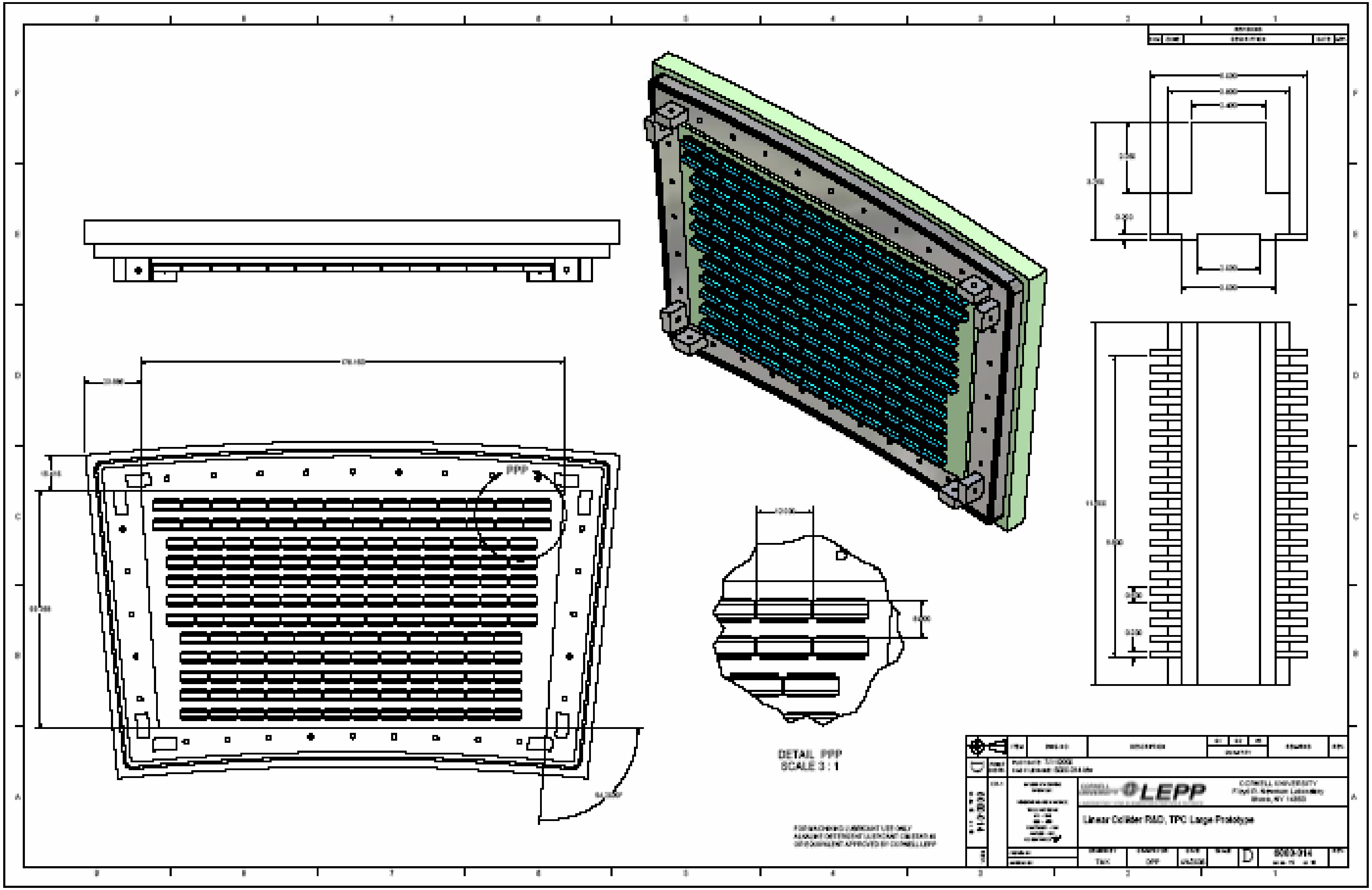
Endplate





basic panel
outer size: 225 x 135 mm
inner size: 170 x 92.5 mm
27000 mm^2

connectors: spaced 12mm x 8 mm
153 connectors, 32 channels each
4896 channels
5.51 mm^2 per channel


PPP
DETAIL PPP
SCALE 3 : 1
LEPP
CORNELL UNIVERSITY
Linear Collider R&D, TPC Large Prototype
D

TPC milestones

2006-2010	Continue LCTPC R&D via small-prototypes and LP tests
2010	Decide on all parameters
2011	Final design of the LCTPC
2015	Four years construction
2016	Commission/Install TPC in the LC Detector

No conclusions…

Backup slides…

AGENDA

-Another topic on the goals for LCTPC/LP.

For your info: we (Fabio Sauli, Madhu Dixit, Martin Killenberg, Akira Sugiyama, RS, a.o.) have started on thinking about ways to test Gem gating with (a) small prototype(s). Martin thinks we might have a scheme that works, but it has to be tried out. If you are interested or have suggestions, let us know…

AGENDA

-Gem endplate (a.o.) for the LP

Akira (WP convener for the LP Gem endplate) sent a mail asking which groups want to participate in the work of making/testing the Gem endplate(s) for the LP. The division of work among groups will be a part of the general organization of the LCTPC/LP collaboration which has to be done within the next few weeks. For the Gem-endplate question, more from Akira…

AGENDA

-LP endplate discussions

Reminder: most urgent point for LP is to design layout of endplate and finalize ~12/2006

-One picture from the note Leif described at the last meeting,
http://mppmu.mpg.de/~settles/tpc/lp/wpmtg/lpconnectorarr.pdf

-one foil from Madhu's proposal for the LCTPC electronics,
-one drawing from Paul and
-three pictures of Dan's iteration of the last meeting
http://w4.lns.cornell.edu/~dpp/linear_collider/LargePrototype.html

follow in the next six foils…

ack of the pad-plane would be WR-40P-HF-HD.

Leif Jonsson, Luciano Musa

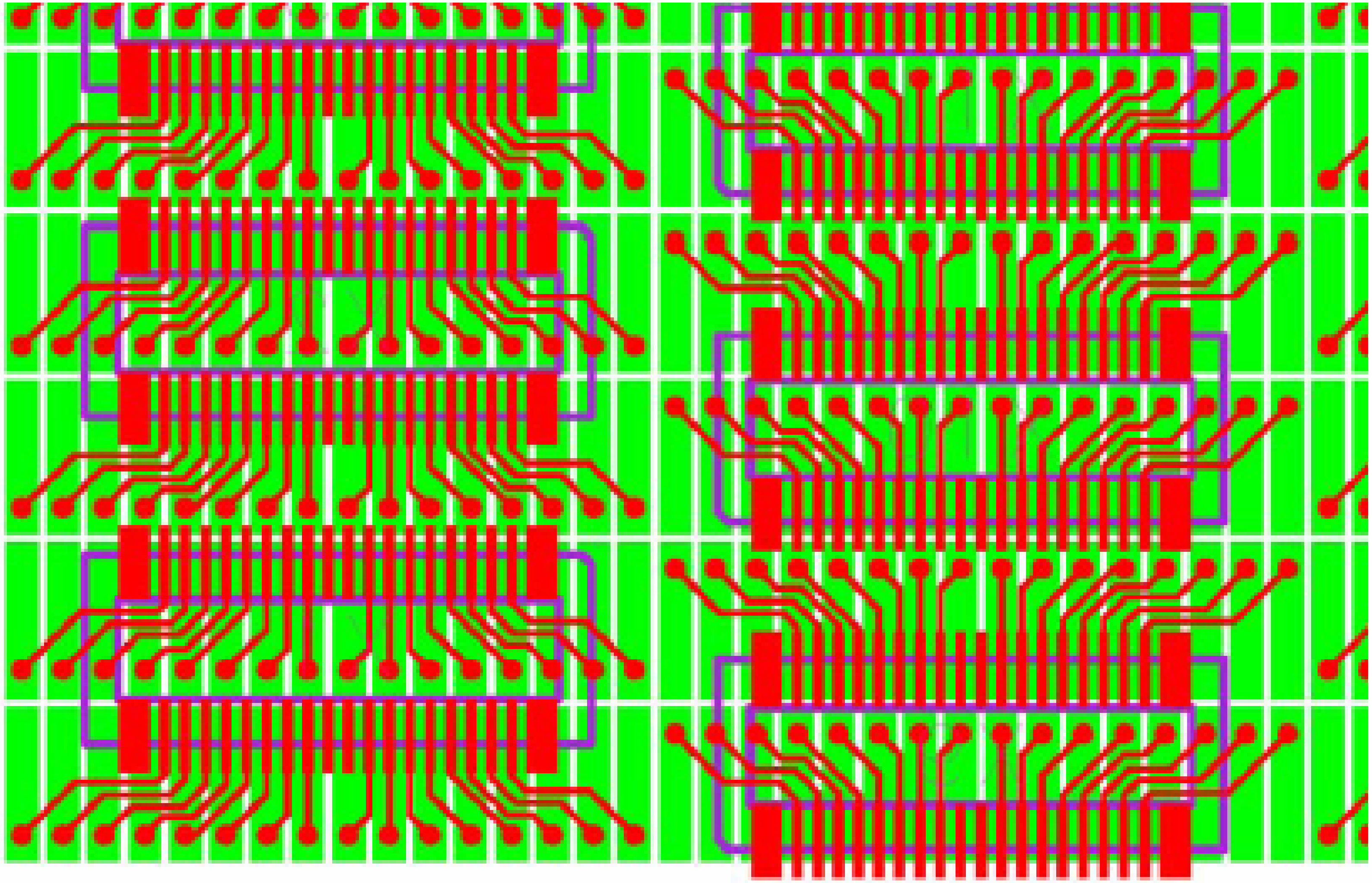
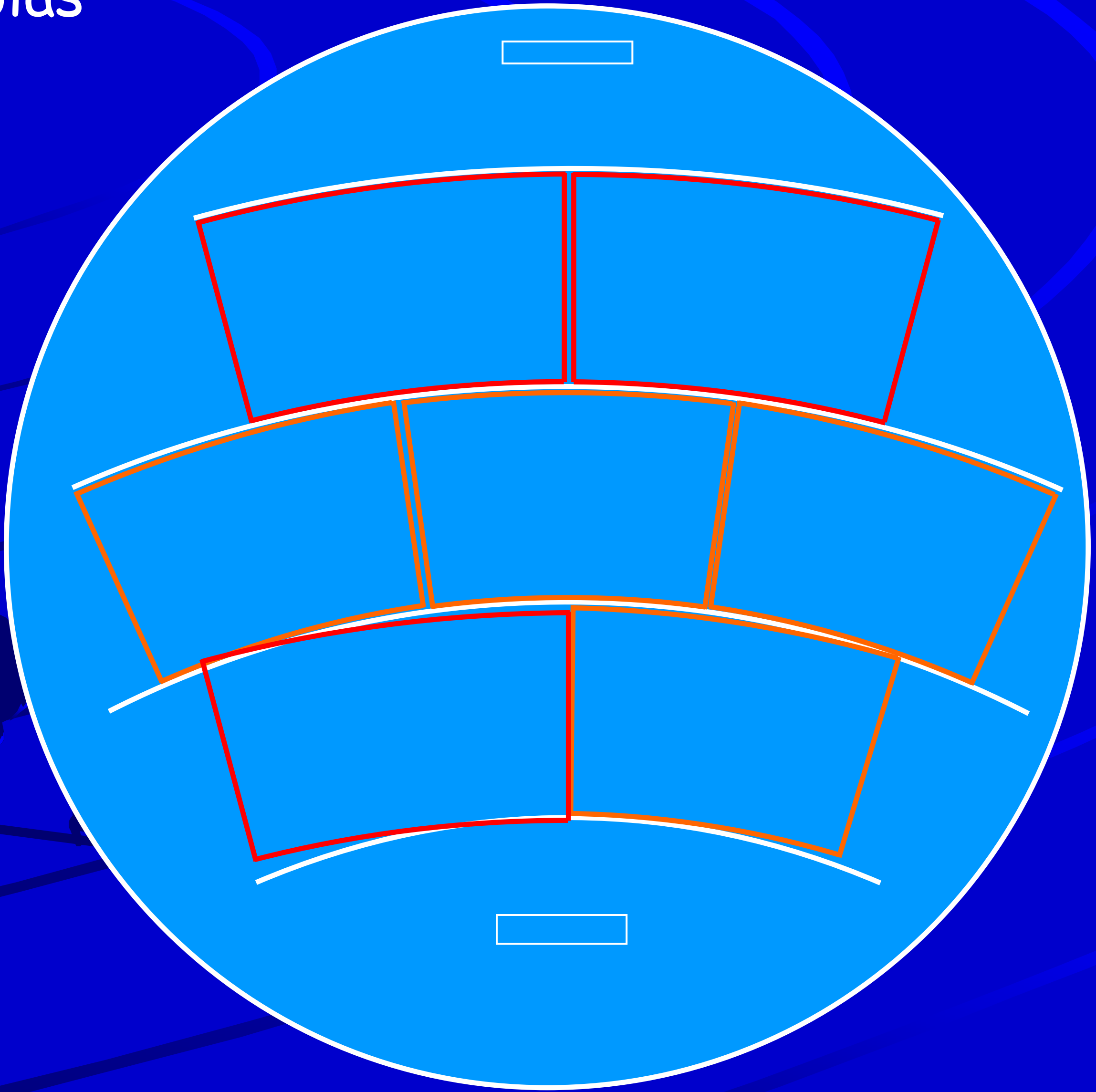


Figure 1) Example of signal routing from 1x4 mm^2 pad to WR-40S (ground routing not shown)

Paul Colas



LC-TPC Motivation/Goals

…to be tested@the LP where possible…

- continuous 3-D tracking, easy pattern recognition throughout large volume, well suited for large magnetic field
- ~98-99% tracking efficiency in presence of backgrounds
- time stamping to 2 ns together with inner silicon layer
- minimum of X_0 inside Ecal (<3% barrel, <30% endcaps)
- σ_{pt} ~ 100µm (rφ) and ~ 500µm (rz) @ 3or4T for right gas if diffusion limited
- 2-track resolution <2mm (rφ) and <5-10mm (rz)
- dE/dx resolution <5% -> e/pi separation, for example
- easily maintainable if designed properly, in case of beam accidents, for example
- design for full precision/efficiency at 30 x estimated backgrounds

Two other LC-TPC features

→will be compensated by good design…

- ~ 50 μs drift time integrates over 150 BX

  → design for very large granularity: ~ 2 – 20 x 10^9 voxels

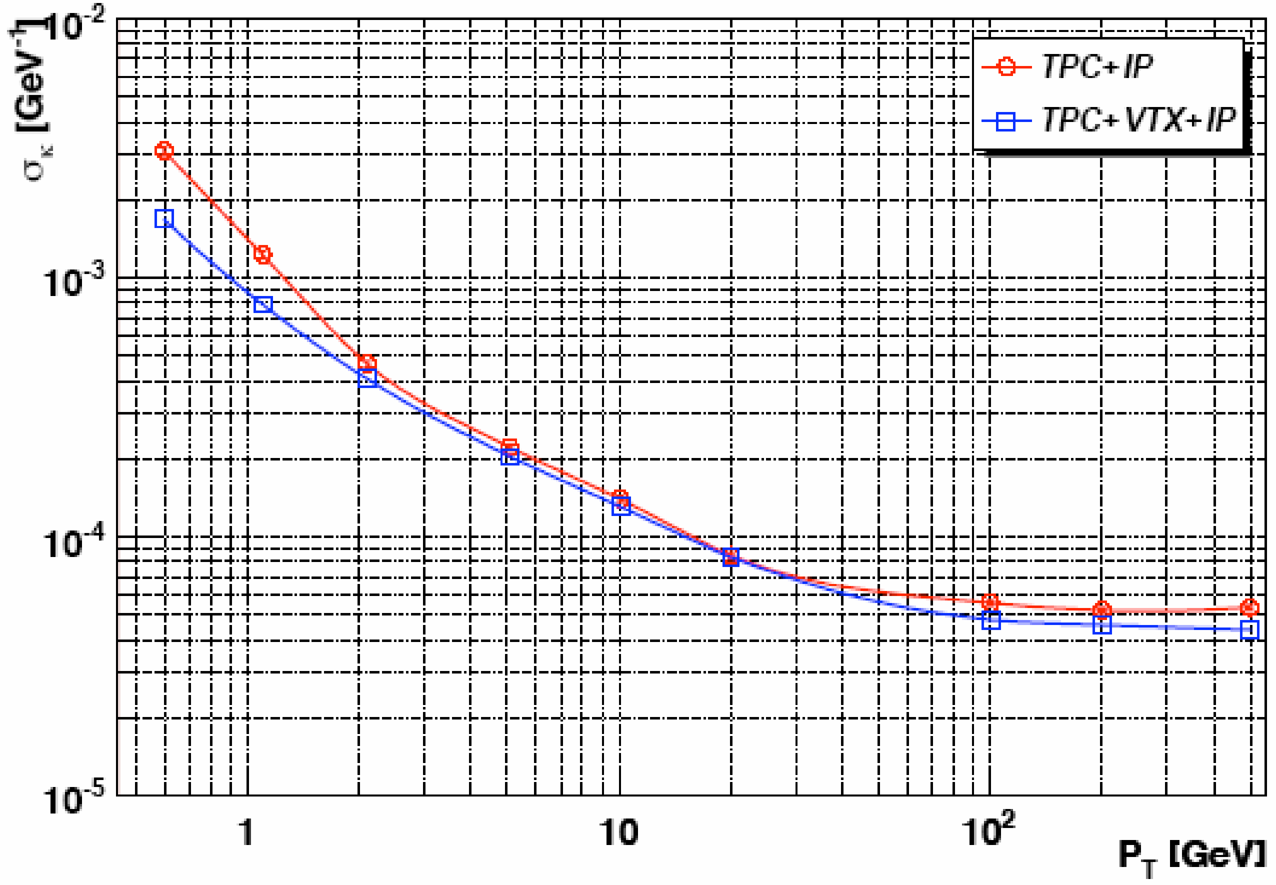
  (two orders of magnitude more if CMOS pixel version)

- ~ end caps with large density of electronics (several million pads) are a fair amount of material

  → design for smallest amount: ~ 30%X_0 or less is feasible

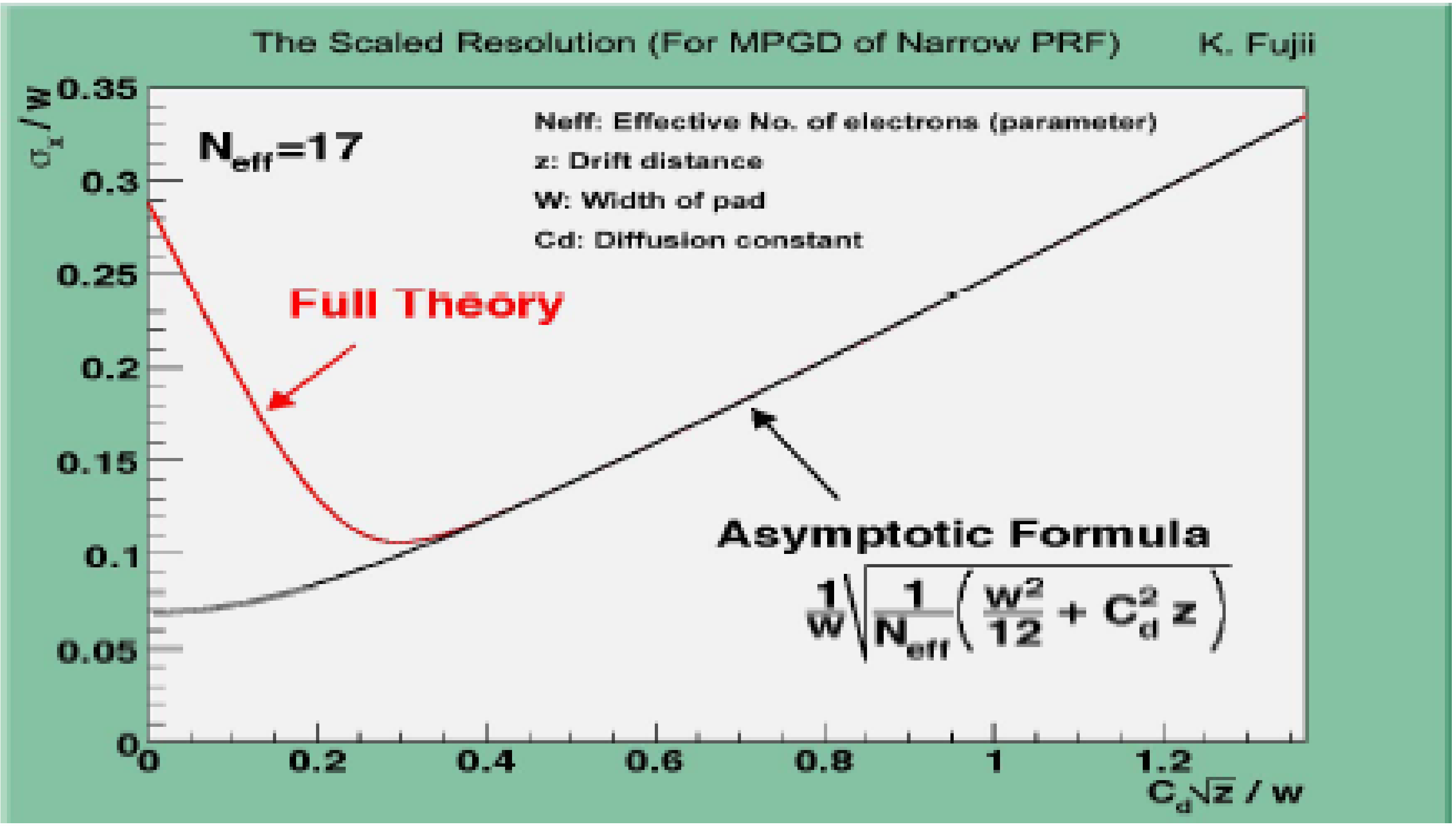
- design for full precision/efficiency at 30 x estimated backgrounds

Momentum resolution vs P_t with IP constraint (not using IT)



Goals of the Large TPC Prototype Study

Keisuke Fujii, Takeshi Matsuda, WP mtg#2



In the case of the MPGD of wide PRF or the resistive anode, the contribution of the w-dependent term drastically decreases: the diffusion limit.