R&D issues for the LC-TPC design and their feedback to the Large Prototype

OUTLINE of TALK

- Overview
- Motivation, LC-TPC R&D Status
- Next step: Build the Large Prototype (LP)
- The LC TPC design issues
- LC-TPC/LP Work Packages

TPC R&D Groups

Europe

RWTH Aachen
CERN
DESY
U Hamburg
U Freiburg
U Karlsruhe
UMM Krakow
Lund
MPI-Munich
NIKHEF
BINP Novosibirsk
LAL Orsay
IPN Orsay
U Rostock
CEA Saclay
PNPI StPetersburg
U Siegen

America

Carleton U
Cornell/Purdue
Indiana U
LBNL
MIT
U Montreal
U Victoria
Yale

Asia

Tsinghua U
XCDC:
Hiroshima U
Minadamo SU-IIT
Kinki U
U Osaka
Saga U
Tokyo UAT
U Tokyo
Kogakuin U Tokyo
KEK Tsukuba
U Tsukuba

Other

MIT (LCRD)
Temple/Wayne State (UCLC)

…Other groups interested?

NB: Started as subset of these groups working together reporting to the DESY PRC; it has recently been expanding so that the organization has to be updated…

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
Dan Peterson (Cornell U., USA)
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

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 $\delta(1/p_t) \sim 6\times10^{-5}\ \mathrm{GeV}/c^{-1}$
- **Particle Flow** $\delta E/E \sim .30/\sqrt{E}$

Energy flow

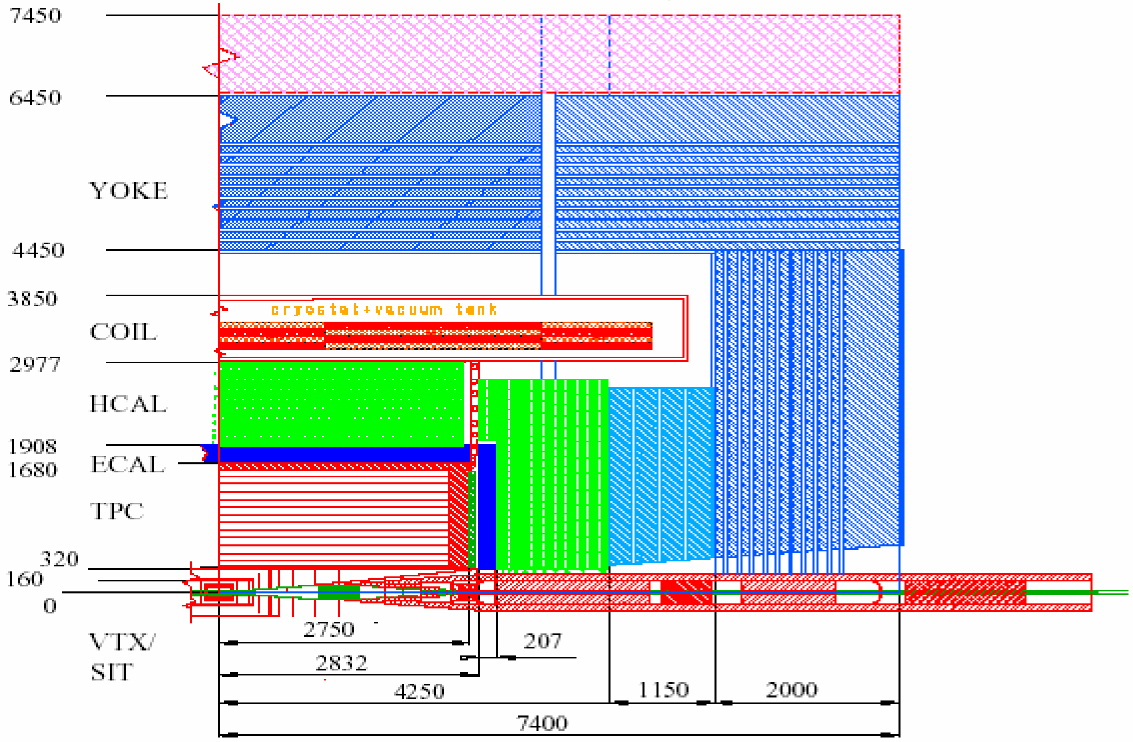
– granularity

– hermeticity

– min. material inside calos

– calos inside 4 T coil

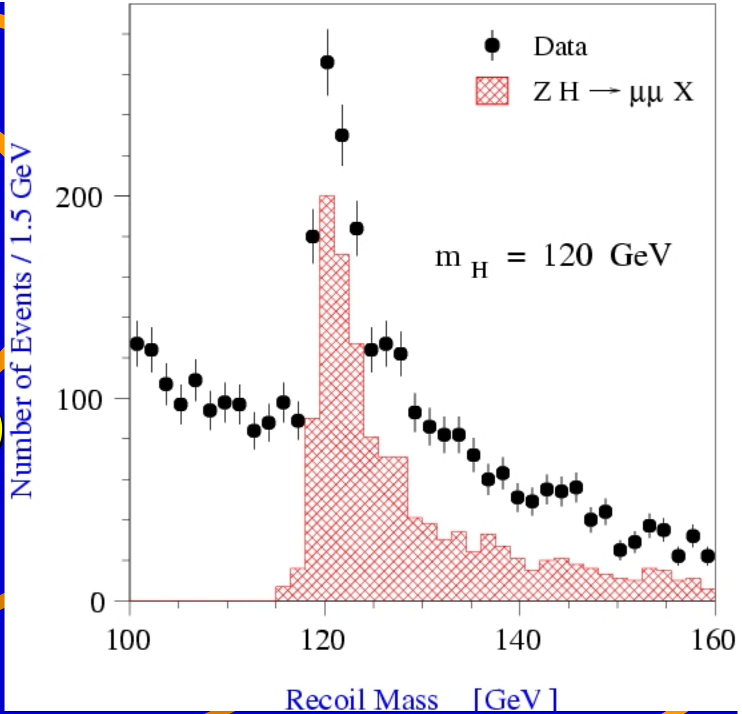
(N.B. below are TDR dimensions, which have changed for latest LDC iteration)



Physics determines detector design

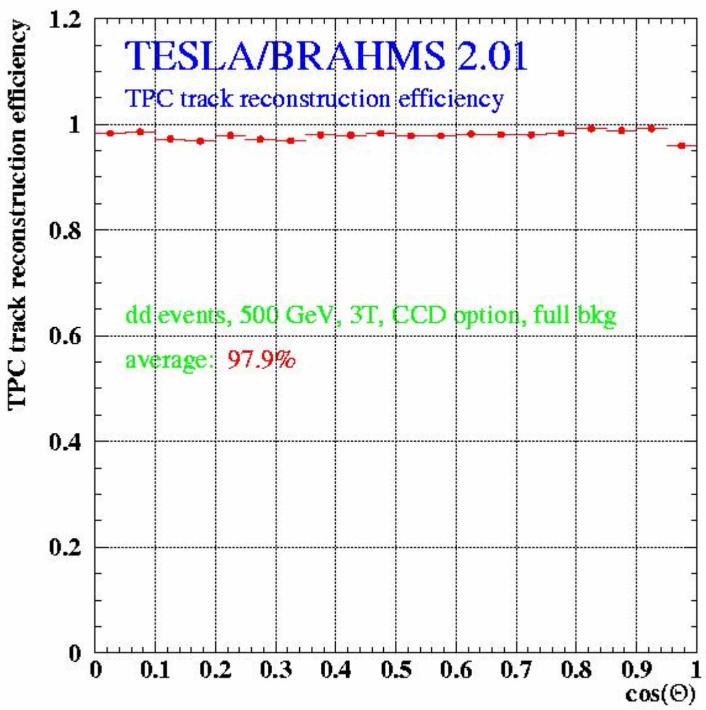
★ **momentum: d(1/p) ~ 10^{-4}/GeV(TPC only)**
~ 0.6×10^{-4}/GeV(w/vertex)
(1/10xLEP)

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

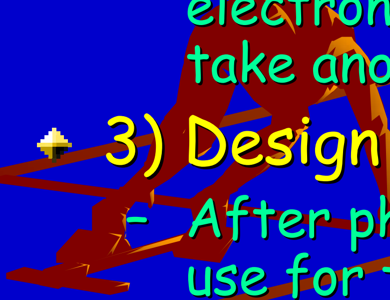


★ **tracking efficiency: 98% (overall)**

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/Si-based ideas this will include a basic proof-of-principle.
- 2) Consolidation phase
  - Build and operate the LP, large prototype, (Ø ≥ 75cm, drift ≥ 100cm), 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 years.
- 3) Design phase
  - After phase 2, the decision as to which endplate technology to use for the LC TPC would be taken and final design started.

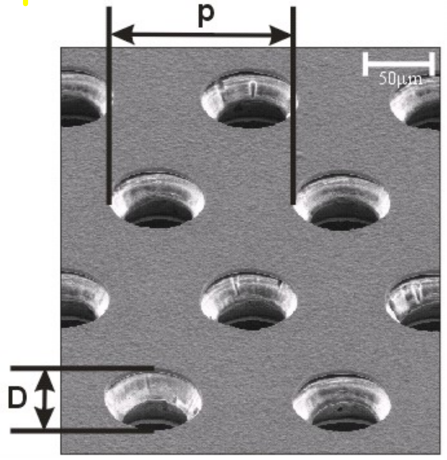
“To-do” list for next few weeks/months

- Detector Outline Documents (LDC and GLD)
- LP planning
- Detector Workshops (Instrumentation@Slac and TPC Applications@LBNL) 3-8April2006
- Status report to the Desy PRC 11May2006 (written version due four weeks earlier)
- Organization of the LC TPC collaboration

What are we doing in Phase 1 ?

Gas-Amplification Systems: Wires & MPGDs→

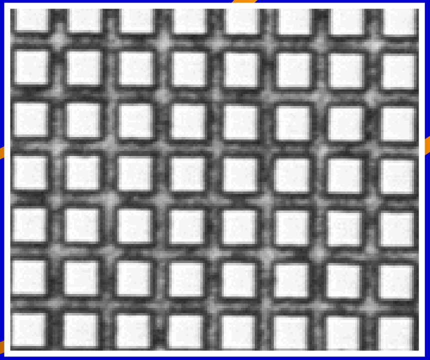
GEM: Two copper foils separated by kapton, multiplication takes place in holes, uses 2 or 3 stages

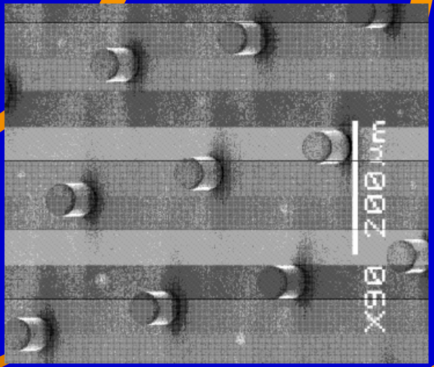


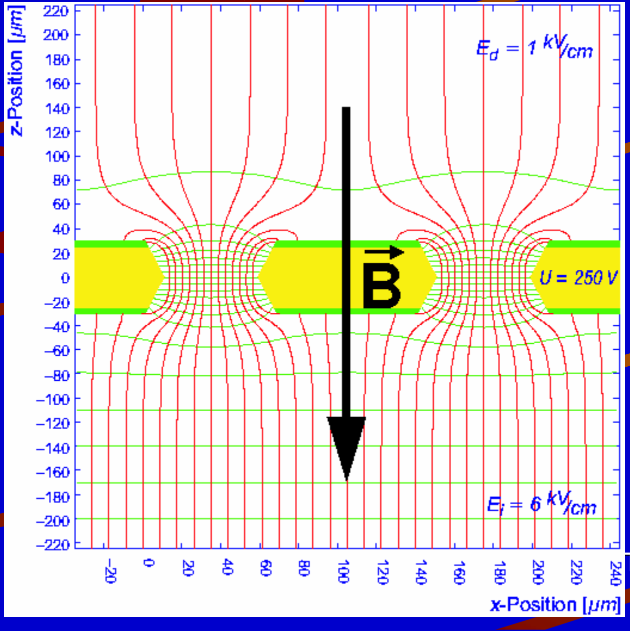
P~140 µm

D~60 µm

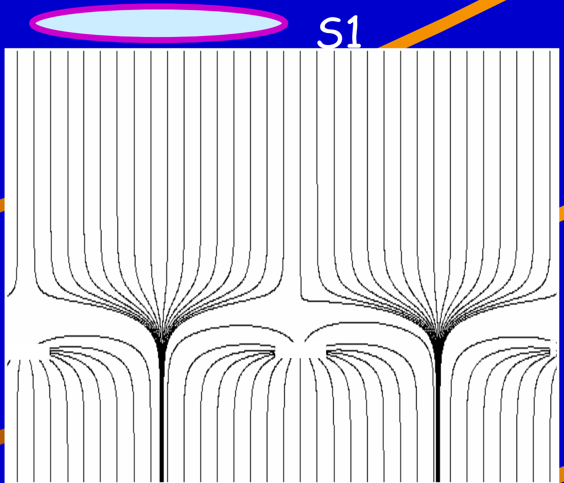
Micromegas: micromesh sustained by 50µm pillars, multiplication between anode and mesh, one stage



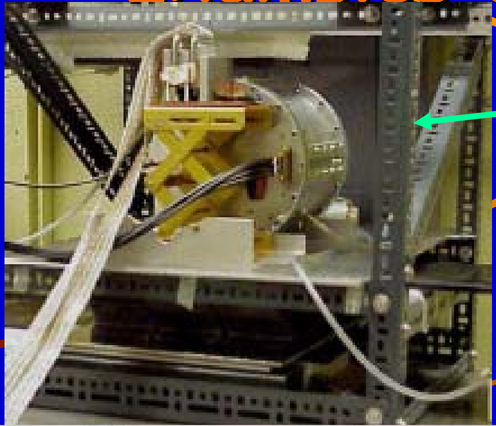




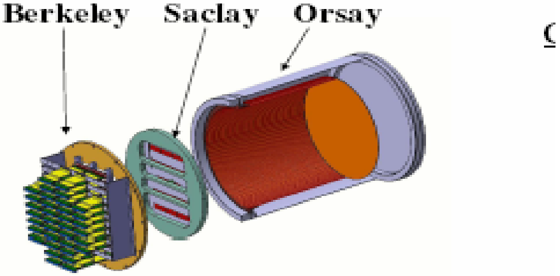
S1/S2 ~ Eamplif / Edrift

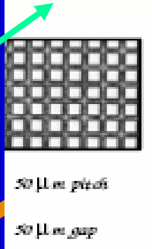


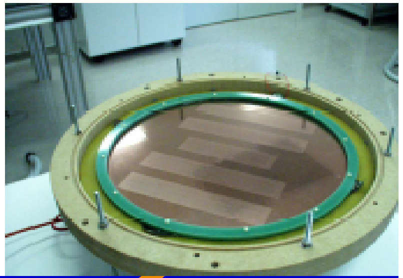
Examples of Prototype TPCs



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

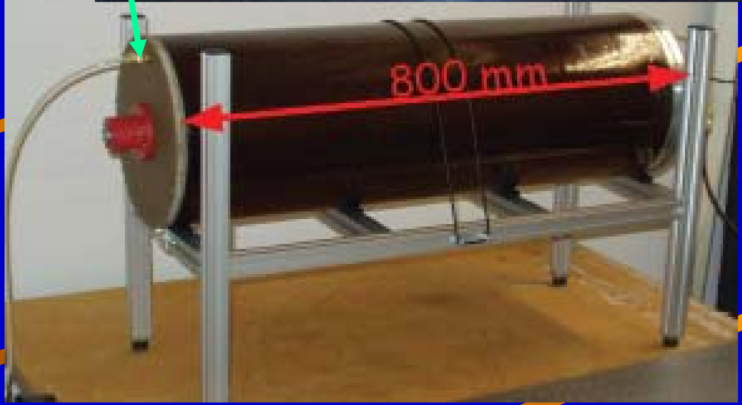






Saclay, Victoria, Desy
(fit in 2-5T magnets)

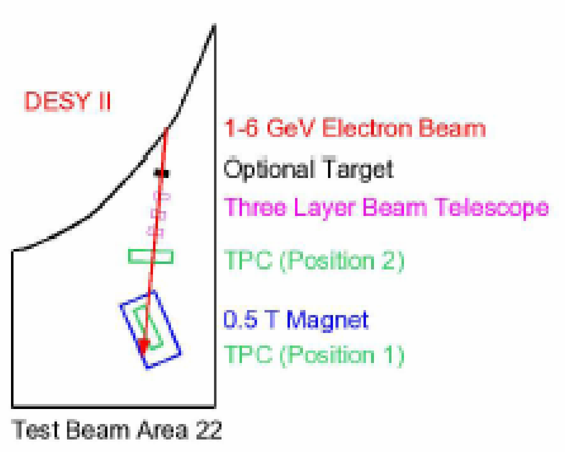
Karlsruhe, MPI/Asia,
Aachen built test TPCs
for magnets (not shown),
other groups built small
special-study chambers



Facilities

Desy 5T magnet, cosmics, laser

Saclay 2T magnet, cosmics

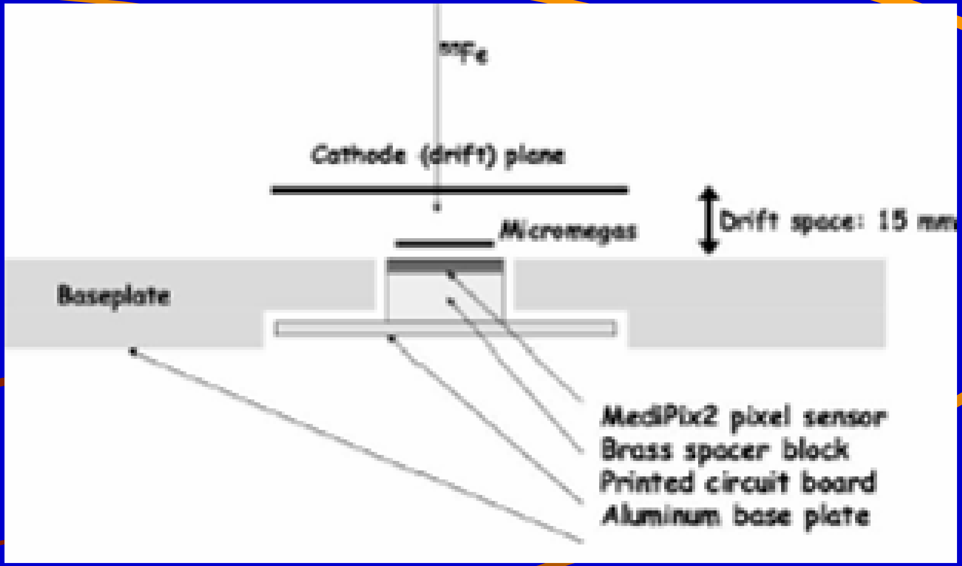


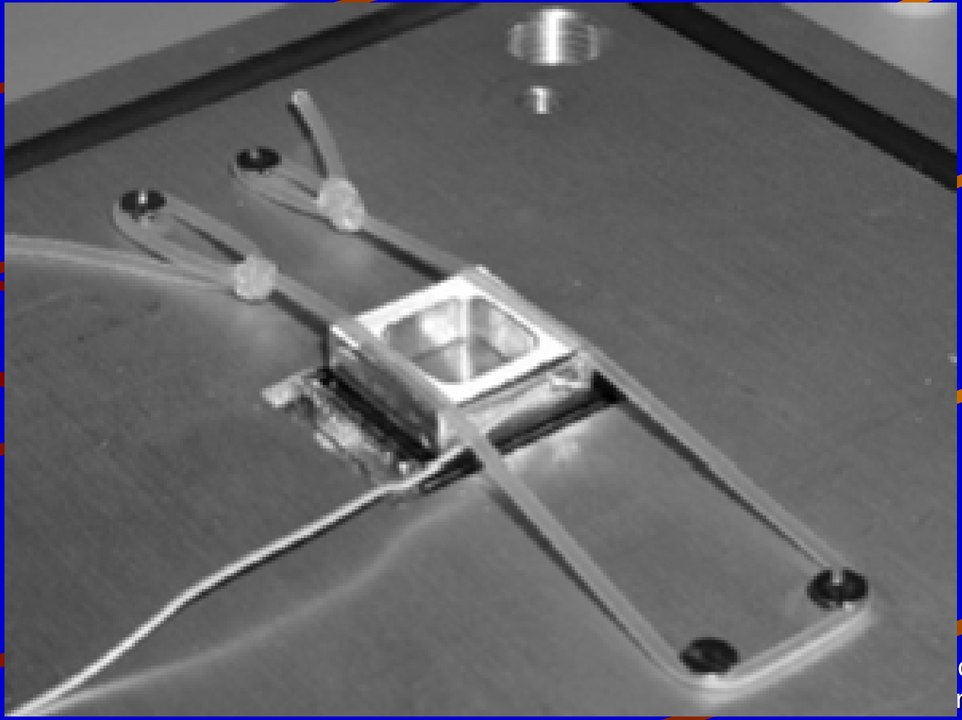
Desy 1T, 6GeV e- test-beam

Cern test-beam (not shown)

Kek 1.2T, 4GeV adr. test-beam

Pixel TPC Development





Nikhef on CMOS readout techniques, joined by Saclay

~ 50 x 50 μm^2 CMOS pixel matrix + Micromegas or Gem

~ preamp, discr, thr.daq, 14-bit ctr, time-stamp logic / pixel

~ huge granularity(digital TPC), diffusion limited, sensitive to indiv. clusters for right gas

~ 1st tests with Micromegas + MediPix2 chip

→ more later…

TPC R&D Summary

- Now 4 years of MPGD experience gathered
- Gas properties rather well understood
- “Diffusion-limited” resolution being understood
- Resistive foil charge-spreading demonstrated
- CMOS RO demonstrated
- Design 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)

- The Eudet infrastructure gives us a starting basis for the LP work
- There other LC TPC R&D issues in addition to the LP R&D which will be planned in conjunction with it

EUDET Detector R&D for the International Linear Collider

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

I3 Proposal → "Integrated Infrastructure Initiative"

7 M € from EU over 4 years approved to provide infrastructure for detector R&D ⇒ Kickoff meeting in Feb 06

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.

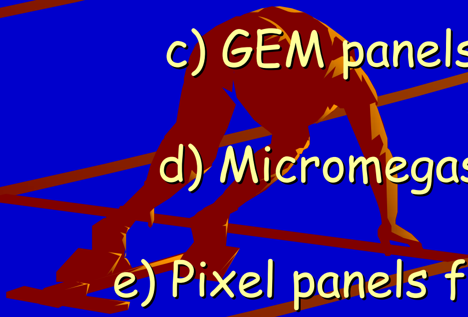
The idea is that this will provide a basis for the LC TPC groups to help get funding for the LP and other LC TPC work.

Work Packages for the LP and related work on the LC TPC

convener in white color

1) Workpackage MECHANICS

Ron Settles

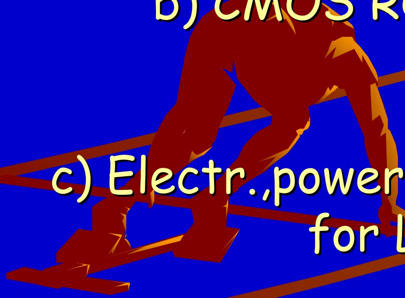


Work package	Convener	Groups expressing interest to date(others?)
a) LP design (incl. endplate structure)	Dan Peterson	Cornell, Desy, IPNOrsay, MPI, +contribution from Eudet
b) Fieldcage, laser, gas	Ties Behnke	Aachen, Desy, St.Petersburg, +contribution from Eudet
c) GEM panels for endplate	Akira Sugiyama	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 LP and related work on the LC TPC

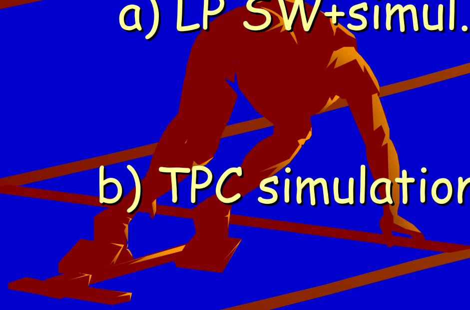
2) Workpackage ELECTRONICS

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 LP and related work on the LC TPC



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 LP and related work on the LC TPC

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

Work Packages for the LP and related work on the LC TPC - convener candidates

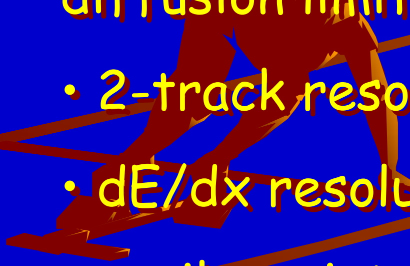
Overall composition of conveners ~ 50:50 between ExtraEudet and Eudet affiliation

What are the TPC design issues that have to be kept in mind when laying out the LP?

These are summarized in the TPC central-tracker DOD ('Detector Outline Document') for the LDC and GLD, submitted to the WWSOC at LCWS06 in Bangalore

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

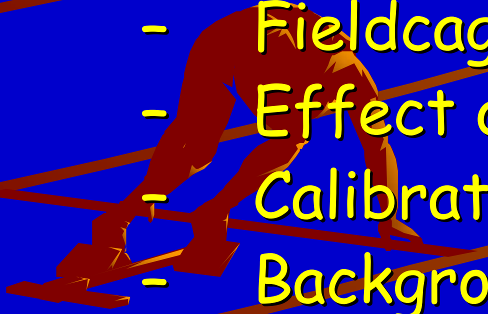
  (two orders of magnitude more if CMOS pixel version)

- ~ 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

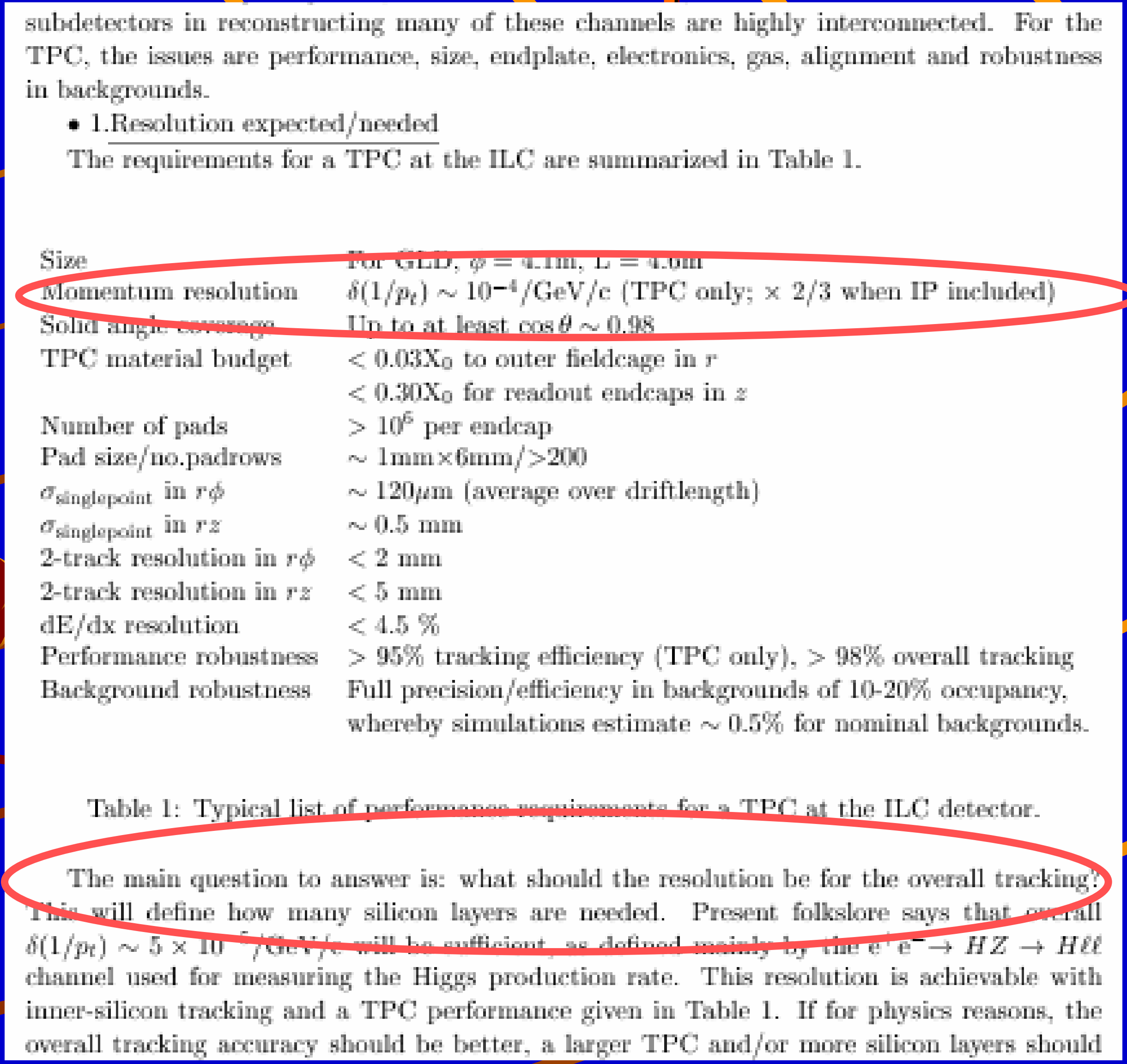
Excerpts from DODs for GLD and LDC used here as examples



DESIGN ISSUES for the LC TPC

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

LC TPC Resolution expected/needed



subdetectors in reconstructing many of these channels are highly interconnected. For the TPC, the issues are performance, size, endplate, electronics, gas, alignment and robustness in backgrounds.

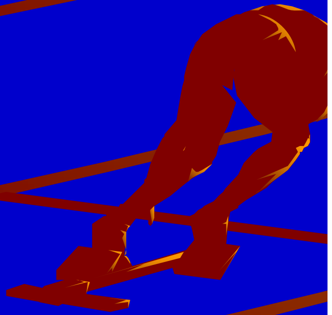
- 1.Resolution expected/needed

The requirements for a TPC at the ILC are summarized in Table 1.

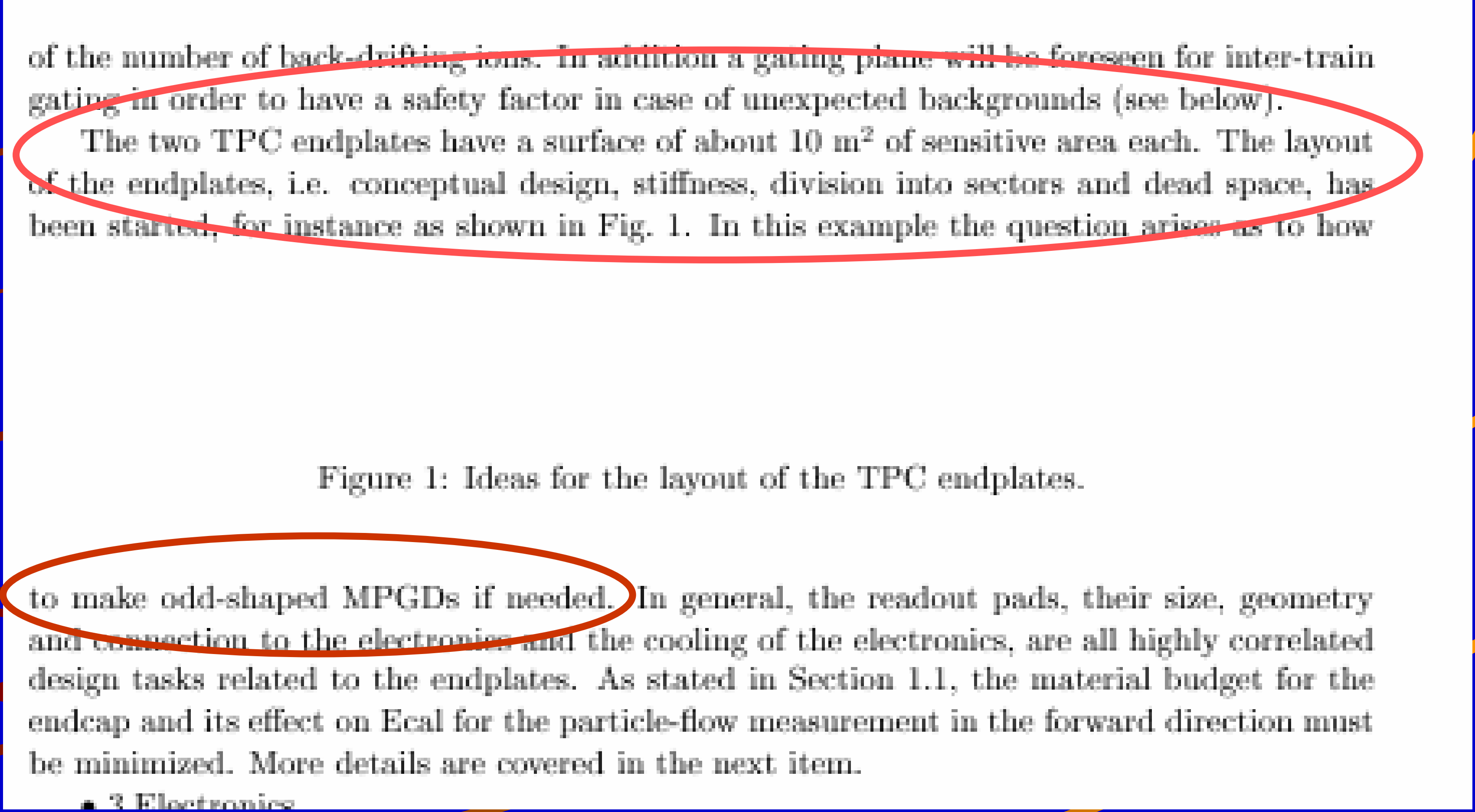
Size	For GLD, $\phi = 4.1$m, $L = 4.6$m
Momentum resolution	$\delta(1/p_t) \sim 10^{-4}$/GeV/c (TPC only; × 2/3 when IP included)
Solid angle coverage	Up to at least $\cos\theta \sim 0.98$
TPC material budget	$< 0.03X_0$ to outer fieldcage in r $< 0.30X_0$ for readout endcaps in z
Number of pads	$> 10^6$ per endcap
Pad size/no.padrows	$\sim$ 1mm×6mm/>200
$\sigma_{\text{singlepoint}}$ in $r\phi$	$\sim 120\mu$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 10-20% occupancy, whereby simulations estimate ~ 0.5% for nominal backgrounds.

Table 1: Typical list of performance requirements for a TPC at the ILC detector.

The main question to answer is: what should the resolution be for the overall tracking? This will define how many silicon layers are needed. Present folkslore says that overall $\delta(1/p_t) \sim 5 \times 10^{-5}$/GeV/c will be sufficient, as defined mainly by the $e^+e^- \to HZ \to H\ell\ell$ channel used for measuring the Higgs production rate. This resolution is achievable with inner-silicon tracking and a TPC performance given in Table 1. If for physics reasons, the overall tracking accuracy should be better, a larger TPC and/or more silicon layers should



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.

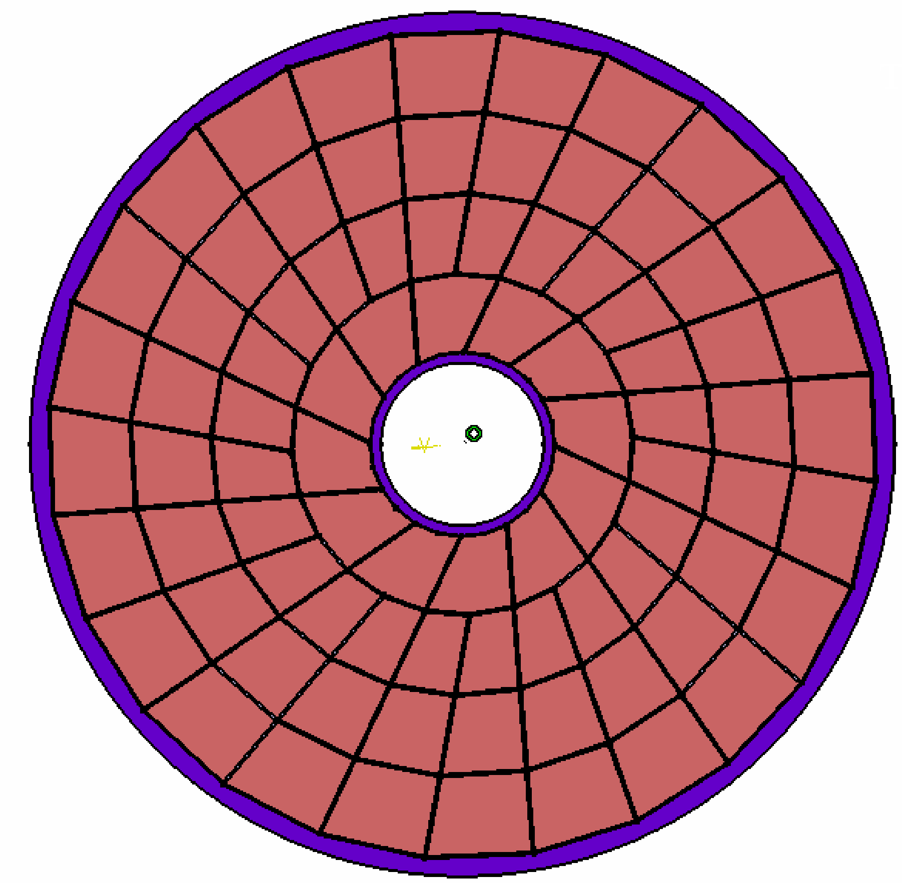
- 3 Electronics

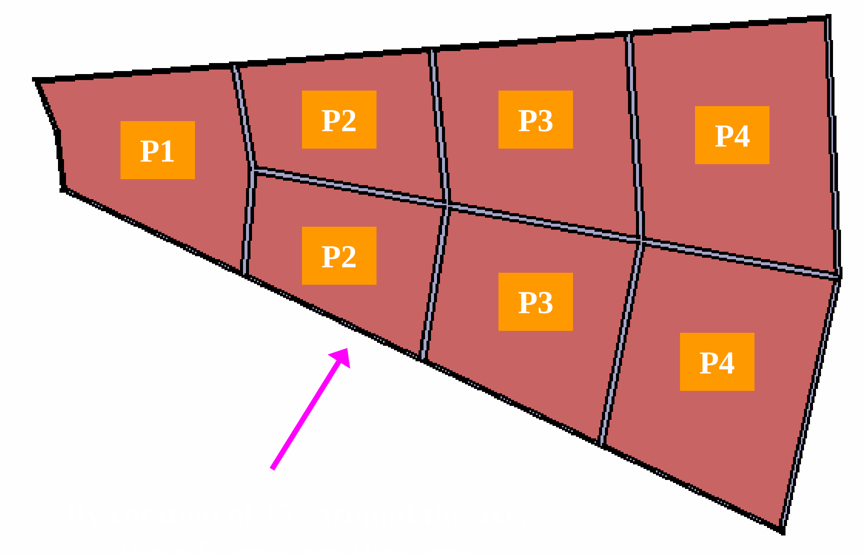
Arrangements of detectors on the active area of the end cap (2/2)
Trapezoidal shapes assembled in iris shape

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

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

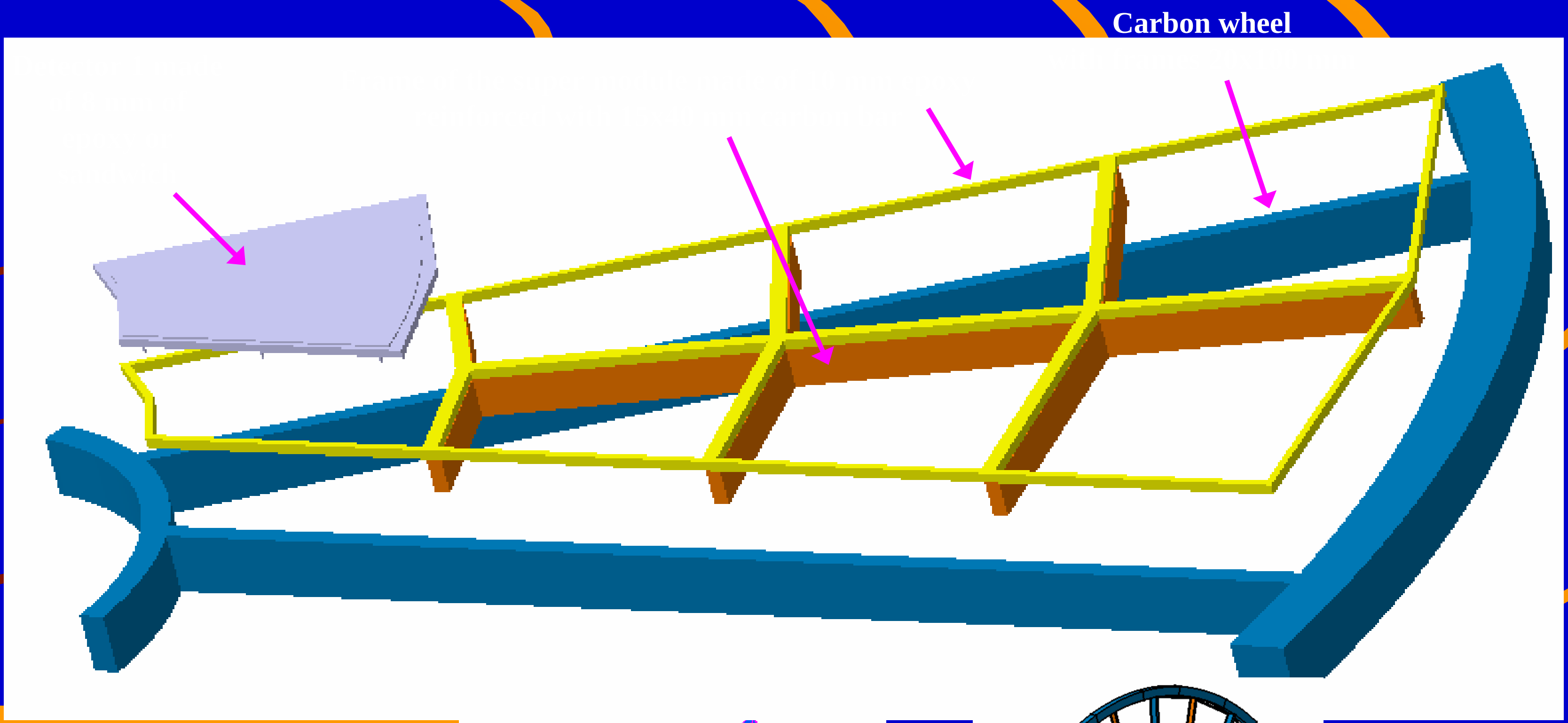




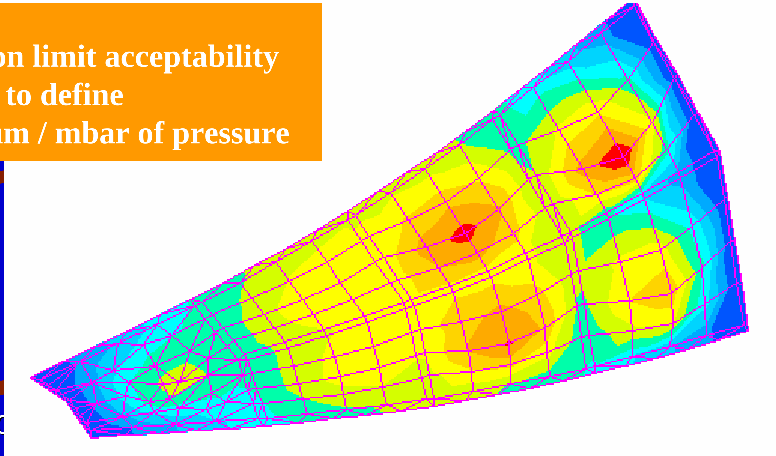
these frames are the same

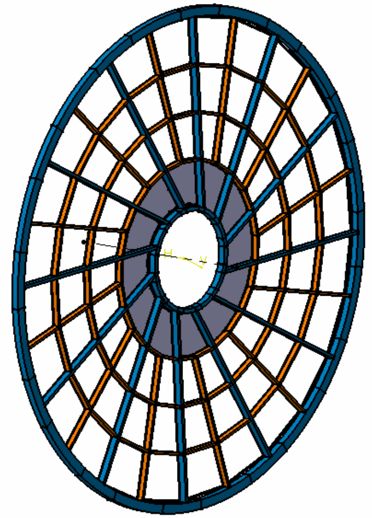
These arrangement seems to be the best as only 4 different PADS are necessary

Principle for a Super Module equipped with detector 1



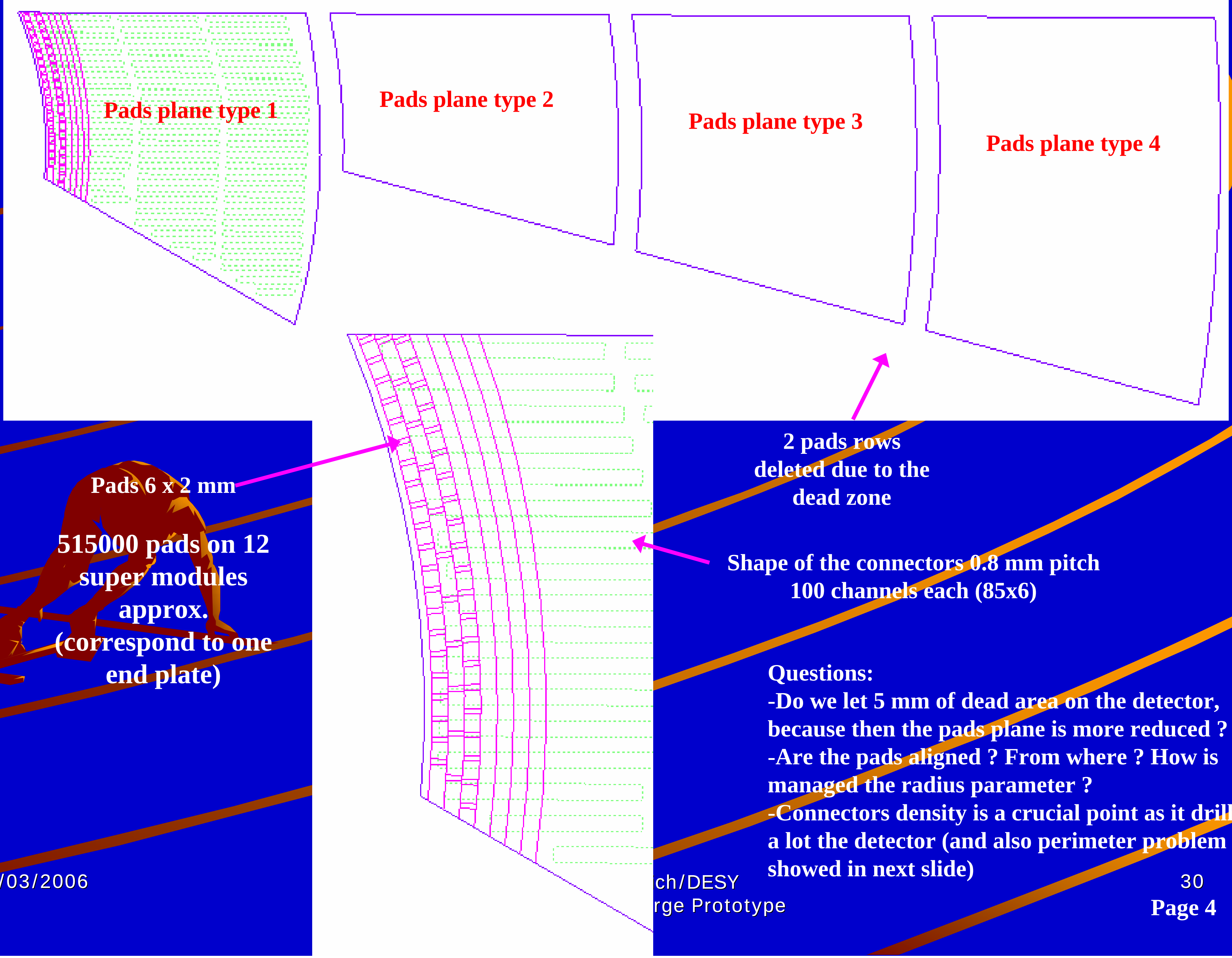
Deformation limit acceptability
to define
Here is 20 µm / mbar of pressure





Complete wheel
with 12 super
modules

Principle for the 4 types of Pads plane



Pads 6 x 2 mm

515000 pads on 12 super modules approx. (correspond to one end plate)

2 pads rows deleted due to the dead zone

Shape of the connectors 0.8 mm pitch
100 channels each (85x6)

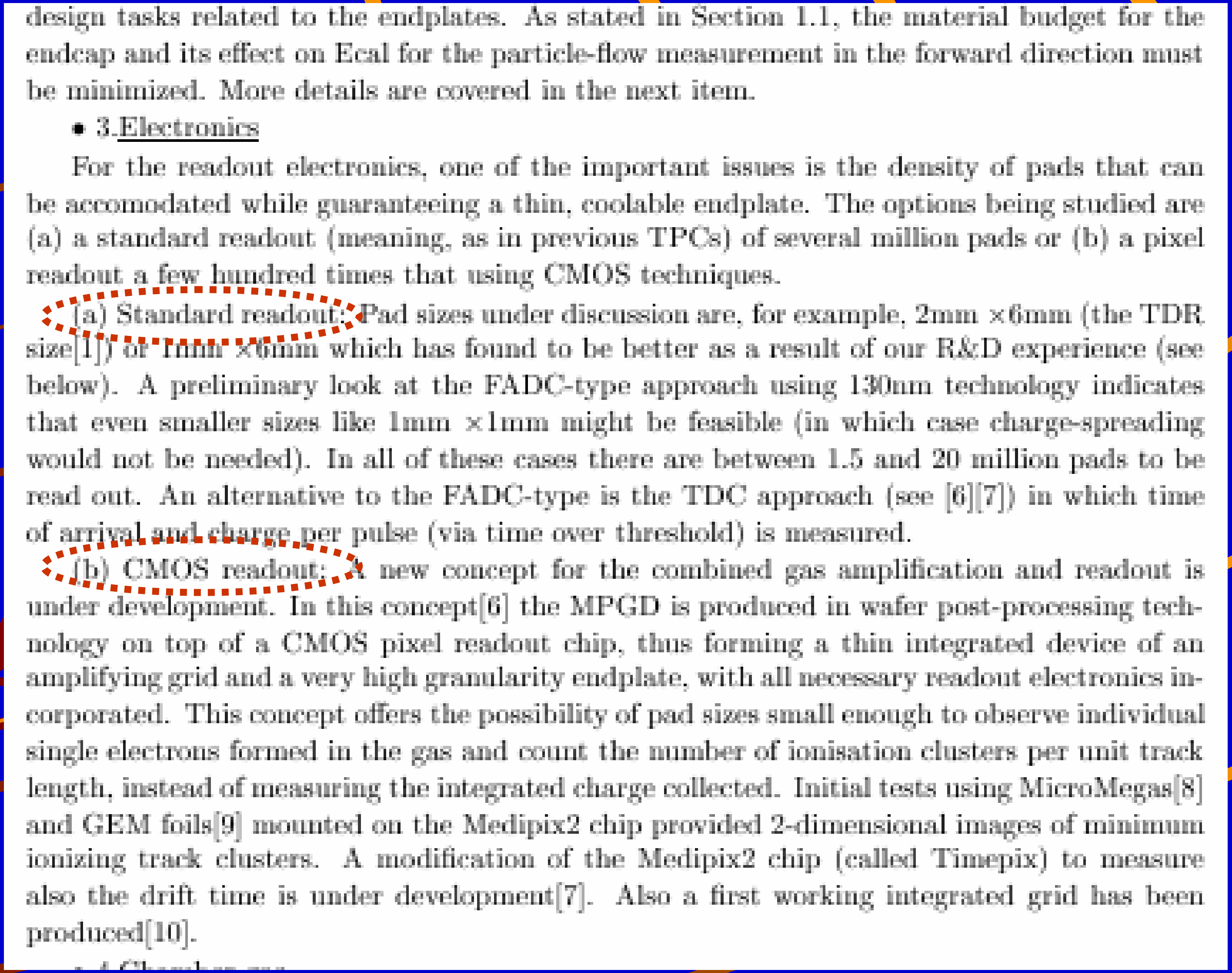
Questions:

-Do we let 5 mm of dead area on the detector, because then the pads plane is more reduced ?

-Are the pads aligned ? From where ? How is managed the radius parameter ?

-Connectors density is a crucial point as it drills a lot the detector (and also perimeter problem showed in next slide)

LC TPC Electronics



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.

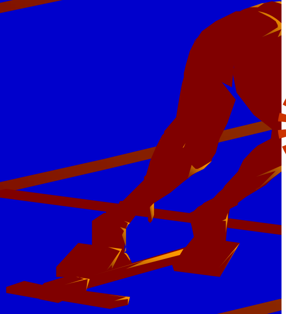
- 3.Electronics

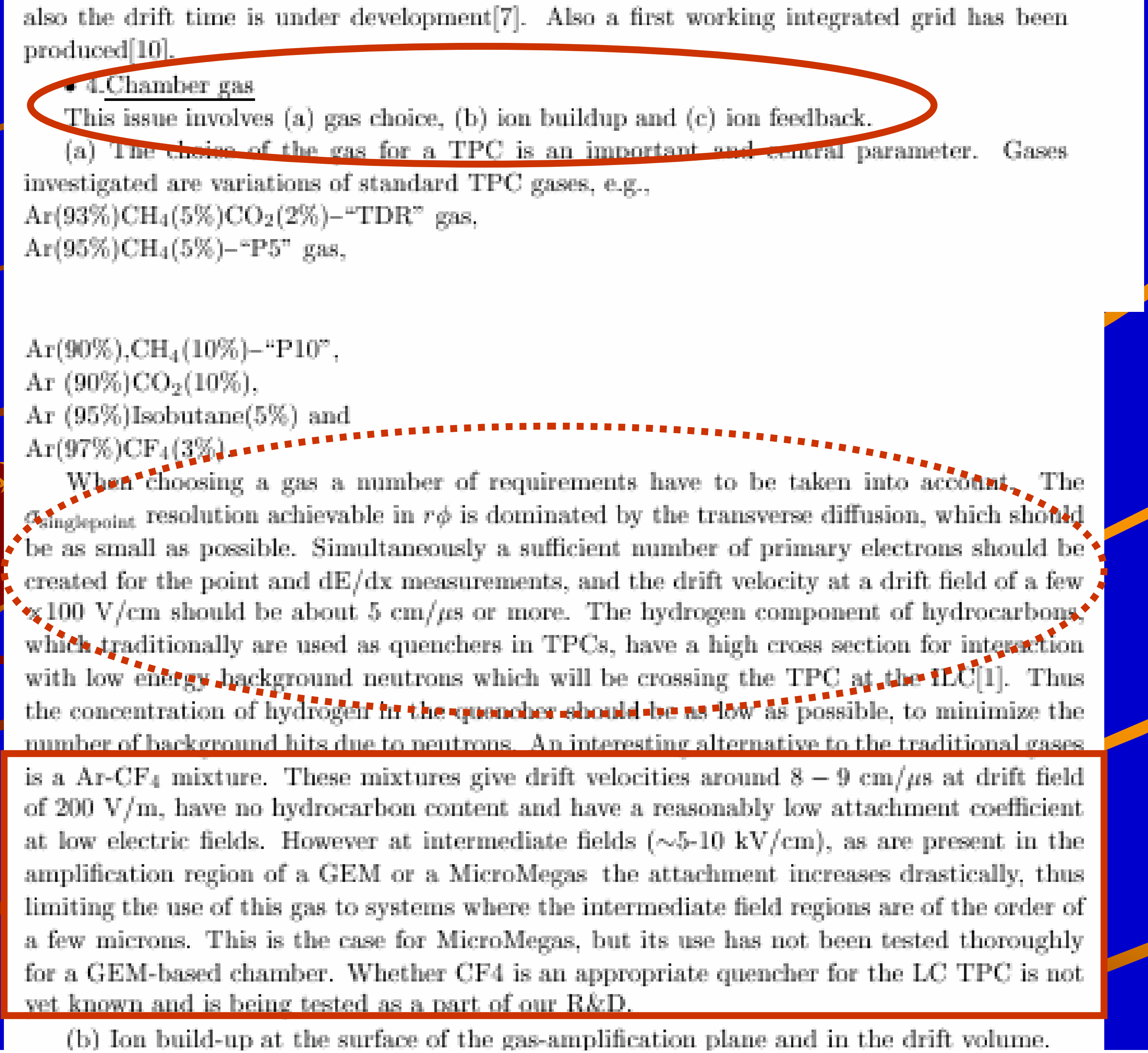
For the readout electronics, one of the important issues is the density of pads that can be accomodated while guaranteeing a thin, coolable endplate. The options being studied are (a) a standard readout (meaning, as in previous TPCs) of several million pads or (b) a pixel readout a few hundred times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

(a) Standard readout: Pad sizes under discussion are, for example, 2mm ×6mm (the TDR size[1]) or 1mm ×6mm 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 130nm technology indicates that even smaller sizes like 1mm ×1mm 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.

(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 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[8] and GEM foils[9] 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[10].

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.

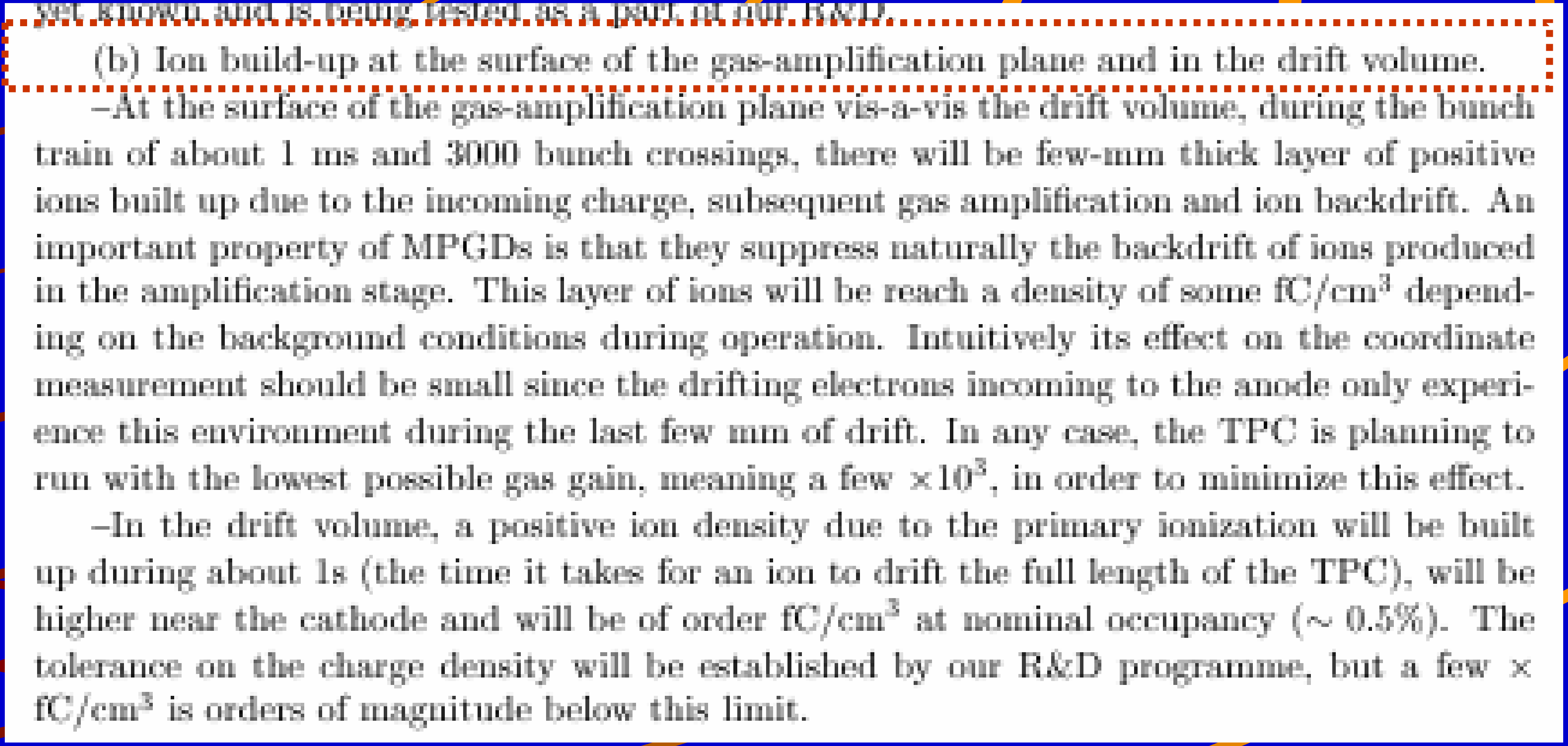
(a) The choice of the gas for a TPC is an important and central parameter. Gases investigated are variations of standard TPC gases, e.g.,
Ar(93%)CH$_4$(5%)CO$_2$(2%)–"TDR" gas,
Ar(95%)CH$_4$(5%)–"P5" gas,

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



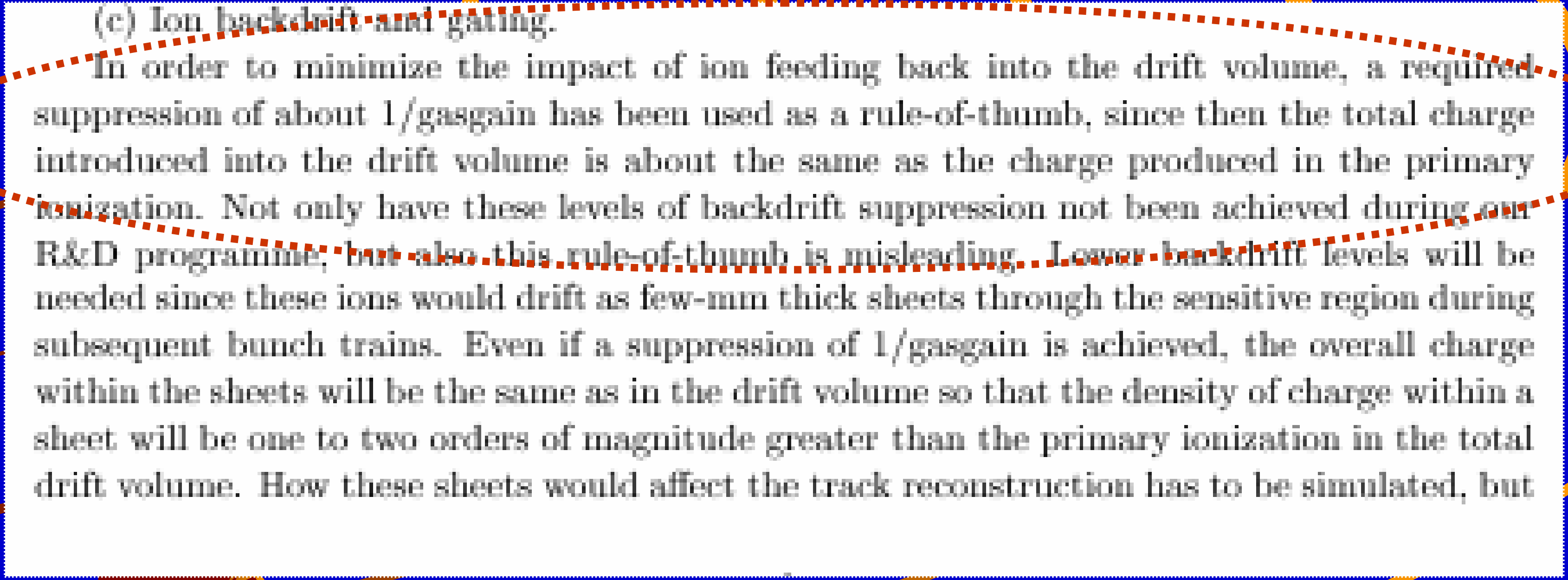
yet known and is being tested as a part of our R&D.

(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.

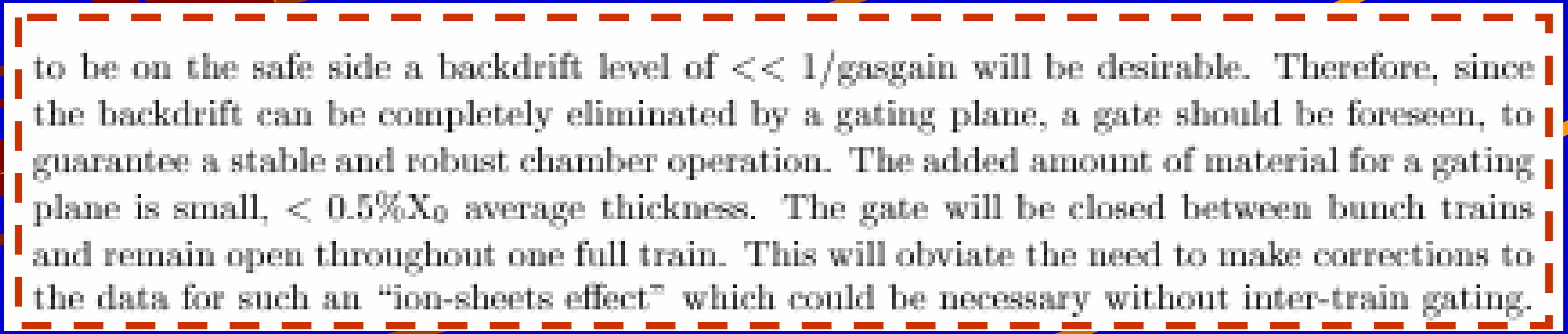
–In the drift volume, a positive ion density due to the primary ionization will be built up during about 1s (the time it takes for an ion to drift the full length of the TPC), will be higher near the cathode and will be of order fC/cm^3 at nominal occupancy ($\sim 0.5\%$). The tolerance on the charge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

LC TPC Chamber gas
(c) ion backdrift/gating



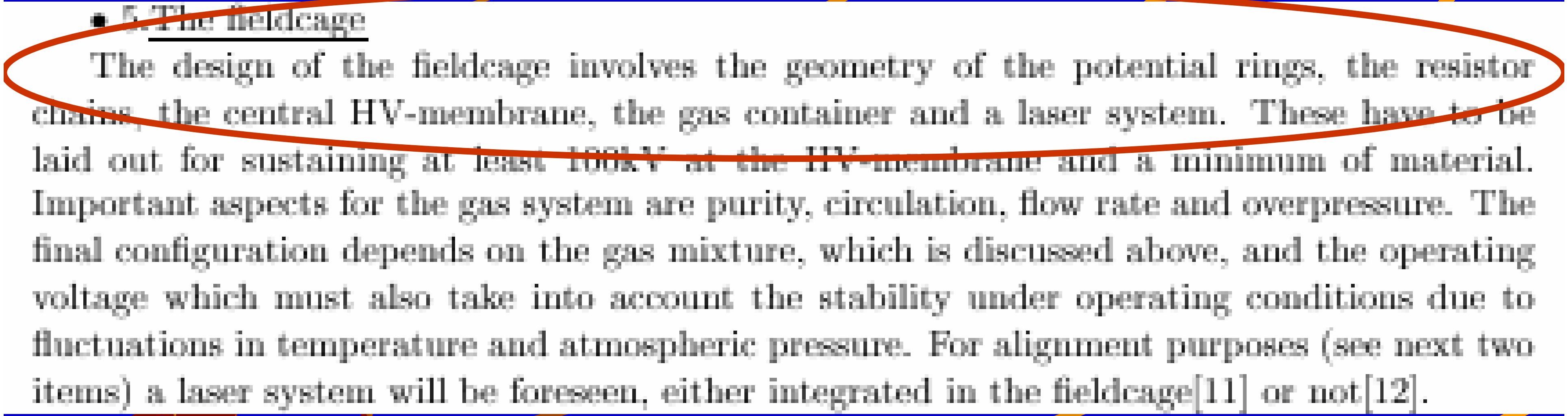
(c) Ion backdrift and gating.

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.

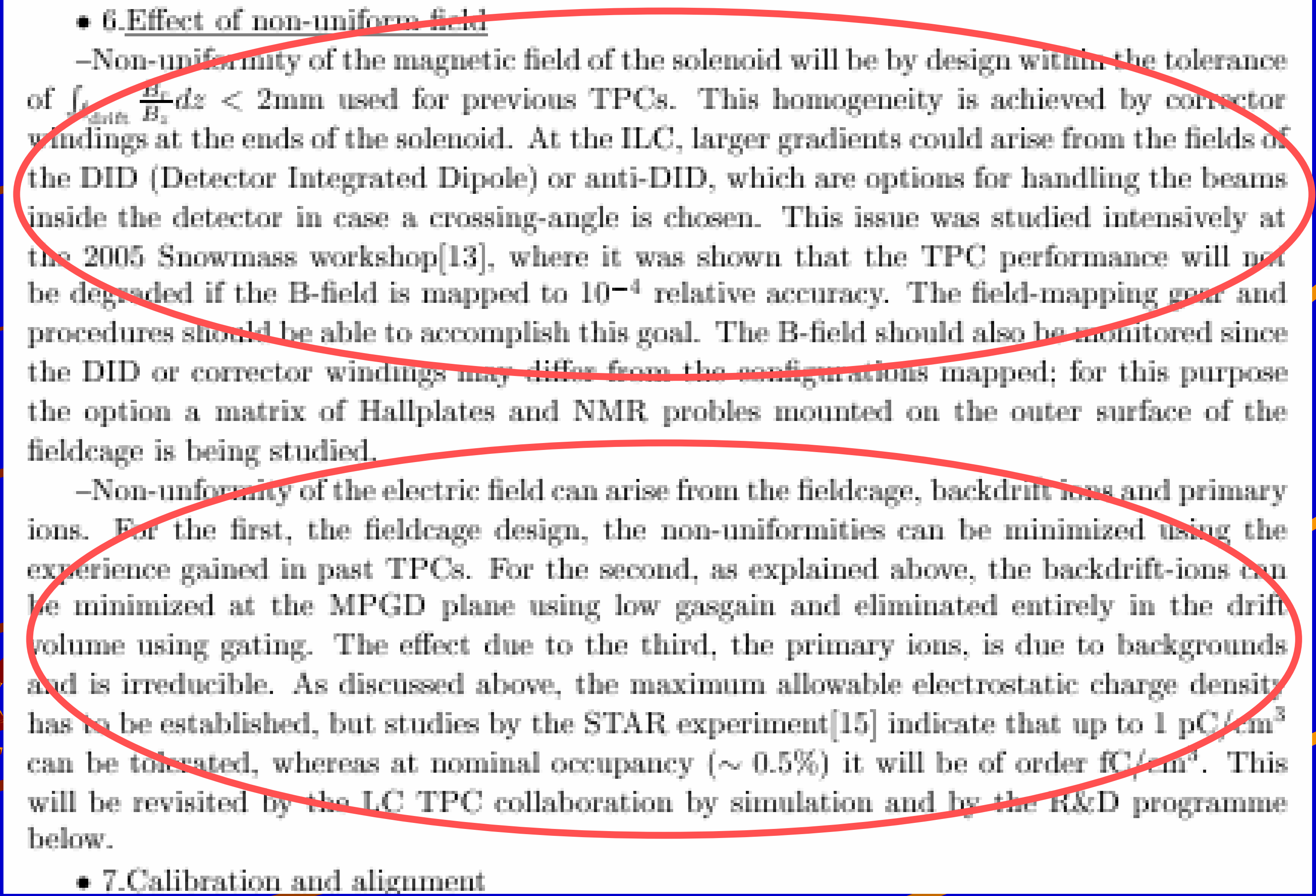
LC TPC Fieldcage



- 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].

LC TPC Non-uniform fields



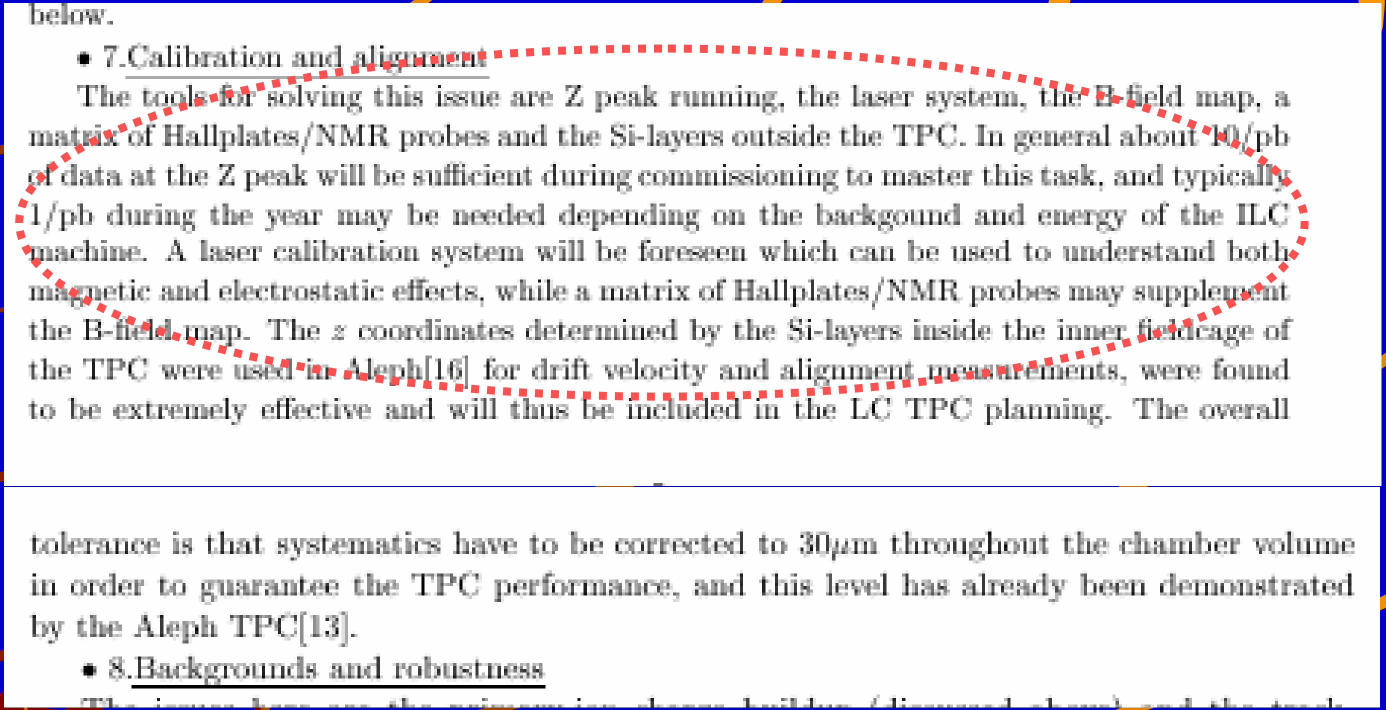
- 6.Effect of non-uniform field

–Non-uniformity of the magnetic field of the solenoid will be by design within the tolerance of $\int_{L_{\rm drift}} \frac{B_r}{B_z} dz < 2$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 crossing-angle is chosen. This issue was studied intensively at the 2005 Snowmass workshop[13], where it was shown that the TPC performance will not be degraded if the B-field is mapped to 10^{-4} relative accuracy. The field-mapping gear and procedures 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 a matrix of Hallplates and NMR probles mounted on the outer surface of the fieldcage is being studied.

–Non-uniformity 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[15] indicate that up to 1 pC/cm^3 can be tolerated, whereas at nominal occupancy ($\sim 0.5\%$) it will be of order fC/cm^3. This will be revisited by the LC TPC collaboration by simulation and by the R&D programme below.

- 7.Calibration and alignment

LC TPC Calibration/alignment



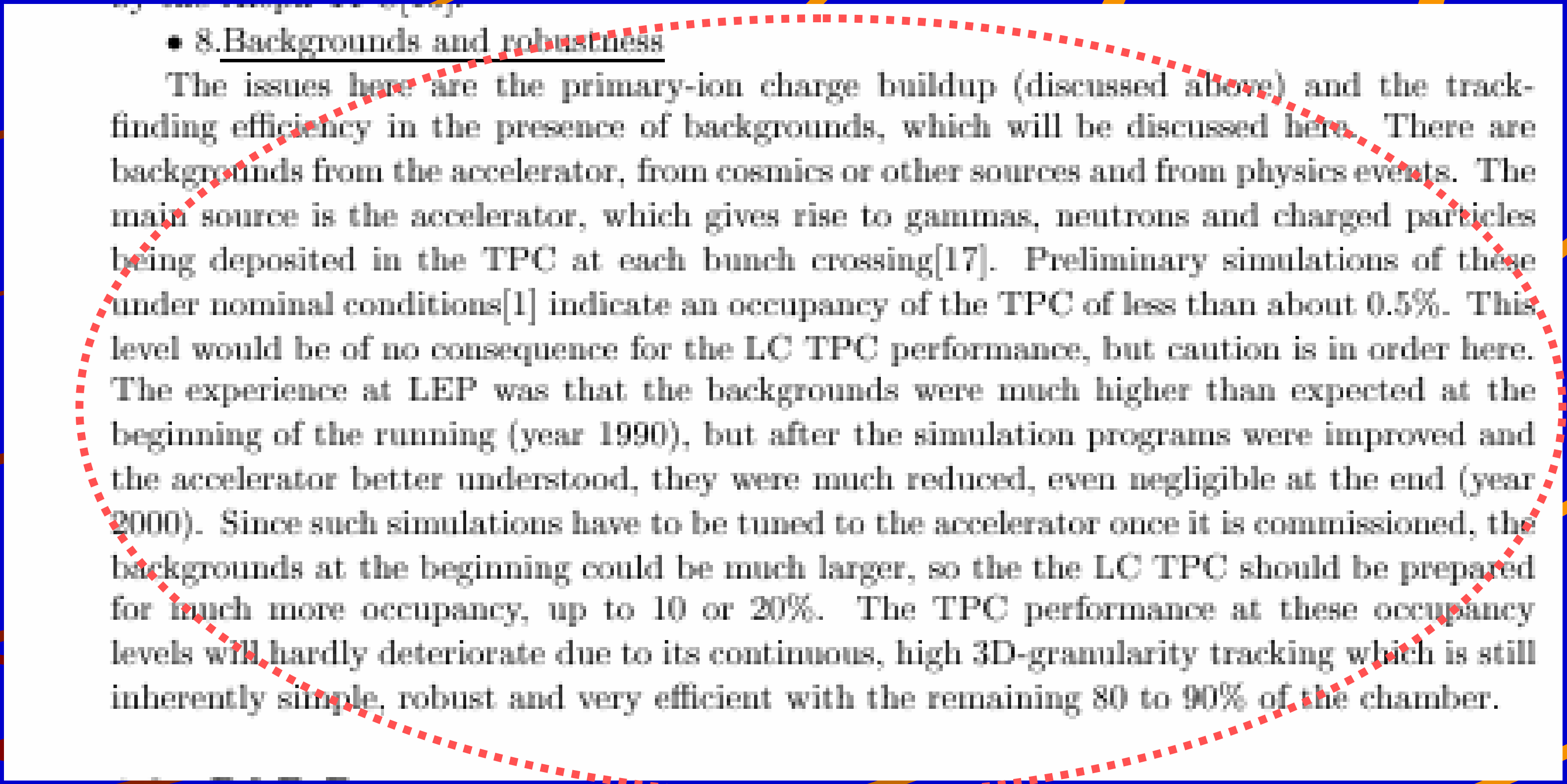
below.

- 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

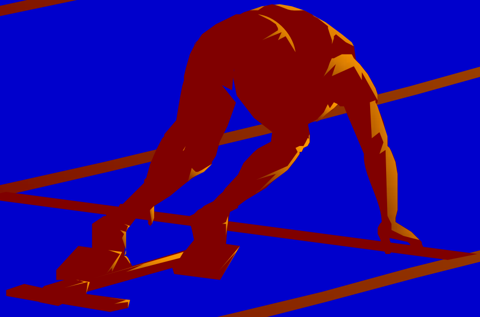
The issues here are the primary-ion charge buildup (discussed above) and the track-finding efficiency in the presence of backgrounds, which will be discussed here. There are backgrounds from the accelerator, from cosmics or other sources and from physics events. The main source is the accelerator, which 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.

TPC milestones

2006	Continue LC-TPC R&D via small-prototype tests, organize work for Large Prototype
2007-2009	Test Large Prototype, decide technology
2010	Final design of LC TPC
2014	Four years construction
2015	Commission/Install TPC in LC Detector

No conclusion,

work continuing...



Backup slides…

Performance/Simulation

- Momentum precision needed for overall tracking?
- Momentum precision needed for the TPC?
- Arguments for dE/dx, 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 outer diameter
- TPC inner diameter
- TPC length
- Required B-mapping accuracy in case of non-uniform B-field?

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

Backgrounds/alignment/distortion-correction

- Revisit expected backgrounds -> DOD
- Maximum positive-ion buildup tolerable? -> DOD
- Maximum occupancy tolerable?
- Effect of positive-ion backdrift: gating plane?
- Tools for correcting space charge in presence of bad backgrounds? -> DOD (from Snowmass study)