A Short Overview
of
R&D by LDTPC Collaboration

Takeshi Matsuda
(on behalf of Akira Sugiyam)

2013 Tokusui Annual Meeting
18 Dec 2013 @ KEK

LC TPC Review by ECFA Detector Panel

4-5 Nov. 2013
DESY

T. Matsuda

Friday Meeting
ILC Physics and Detector Group, KEK
6 Dec, 2013

ECFA Detector Panel

http://ecfa-dp.desy.de/

(ECFA DP is the successor of the DESY PRC)

The ECFA Detector Panel, a **European committee to review the R&D effort for future projects**, was created by ECFA in its last meeting 24 Nov - 25 Nov 2011. It is aimed at the R&D efforts of large scale projects in their preliminary and preparatory phase, not yet approved and supported by a unique leading or host lab, as for example the European LC community's R&D.

This new European committee **receives R&D proposals on authors' request**, makes recommendations after evaluation, and monitors their progress.

It helps to create a coherence of the global R&D effort by encouraging synergies between different activities and advising the funding agencies if they wish.

It is primarily concerned with large R&D projects, related to accelerator experiments, involving many laboratories and requiring significant resources.

DESY will host this new committee which is planned to meet twice per year. **Chair**: Yannis Karyotakis (director of the Laboratoire d'Annecy le Vieux de Physique des Particules) **Scientific Secretary**: Doris Eckstein (DESY)

ECFA Detector Panel

Meets: Twice a year at DESY since May 2012 (2 days meeting)
- Calorimetry for LC (CALICE) (2012)
- Forward Calorimetry (FCAL) 2013)
- **LC-TPC (Nov. 2013)** (No review report received yet)

Member	Institute	Contact
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LCTPC Review by ECFA Detector Panel

4 – 5 Nov. 2013

ECFA Detector Panel Meeting - Open Session (4 Nov.2013 13:00-16:25)

13:00 - 13:15	Welcome	Yannis Karyotakis (LAPP, Université de Savoie, CNRS/IN2P3)
13:15 - 13:55	Introduction/Overview	Jan Timmermans (NIKHEF)
13:55 - 14:35	Technologies	Jochen Kaminski (University of Bonn)
14:35 - 15:15	Ion feed back & Gate	Philippe Gros (LLR) (*)
15:45 - 16:25	Electronics	Paul COLAS (CEA/Irfu Saclay)
16:25 - 17:05	Studies on mechanical aspects	Jochen Kaminski (University of Bonn)
17:05 - 17:45	Software / simulations	Astrid Muennich (CERN)
17:45 - 18:25	Outlook	Takeshi Matsuda (KEK)

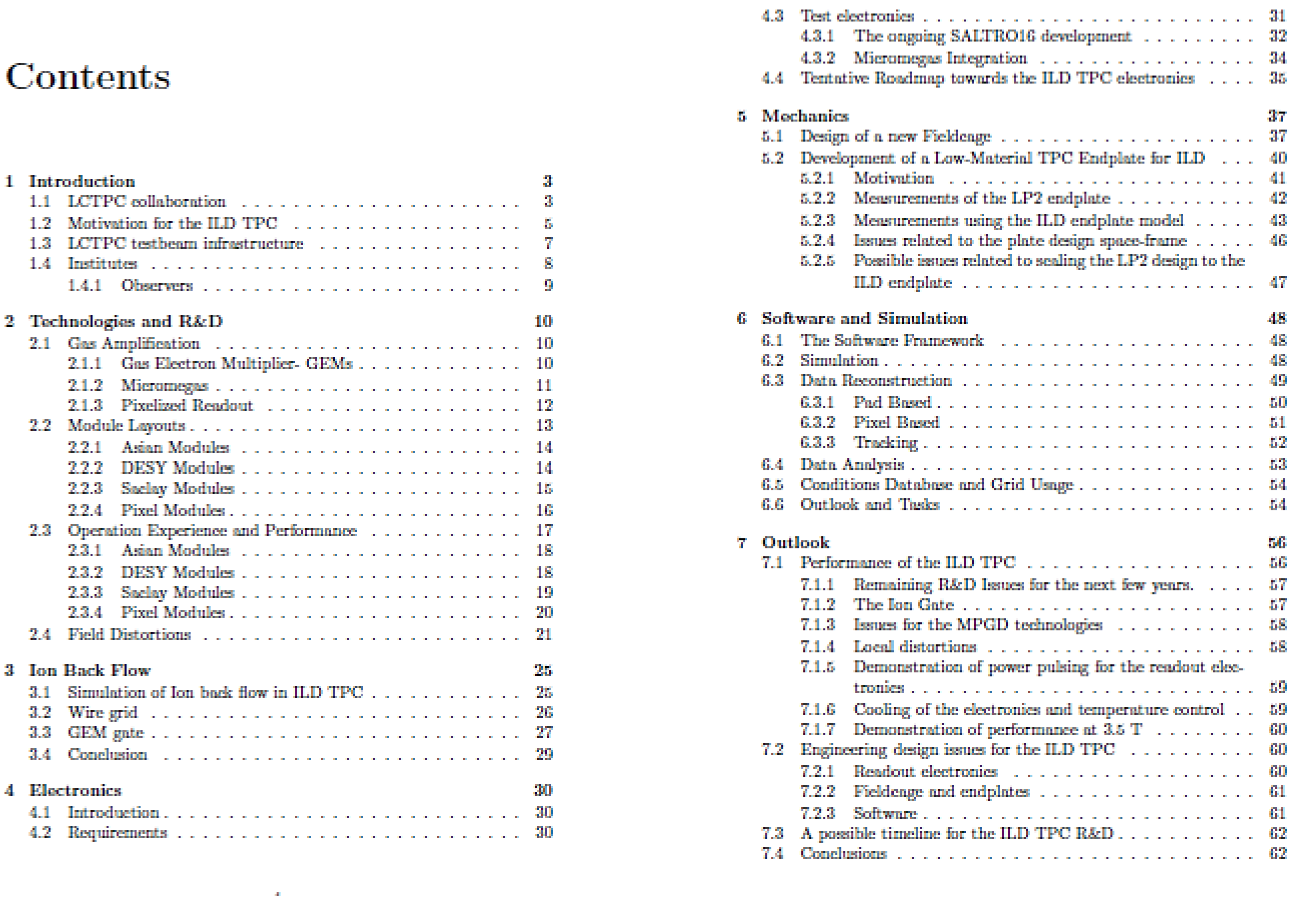
ECFA Detector Panel Meeting - Closed Session (5 Nov.2013 in the morning)

Note that it may be apparent in the agenda already that LCTPC does have no proper engineering groups (in the mechanics and the electronics).

ECFA Detector R&D Panel

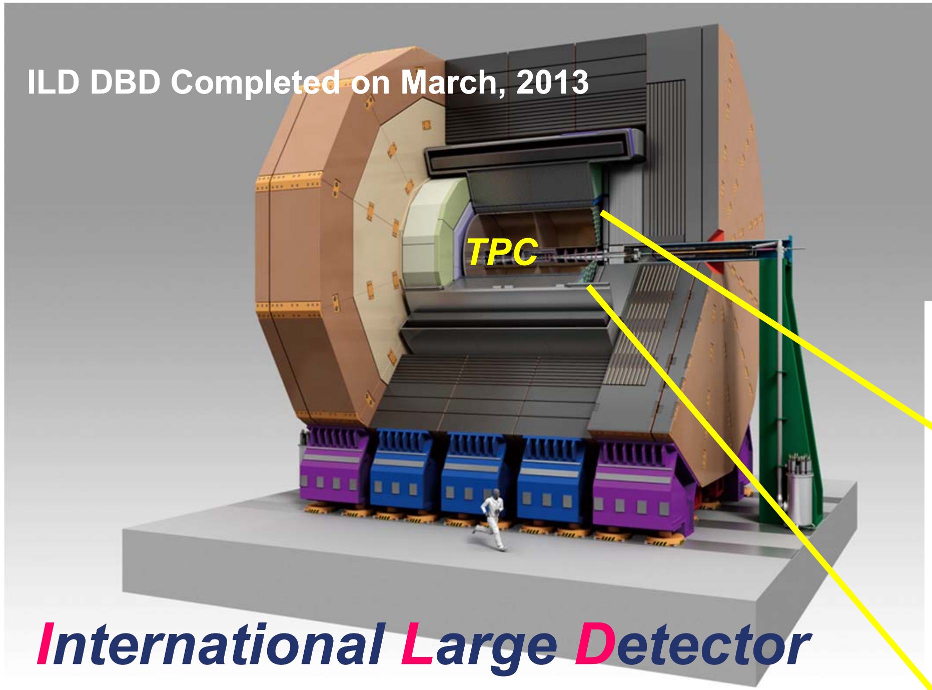
LCTPC Review Report by LCTPC collaboration

November 3, 2013



Contents

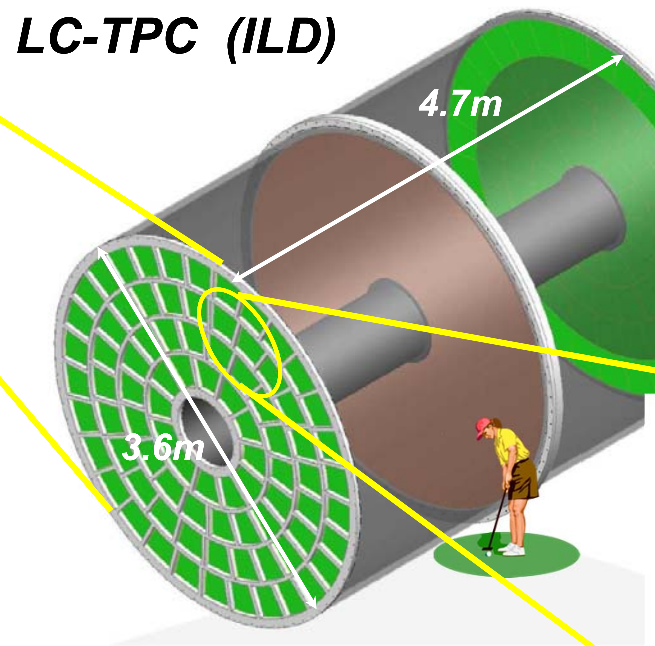
LC-TPC

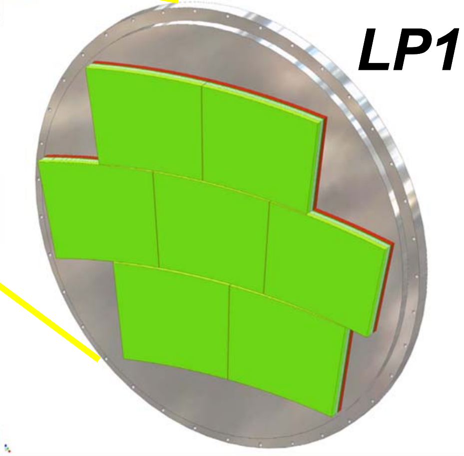


International Large Detector

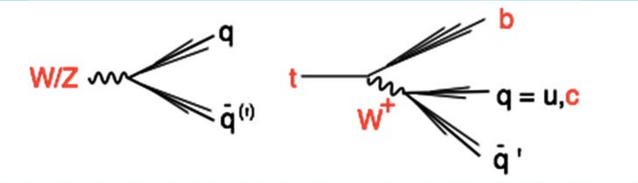
Performance Goals as compared to LHC detectors

Vertex resolution	2-7 times better
Momentum resolution	10 times better
Jet energy resolution	2 times better





ILD : optimized for Particle Flow Analysis



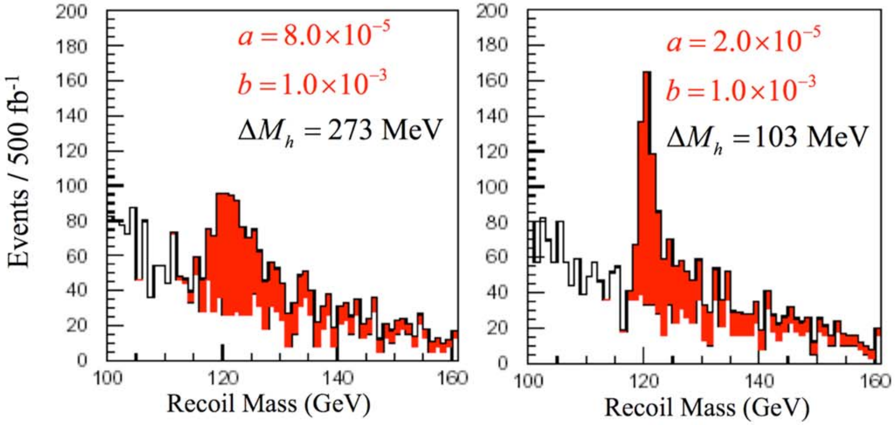
Highly efficient tracking in a jetty environment is an essential ingredient for PFA

Micro Pattern Gas Detector readout TPC provides pictorial 3D tracking by ~200 space points with $\sigma_{r\varphi}$~100 μm and two-hit separation of ~2mm

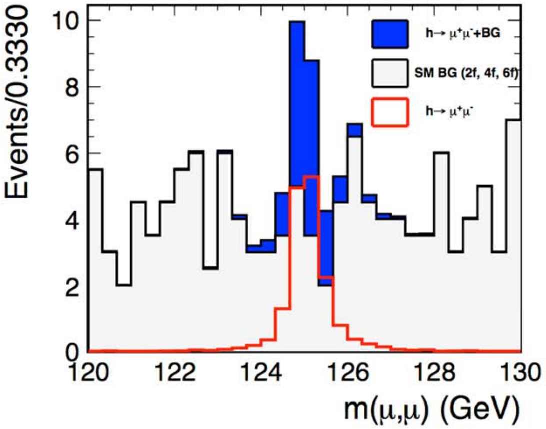
Large Prototype
being tested at DESY

Performance Goals

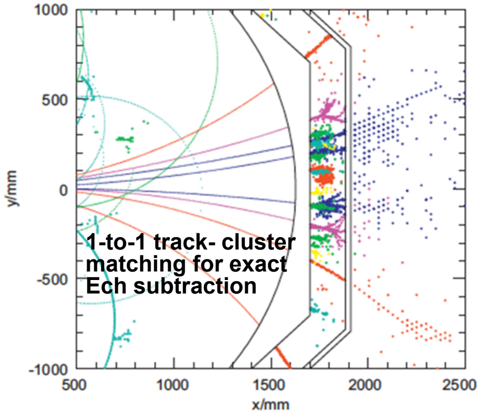
- **Momentum Resolution:** $\sigma(1/p_t) = 2\times10^{-5}$ (GeV^{-1})
  >200 sampling points along a track with a spatial resolution better than $\sigma_{r\varphi}\sim100$ μm over the full drift length of >2m in B=3.5T (recoil mass, $H\to\mu^+\mu^-$).
- **High Efficiency:** 2-track separation better than ~2mm to assure essentially 100% tracking efficiency for PFA in jetty events.
  High tracking efficiency also requires minimization of dead spaces near the boundaries of readout modules.
- **Minimum material:** for PFA calorimeters behind, also to facilitate extrapolation to the inner Si tracker and the vertex detector



Recoil Mass Measurement

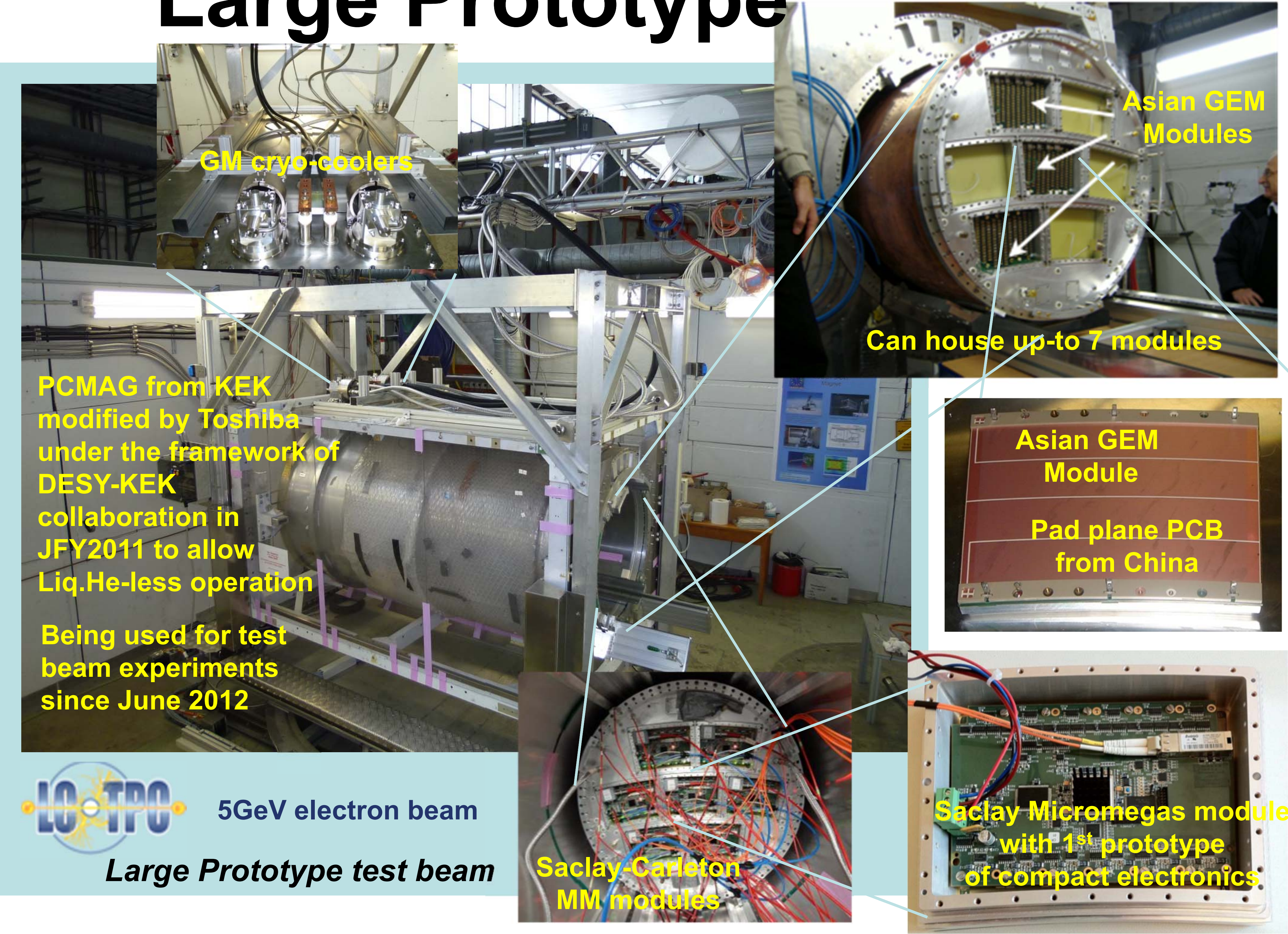


$H\to\mu^+\mu^-$



***P**article **F**low **A**nalysis*

Large Prototype



GM cryo-coolers

PCMAG from KEK modified by Toshiba under the framework of DESY-KEK collaboration in JFY2011 to allow Liq.He-less operation

Being used for test beam experiments since June 2012

5GeV electron beam

Large Prototype test beam

Asian GEM Modules

Can house up-to 7 modules

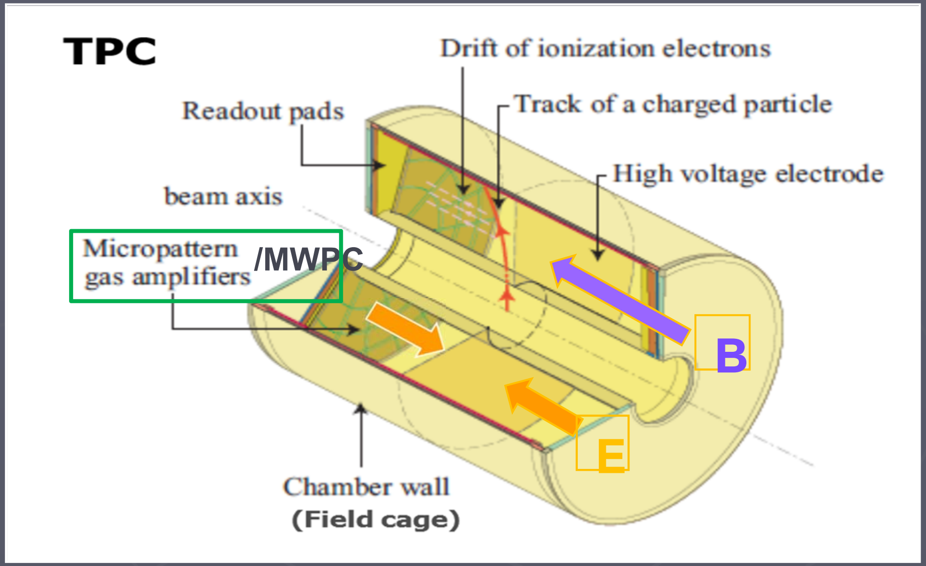
Asian GEM Module

Pad plane PCB from China

Saclay-Carleton MM modules

Saclay Micromegas module with 1st prototype of compact electronics

Time Projection Chamber (TPC)



Consists of:	**R&D/prototype**
(1) A field cage/gas container:	LP1 TPC field cage
(2) A central cathode:	
(3) Two endplates:	LP1 and Space-frame prototype
(4) MPGD modules:	Different prototypes for LP beam test
(5) Readout electronics:	ALTRO, S-ALTRO16 (16ch version T2K and T2K compact (all for LP)
(6) 50kV HV system and a gas system:	
(7) Cooling & temperature control :	A test system of 2PCO2 cooling
(8) Software package:	Marlin TPC

MPGD Technology
and
MPGD module

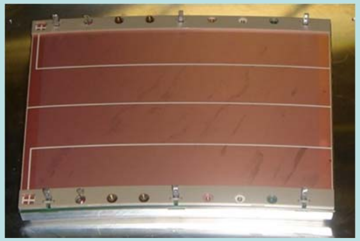
MPGD Options

After the initial stage of R&D with many small TPC prototypes, we are left with three options of MPGD TPC readout technologies for ILC, being tested at the Large prototype (LP) TPC at DESY.

I. Analog (Pad) TPC: **Subject to the gas gain fluctuation in the gas amplification. Need to spread the avalanche charge for charge centroid.**

(1) Multi layer GEM with the standard pad (~1x5mm^2) readout :
(charge spread by diffusion)
Asian (KEK-Saga-Tsinghua) Module, DESY module

Asian GEM module



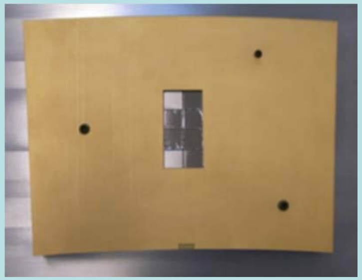
(2) Micromrgas with the resistive-anode (pad: ~3x7mm^2) readout :
Saclay-Carleton Module

MM (resistive anode)

II. Digital (Pixel) TPC: **Free from the gas gain fluctuation. Expect 20-30% improvement of position resolution in the case of digital readout.**
No angular pad effect.
Theoretically the best but not yet ready for full implementation of a module.

(3) InGrid Micromegas mesh on Timepix chips (pixel: ~50x50µm^2)
NIKHEF-Saclay Module, Bonn-module

InGrid+Timepix



→ being tested in ***Large Prototype*** at DESY

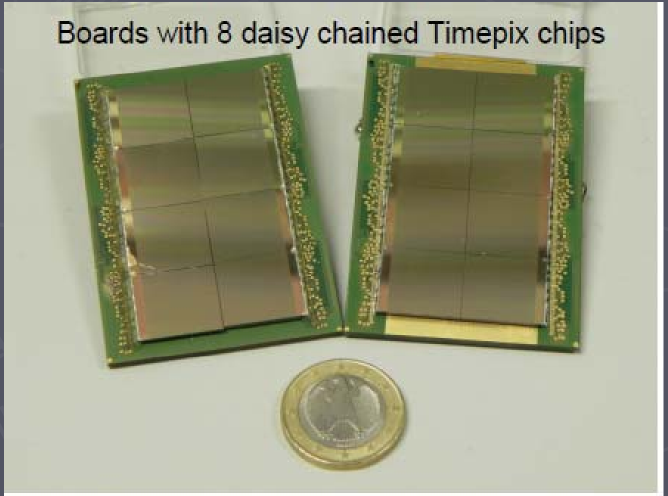
The Best MPGD TPC?

From the Principles of the Gas Physics and MPGD

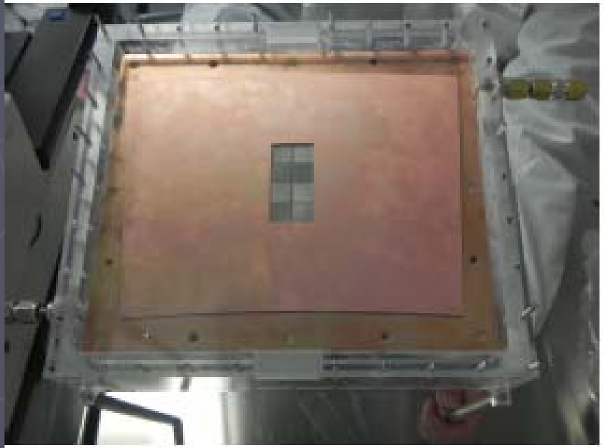
How to utilize all the information ionization electrons carry when No. of electrons and the diffusion are determined by TPC gas, the TPC lever arm, the max drift distance, and the magnetic field.

The Best: The Digital TPC (Grid Pix TPC)

Measure the arrival times and positions of all ionization electrons from all particle tracks individually by using the micromegas structure (the grid pix). Free from the gas gain fluctuation: some 30% improvement in the position resolution. Very elegant when realized!

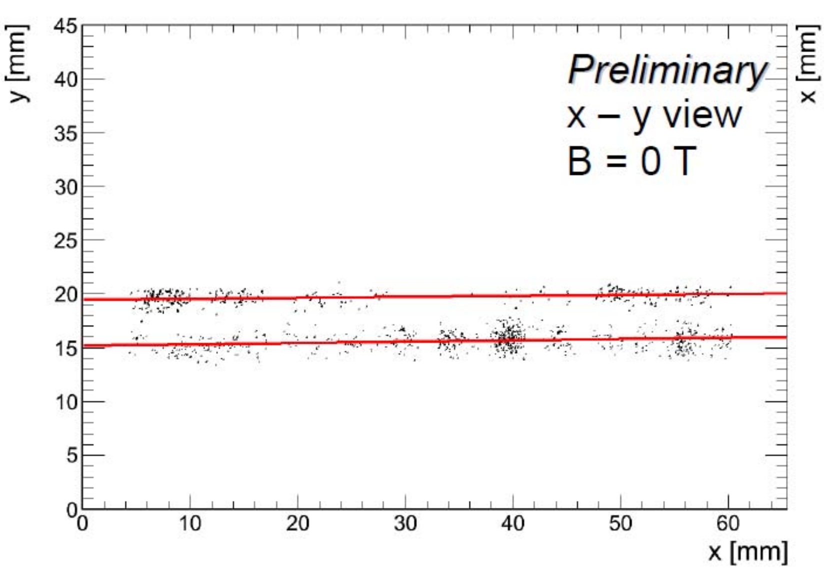


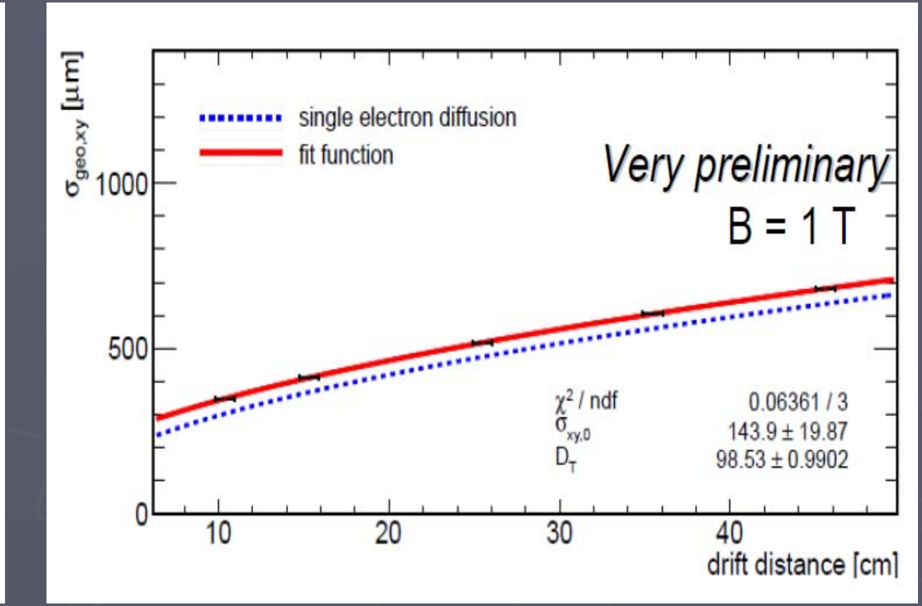
Michael Lupberger MPGD2013



Michael Lupberger MPGD2013

Recent results: MPGD2013（M. Lupberger）:





To be done:

Dead region and distortion in the chip boundaries. Remove the wire bonding by the silicon through holes -> Timepix III.

Cooling and temperature control for TPC (a separate pixel-pad plate with cooling the time pixels might be bonded on?)

Miniaturized backend electronics of higher performance.

Position and time measurement of “all” electrons for the full drift distance of ILD TPC (the multi hit capability).

Ideas to implement the Ion gate?

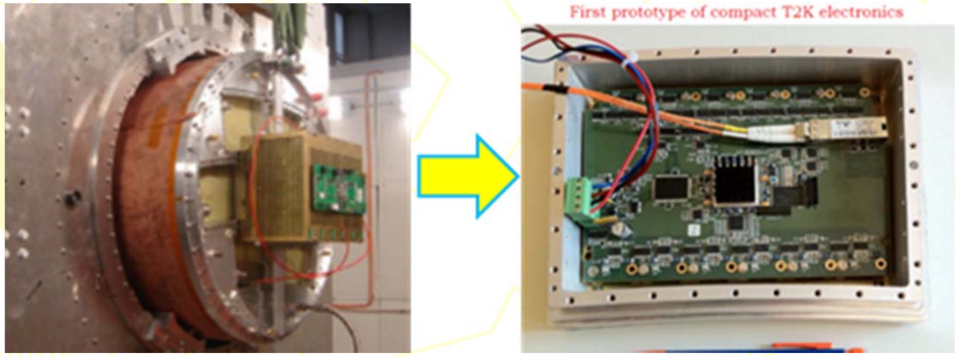
The Best MPGD TPC?

"Based on the Principles of the Gaseous TPC and MPGD"

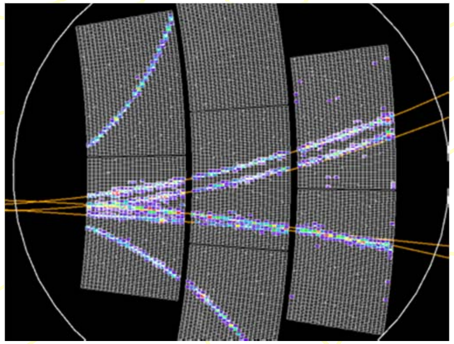
The second to the best: The Analog TPC (Pad TPC).

May be more practical at this moment. The Standard pad TPC. The position of electron obtained by the pulse heights of a few pads. Subject to the gas gain fluctuation. Use only a part of the electrons (the Effective No. of electrons Neff to obtain the hit point. Then a 30% degradation in the position resolution compared to the ideal digital TPC.

(1) **Micromegas LP module with the resistive anode:** With the nice compact T2K electronics. (Unfortunately the T2K electronics can not be used at ILD TPC.)



T2K electronics (Aug. 2012)



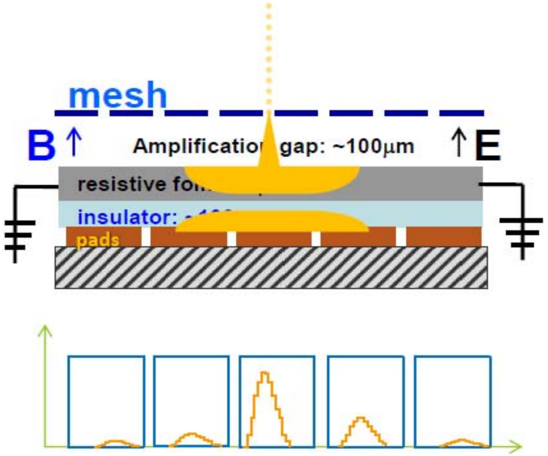
An event with the 7 modules
In the beam test in 2012.

Charge dispersion by the resistive anode does not see real charges.

$$\frac{\partial \rho}{\partial t} = \frac{1}{RC}\left(\frac{\partial^2 \rho}{\partial r^2} + \frac{1}{r}\frac{\partial \rho}{\partial r}\right)$$

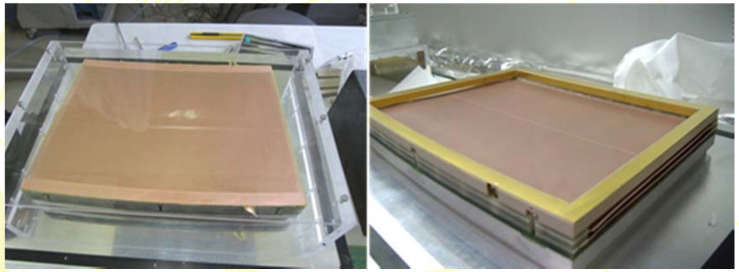
$$\Longrightarrow \rho(r,t) = \frac{RC}{2t} exp\left(\frac{-r^2 RC}{4t}\right)$$

$\rho(r,t)$: the surface charge density
R: the surface resistivity of the resistive layer
C: the capacitance per unit area.

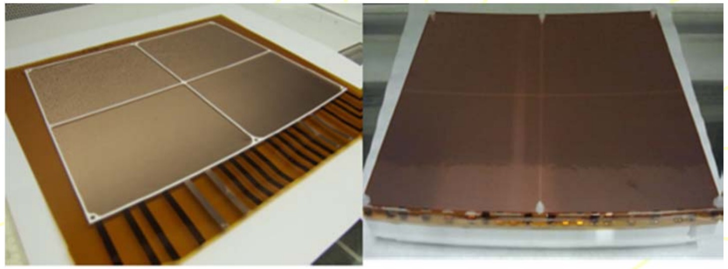


There has been a question if any effect of signal pile up due to the resistive anode in high occupancy? Nice to see a simulation results for ILC event + backgrounds.

(2) LP GEM modules with narrow pads (Pa d: 1mm wide):

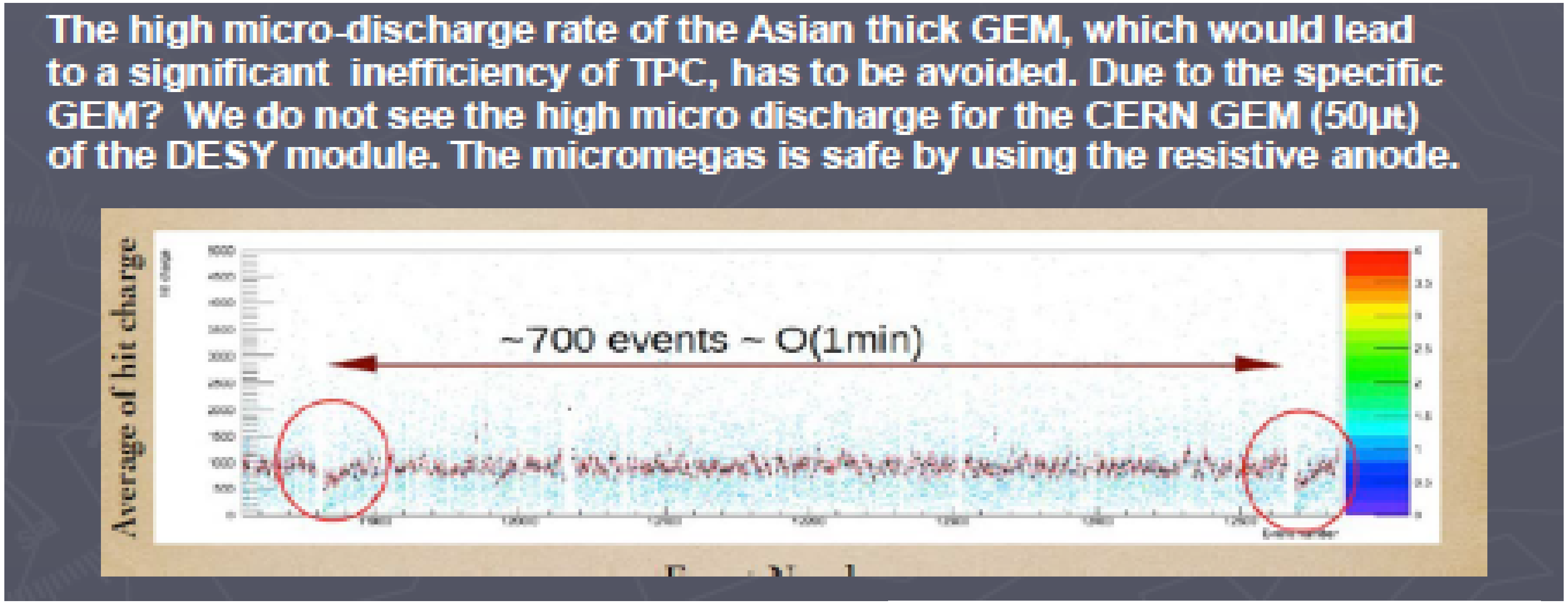


Asian GEM module: Double thick (100µm) GEM without the side support in the sides of GEM. With (Left)/without(Right) a GEM ion gate (50% electron transmission).

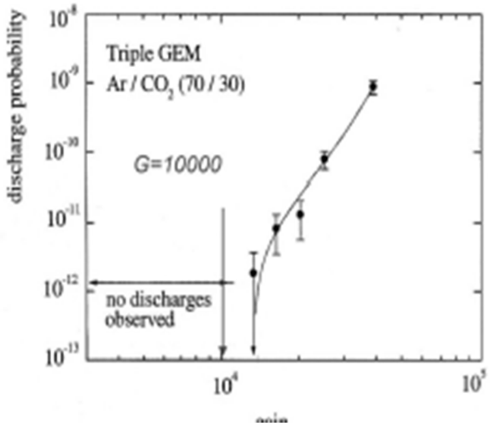


DESY GEM module: Triple CERN GEM with thin (1mmt) ceramic GEM frame (white).

Micro-discharge

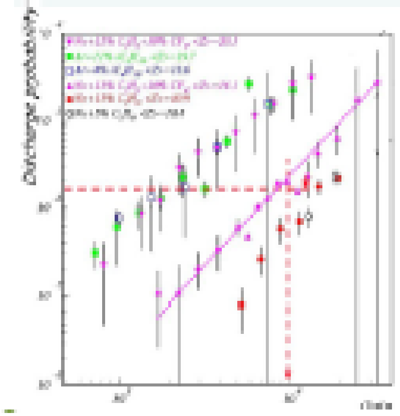


The high micro-discharge rate of the Asian thick GEM, which would lead to a significant inefficiency of TPC, has to be avoided. Due to the specific GEM? We do not see the high micro discharge for the CERN GEM (50μt) of the DESY module. The micromegas is safe by using the resistive anode.



discharge probability of the tracker of COMPASS: $<10^{-12}$

GEM



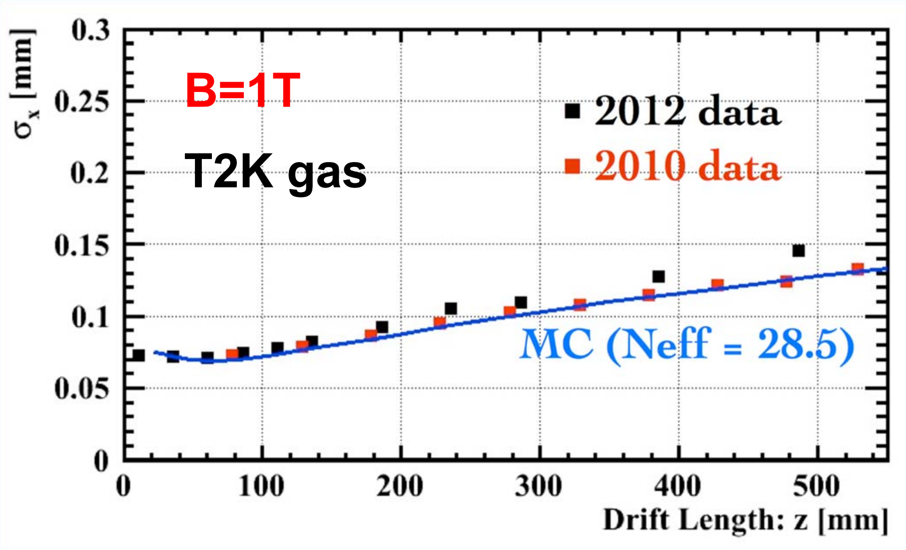
discharge probability of the tracker of COMPASS: $\sim10^{-6}$

Micromegas

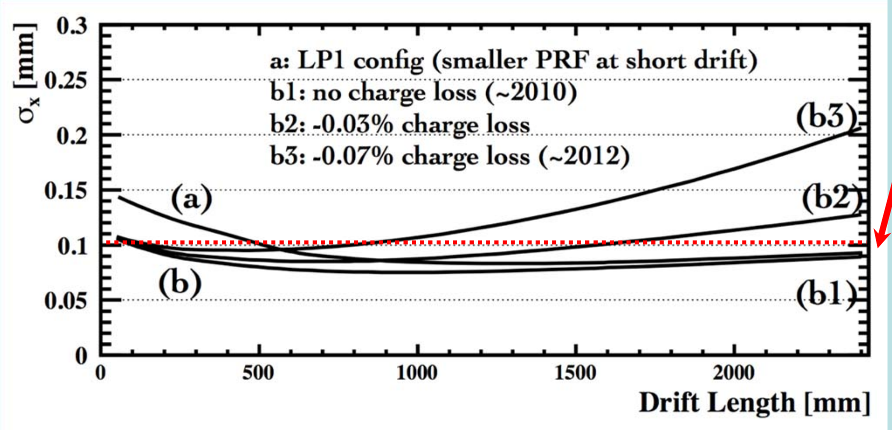
(Note: One discharge was found for the whole LP beam test runs of the DESY modules.)

Spatial Resolution

Asian GEM Module

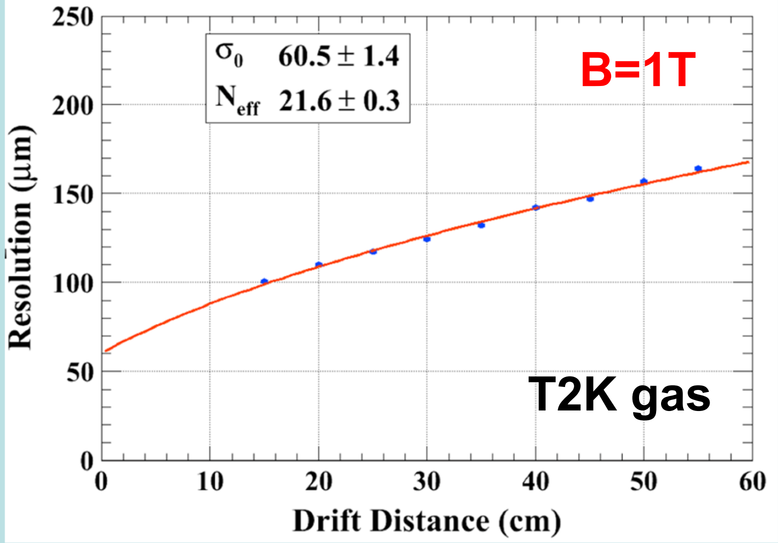


Extrapolation to B=3.5T

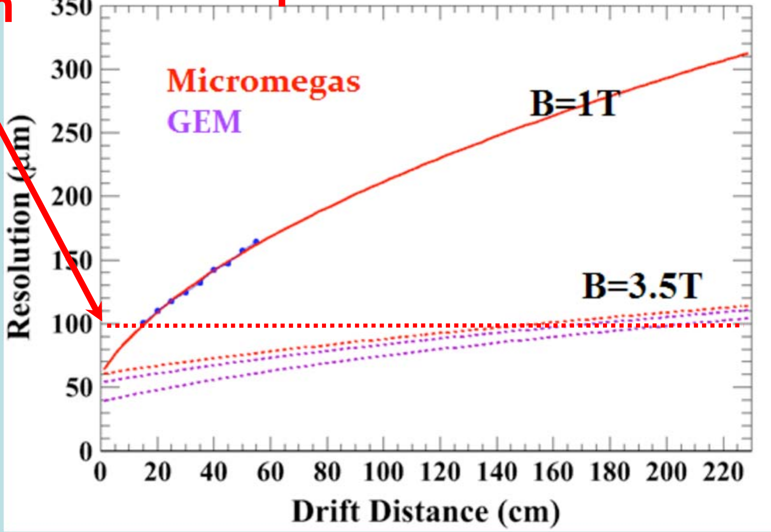


$\sigma_{r\varphi}$=100 μm

Saclay-Carleton MM Module



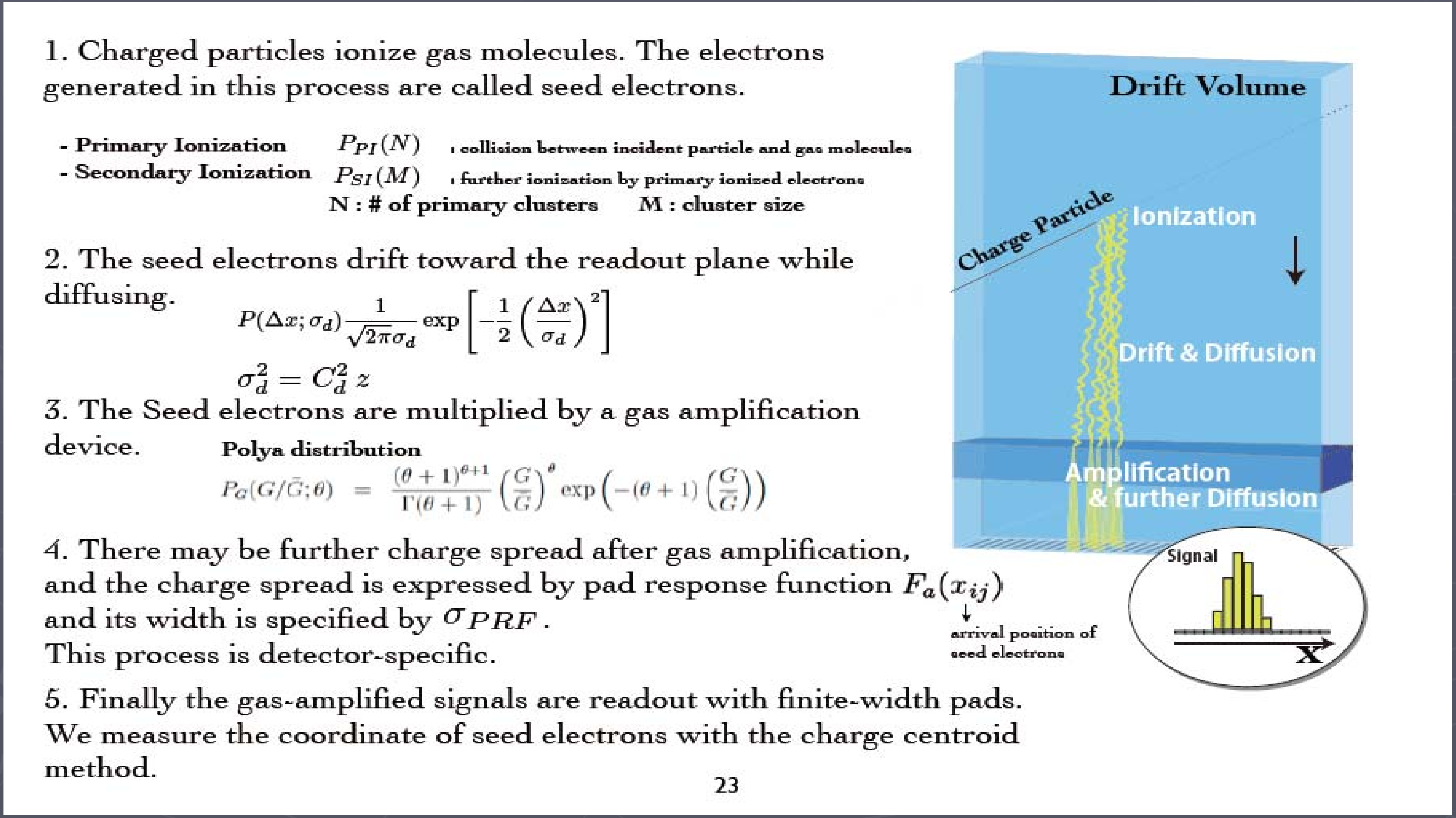
Extrapolation to B=3.5T



Both options seem to satisfy the $\sigma_{r\varphi}$=100μm requirement!

Resolution Formula for GEM TPC

Since TPC operates on the nice and old “gas physics”; ionization, diffusion, gas amplification and fluctuation etc, we have derived for the GEM TPC (the option (1)) the full analytic presentation of the point resolution.



1. Charged particles ionize gas molecules. The electrons generated in this process are called seed electrons.

- **Primary Ionization** $P_{PI}(N)$: collision between incident particle and gas molecules
- **Secondary Ionization** $P_{SI}(M)$: further ionization by primary ionized electrons

N : # of primary clusters M : cluster size

2. The seed electrons drift toward the readout plane while diffusing.

$$P(\Delta x;\sigma_d)\frac{1}{\sqrt{2\pi}\sigma_d}\exp\left[-\frac{1}{2}\left(\frac{\Delta x}{\sigma_d}\right)^2\right]$$

$$\sigma_d^2 = C_d^2\, z$$

3. The Seed electrons are multiplied by a gas amplification device.

Polya distribution

$$P_G(G/\bar{G};\theta) = \frac{(\theta+1)^{\theta+1}}{\Gamma(\theta+1)}\left(\frac{G}{\bar{G}}\right)^{\theta}\exp\left(-(\theta+1)\left(\frac{G}{\bar{G}}\right)\right)$$

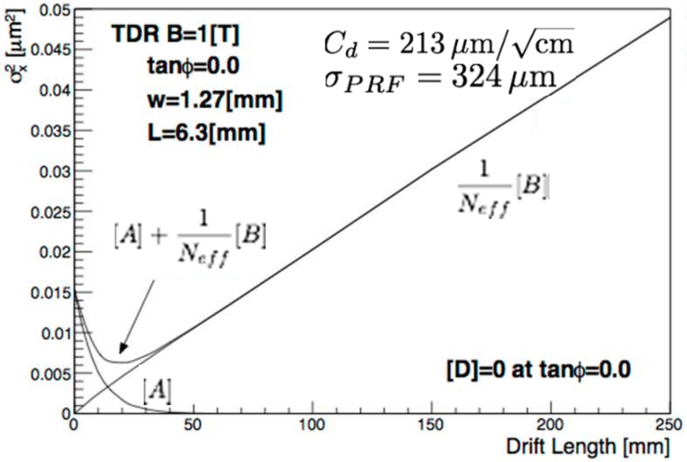
4. There may be further charge spread after gas amplification, and the charge spread is expressed by pad response function $F_a(x_{ij})$ and its width is specified by σ_{PRF}.
This process is detector-specific.

↓ arrival position of seed electrons

5. Finally the gas-amplified signals are readout with finite-width pads. We measure the coordinate of seed electrons with the charge centroid method.

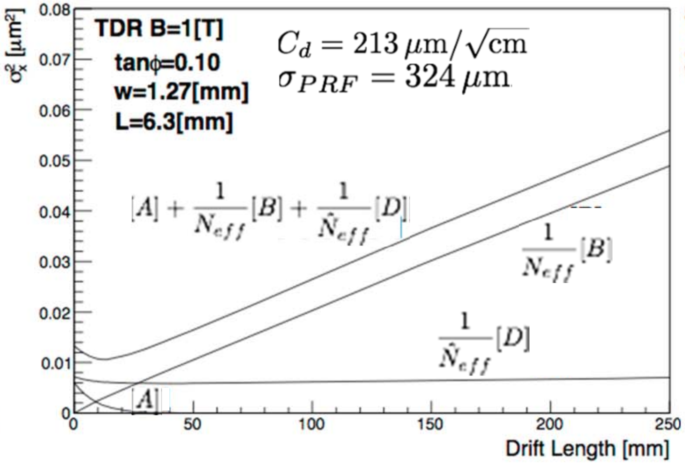
Some Examples from the Resolution Formula

Perpendicular track



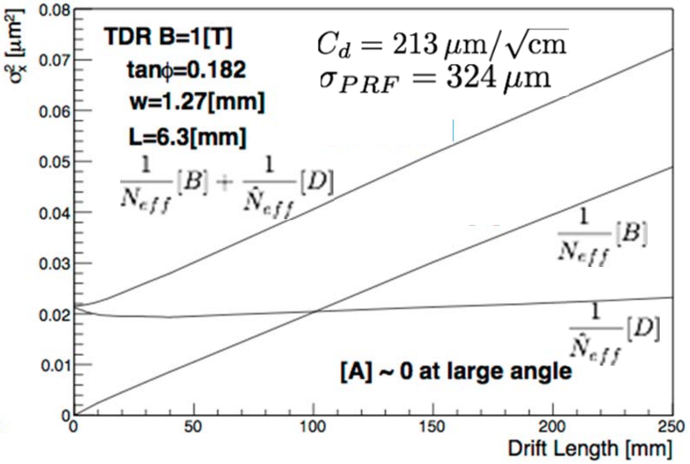
[D] is invisible.

Inclined track (tanφ=0.1)



[A] becomes smaller.
[D] becomes visible.

Inclined track (tanφ=0.18)



[A] becomes invisible.
[D] becomes sizable.

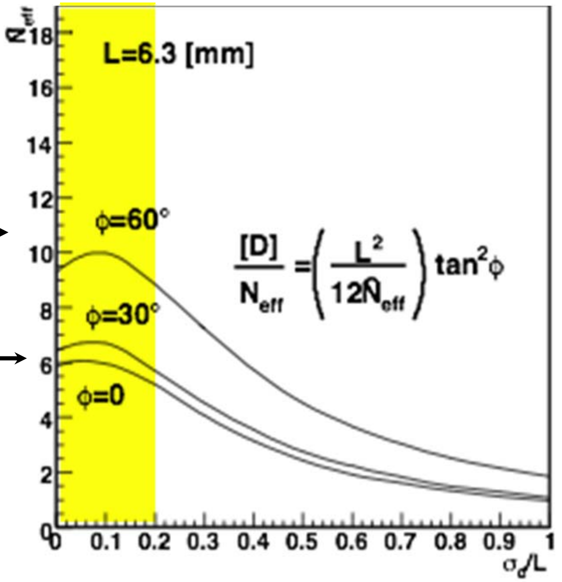
The σ_d/L will not exceed 0.2 for the LC-TPC.

$\hat{N}_{eff}$ is roughly constant in this range.

[D] term contribution is determined
not by N_{eff} but by $\hat{N}_{eff}$

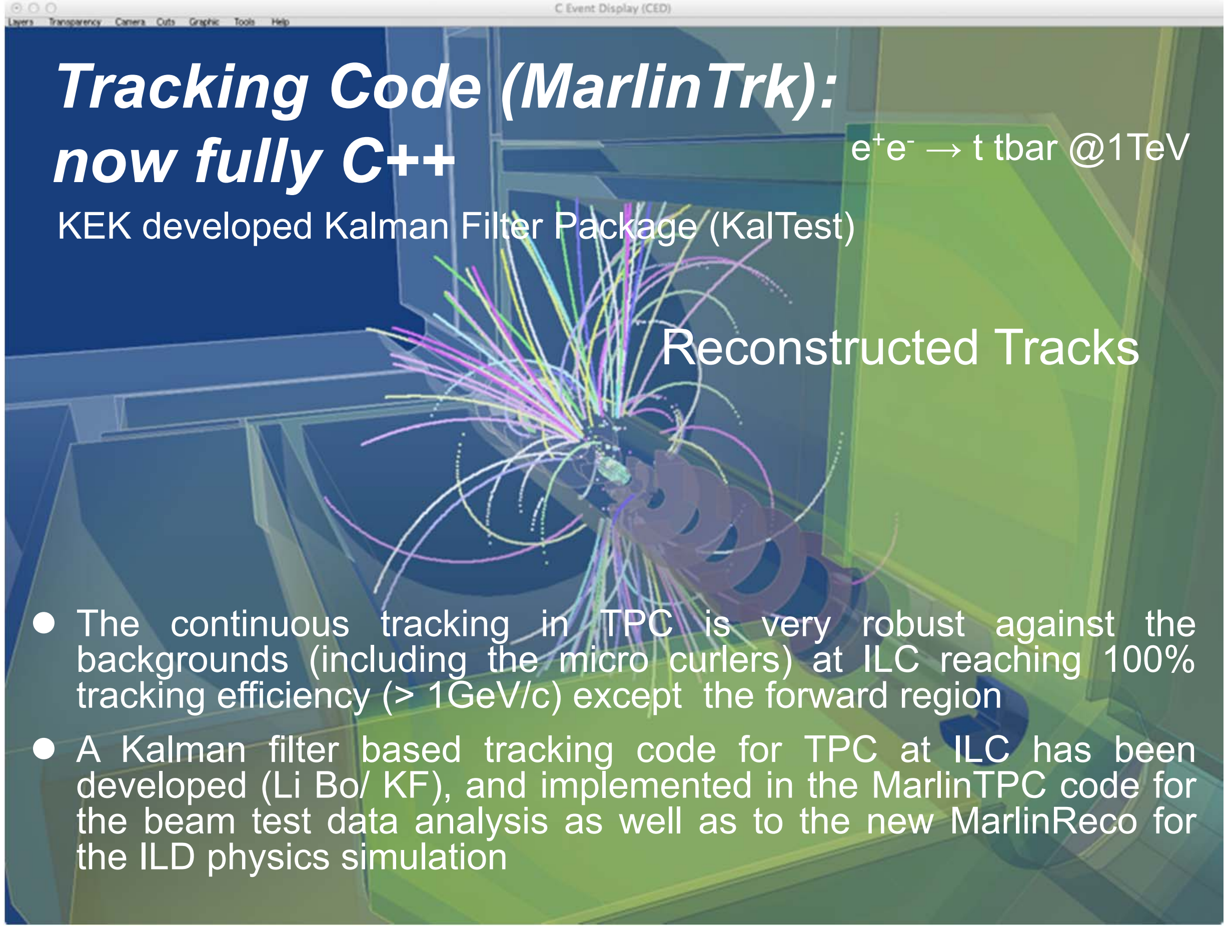
$\hat{N}_{eff} \ll N_{eff}$ → **σ_x quickly deteriorates with angle.**

tanφ=0.18
-->φ=10°



Expected TPC Performance

Tracking for LP TPC and ILD TPC



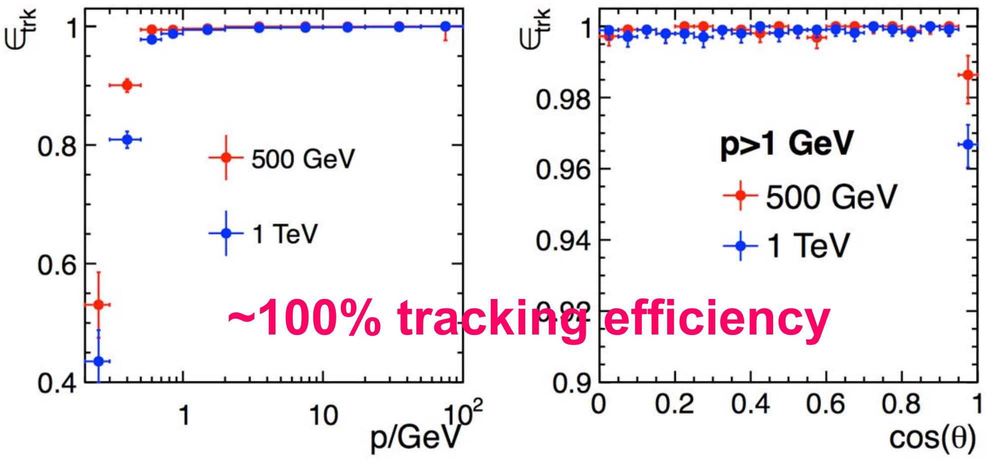
Tracking Code (MarlinTrk): now fully C++

$e^+e^- \rightarrow t\,\bar{t}$ @1TeV

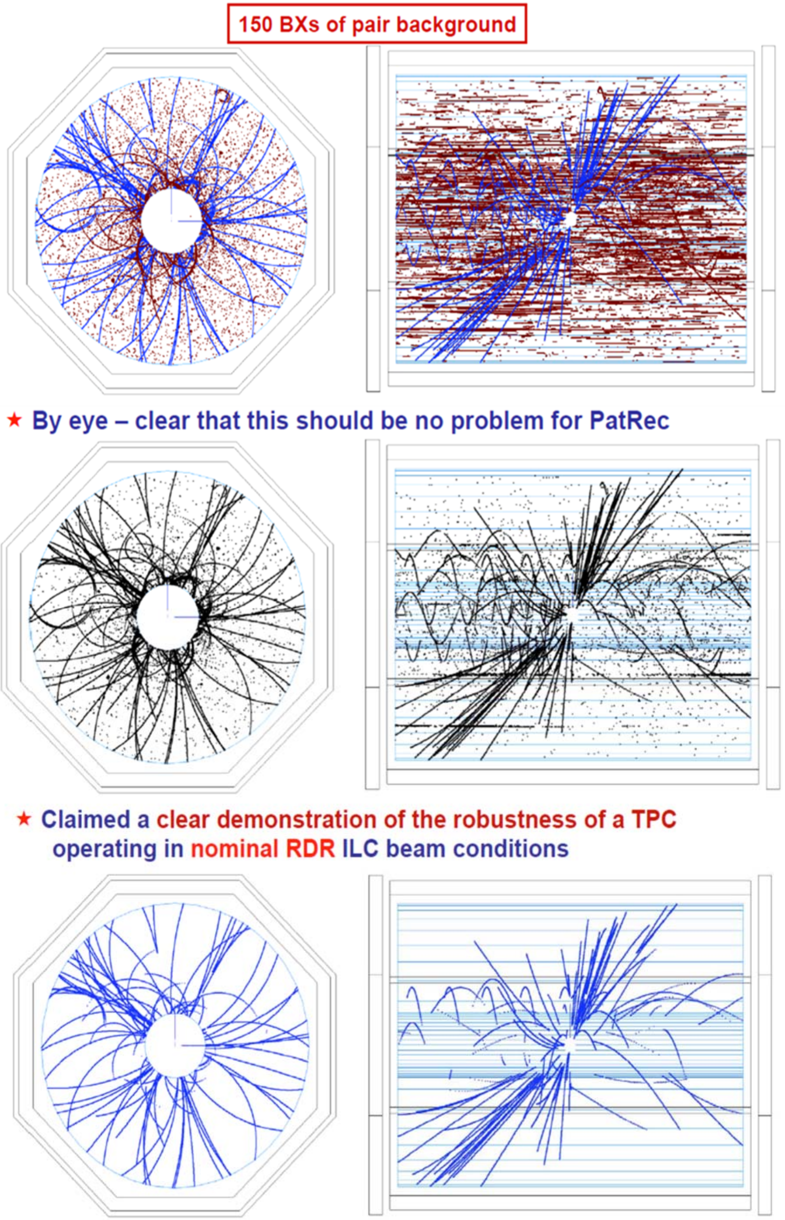
KEK developed Kalman Filter Package (KalTest)

Reconstructed Tracks

- The continuous tracking in TPC is very robust against the backgrounds (including the micro curlers) at ILC reaching 100% tracking efficiency (> 1GeV/c) except the forward region
- A Kalman filter based tracking code for TPC at ILC has been developed (Li Bo/ KF), and implemented in the MarlinTPC code for the beam test data analysis as well as to the new MarlinReco for the ILD physics simulation



~100% tracking efficiency



150 BXs of pair background

★ **By eye – clear that this should be no problem for PatRec**

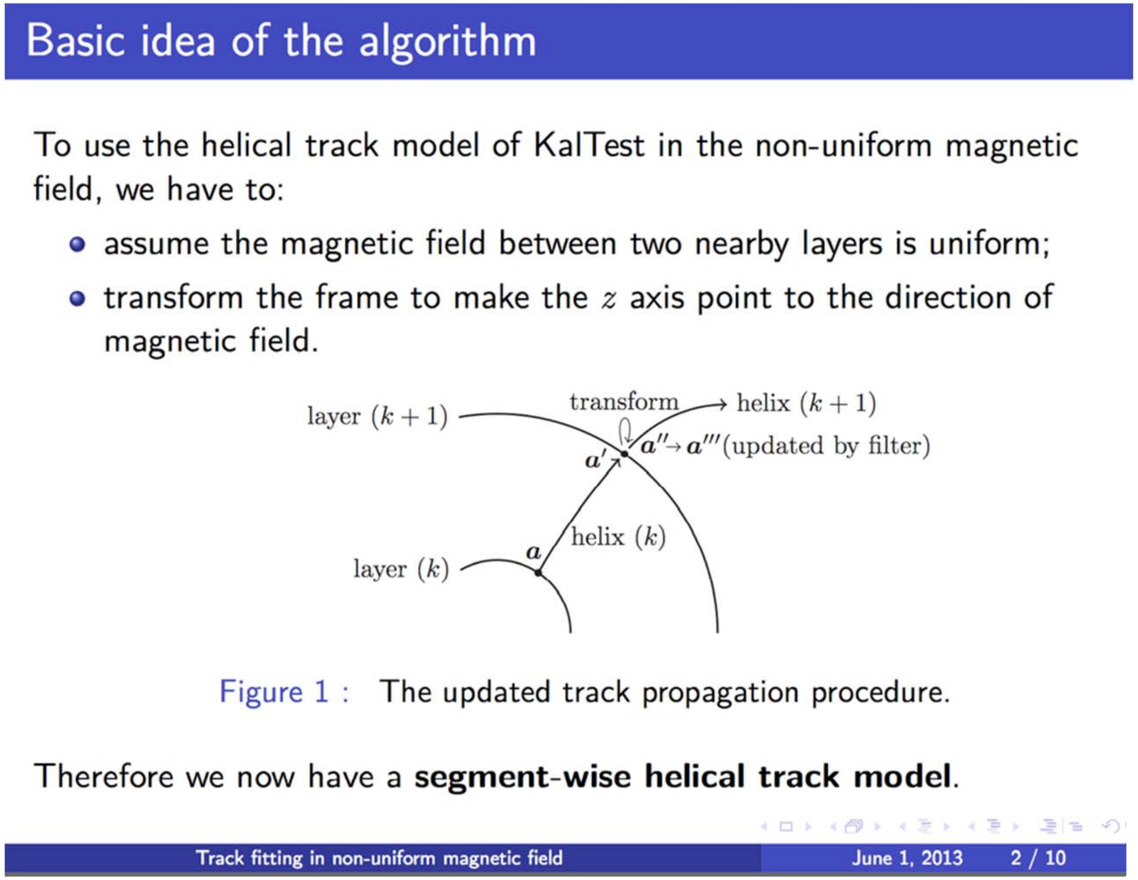
★ **Claimed a clear demonstration of the robustness of a TPC operating in nominal RDR ILC beam conditions**

Despite the more realism (cracks, support structures, and service materials) brought in to the simulator,

PFA performance is now better than that of LoI!

Kalman Filter Based Track Fitting in Non-uniform B Field

arXiv: physics.ins-det/1305.7300



Basic idea of the algorithm

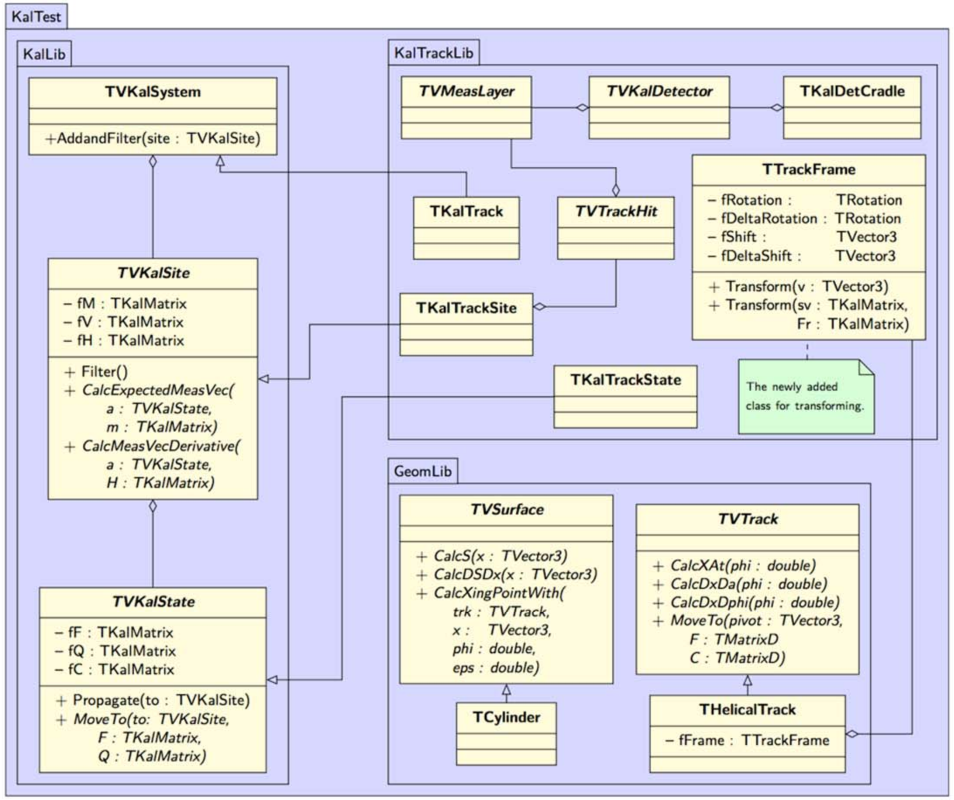
To use the helical track model of KalTest in the non-uniform magnetic field, we have to:

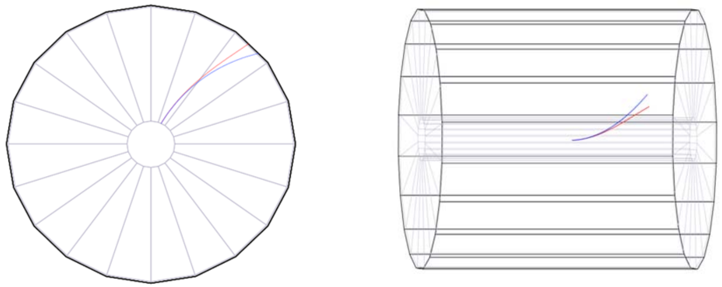
- assume the magnetic field between two nearby layers is uniform;
- transform the frame to make the z axis point to the direction of magnetic field.

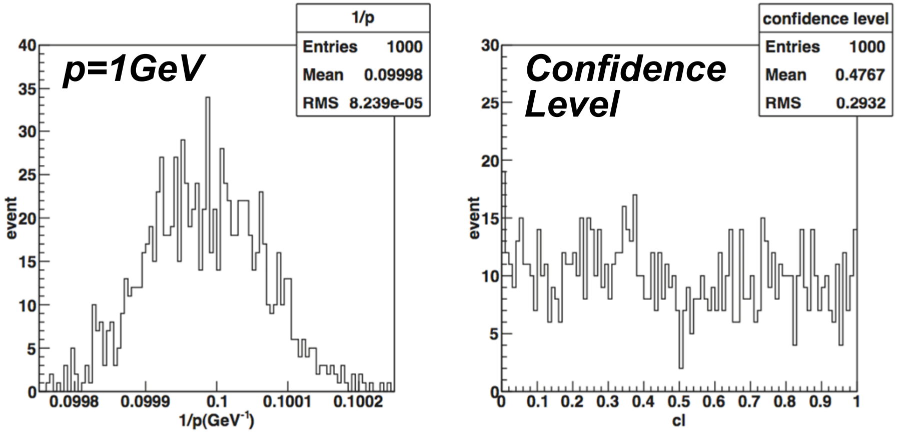
Figure 1 : The updated track propagation procedure.

Therefore we now have a **segment-wise helical track model**.

Track fitting in non-uniform magnetic field June 1, 2013 2 / 10







Works in B field with >40% non-uniformity !

R&D for MPGD TPC

Before ILD DBD for ILC

We have demonstrated through the LP TPC beam tests at DESY:

(1) The basic performance of the MPGD TPCs, in particular, the pad readout options, satisfy the basic requirements for ILD TPC at ILC:

- **MWPC option ruled out,**
- **Micromegas option w/o resistive anode ruled out,**
- **The best possible spatial resolution understood by the analytic formula,**
- **Spatial resolutions by GEM-TPC and Micromegas TPC w/ resistive anode measured at 1T and extrapolated to 3.5T,**
- **Single-electron spatial resolution of the digital TPC measured, and,**
- **Extrapolation confirmed (< 60cm drift) at 4T in the DESY 5T magnet.**

(2) How to build important components of ILD TPC:

- **Thin field cage**
- **Light endplate (Al)**
- **MPGD TPC modules**
- **Experience of the operation of LP TPC**

Outlook
of
R&D for the ILD TPC

LCTPC Review
by
the ECFA Detector ~~R&D~~ Panel
on 4 November 2013

Takeshi Matsuda and Ron Settles
on behalf of LCTPC collaboration

R&D for MPGD TPC

After ILD DBD for ILC

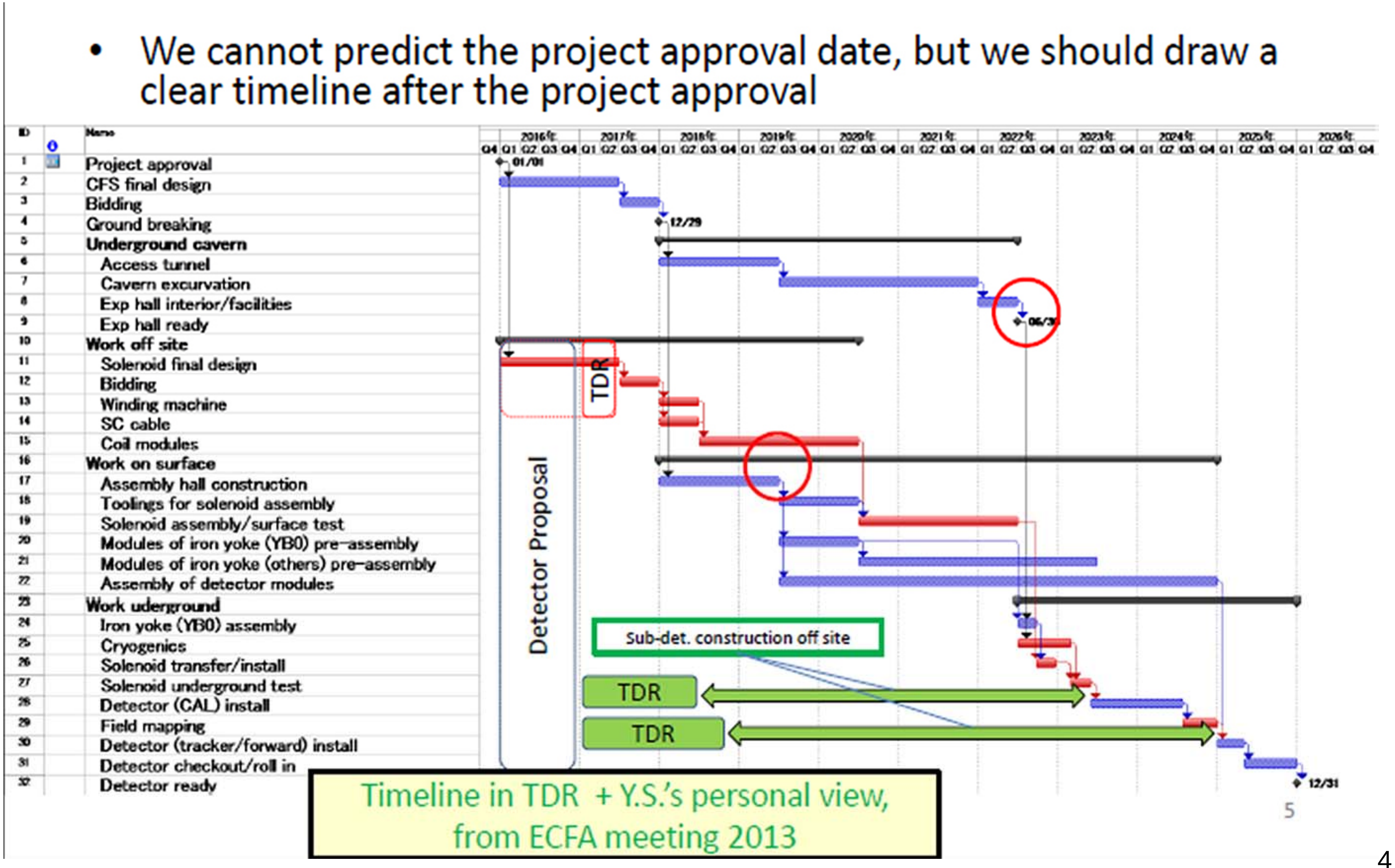
There are, however, a few important basic issues still remain to be addressed before the detector proposal for ILC

Otherwise, we are entering the phase toward the final design of the ILD TPC.

The earliest schedule (next slide) of the construction of ILD detector shown in the ILD meeting at Cracow (Sept 2013) looks very tight though it may deeply depend on the political situation.

A Possible Schedule of ILC in Japan

As presented in the 2013 ILD meeting in Cracow



- We cannot predict the project approval date, but we should draw a clear timeline after the project approval

ID	Name
1	Project approval
2	CFS final design
3	Bidding
4	Ground breaking
5	**Underground cavern**
6	Access tunnel
7	Cavern excurvation
8	Exp hall interior/facilities
9	Exp hall ready
10	**Work off site**
11	Solenoid final design
12	Bidding
13	Winding machine
14	SC cable
15	Coil modules
16	**Work on surface**
17	Assembly hall construction
18	Toolings for solenoid assembly
19	Solenoid assembly/surface test
20	Modules of iron yoke (YB0) pre-assembly
21	Modules of iron yoke (others) pre-assembly
22	Assembly of detector modules
23	**Work underground**
24	Iron yoke (YB0) assembly
25	Cryogenics
26	Solenoid transfer/install
27	Solenoid underground test
28	Detector (CAL) install
29	Field mapping
30	Detector (tracker/forward) install
31	Detector checkout/roll in
32	Detector ready

Timeline in TDR + Y.S.'s personal view, from ECFA meeting 2013

Remaining R&D Issues

Before entering the engineering design of ILD TPC, we still need to study the following issues:

A) Ion gate: the most urgent issue,

B) Some issues with MPGD technologies and MPGD modules,

C) Local distortions of MPGD modules,

D) Demonstration of power pulsing (with the SALTRO16 electronics)

E) Cooling of readout electronics and temperature control of TPC

F) Measurement of basic parameters and demonstration of the performance of MPGD TPC in 3.5T magnetic field. Also some engineering issues to be confirmed in the high magnetic field.

Remaining Issues

Ion Gate: The most urgent issue

***We need a ion gate*:**	**To prevent the backflow of positive ions from the gas amplification region of the MPGD modules to the drift space of TPC. Distortions by the primary ions at ILC are still negligible.**

***Options of ion gate*:**

GEM gate:	**Tested with the electron transmission of 50%.** **Electron transmission: Can be higher toward at least >70%?** **Mechanically most friendly to the current MPGD modules.**
Traditional wire gate:	**Known to work with high electron transmission (LEP etc.),** **Distortion due to the radial wires?** **Mechanical issue to mount on the MPGD module.**
Wire mesh or grid:	**A solution never be tested.** **One with high ion suppression?** **Mechanical issue to mount on the MPGD module.**

It is urgent **Need to select one option (by early 2015) to beam test new modules with the gate before TDR (2017-2018).**

R&D for GEM gate with electron transmission >70% underway.
Measurement of the distortion due to the radial wires (by a laser beam) planned.
Design of module structure with a gate (in particular, the wire gates) needed.

Remaining Issues

MPGD technologies and MPGD modules

Micromegas module w/ resistive anode: Possible signal pileup in the resistive anode at the ILC environment ?

We need a confirmation by simulation that the performance of the Micrormegas with the resistive anode would not be deteriorated by the signal pile up in the resistive anode in the ILC environment. The real charges of Micromegas spread in the resistive anode toward the sides of the resistive anode with some time delays. When many hits, the pads see induced charge of the sum of the current. The pile up depends how the induced signals of different origins might overlap each other in "one event frame" of TPC (typically in the order of 1 μs).

GEM modules: Are the current modules reliable enough for the ILD TPC?

HV connections to GEMs, GEM stretching, Micro discharge of GEM,,,

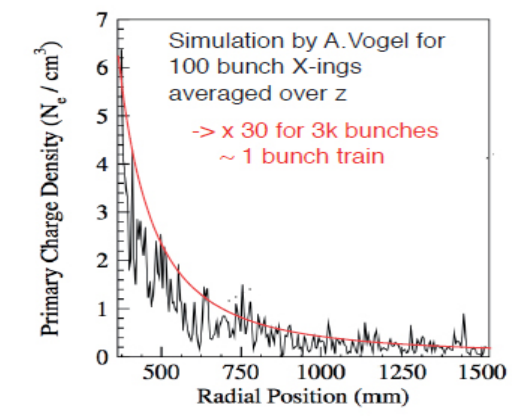
InGrid module: An early transition to Timepix 3 necessary.

Need a module design for ILD TPC with all through-silicon holes to remove all the wire bonding around the InGrid chips, the origin of dead space and distortion.

For all modules: A design with the gate!

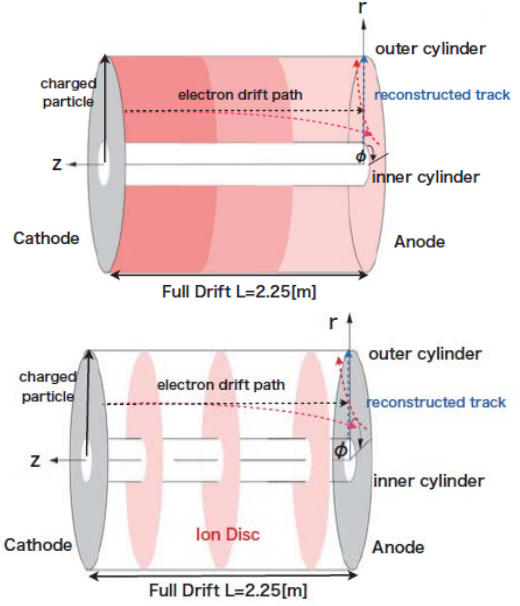
Positive Ions and Ion gate for ILC

- Solve the Passion equation for a given ion density distribution with proper boundary conditions. Then , estimate the distortion of drift electron trajectory by the Langevin equation.
- Estimate the effect of he primary ions and the secondary ions from the amplification w/wo a gating device.
- **For the ion feed back ratio of >10^{-3} (measured both for the triple GEM and Micromegas) and the gas gain of 1,000, an efficinet ion gate device is mandatory.**



No two-photon hadron BG included.
-> underestimate

	without Gating Device	with Gating Device
Primary Ion	8.5μm	8.5μm
Secondary Ion	60μm	0.01μm
sum	70μm	8.5μm



Remaining Issues

Local Distortion

All current LP modules see large distortions; The old TPC problem in the new regime.

We need to minimize the distortions in the hardware level, and, then correct remaining distortions by software.

(1) Distortions due to specific module structures

Micromegas module:	**Grounded guard structure around the module** **To be modified only in next module.**
Asia GEM module:	**Large gaps of the segmented electrodes on the top surface of GEM (a simple mistake with a fear for GEM breakdown)**

(2) Distortions at the module boundary and the 1mm gap:

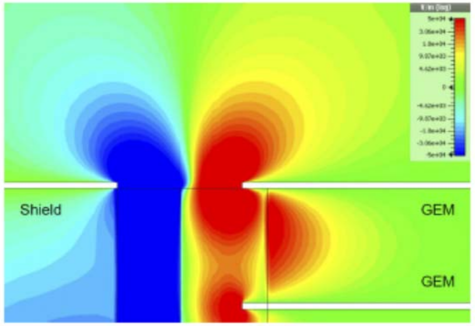
E-field calculation and simulation can suggest solutions to reduce the distortion.
Confirm the solutions by beam tests or laser- beam tests.

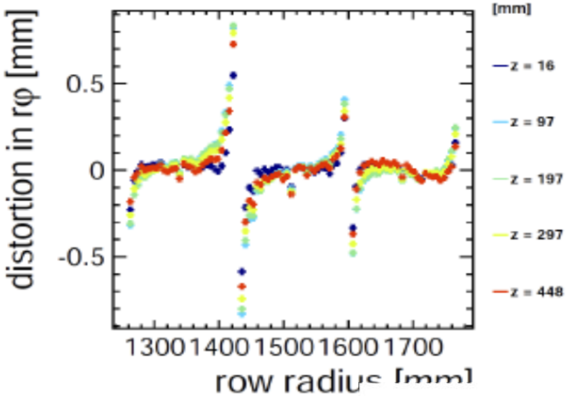
(3) Develop software to correct remaining distortion after (1) and (2)

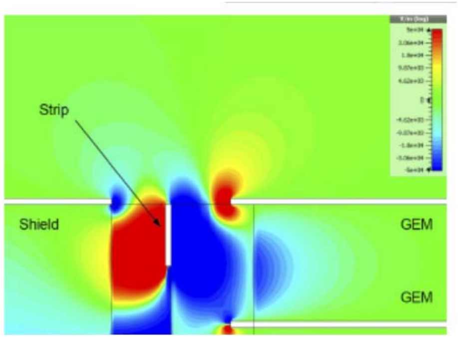
Some deterioration of the spatial resolution will remain after the correction.

Distortions of LP Modules

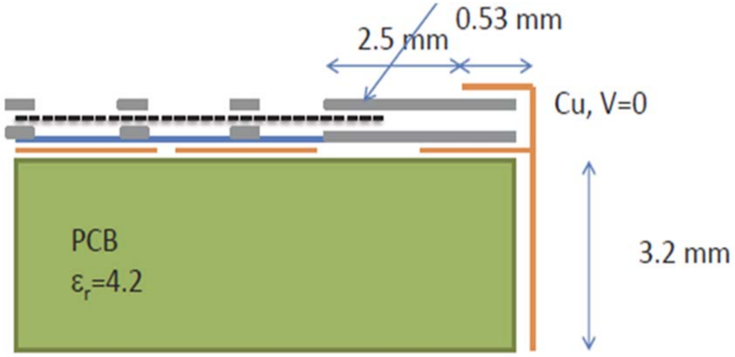
The case of DESY GEM LP module: Due to the 1mm gap between the modules.
Can be improved by additional electrods.



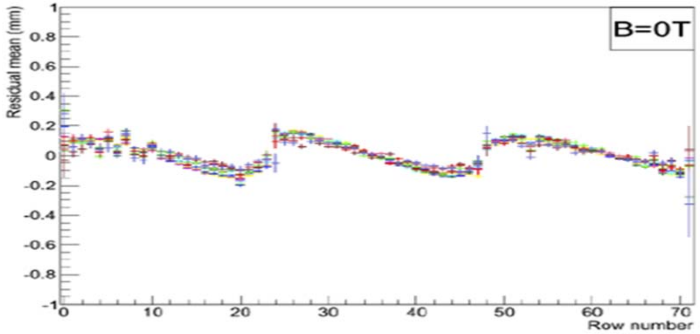


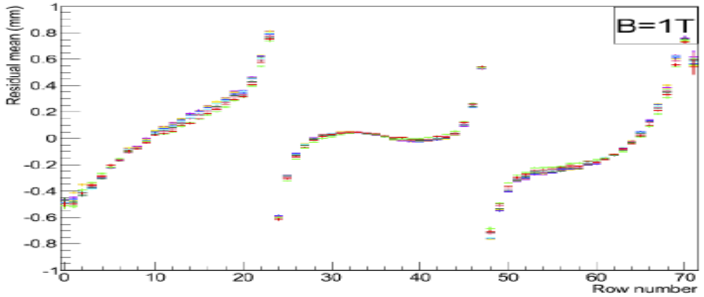


The case of Micromegas LP module



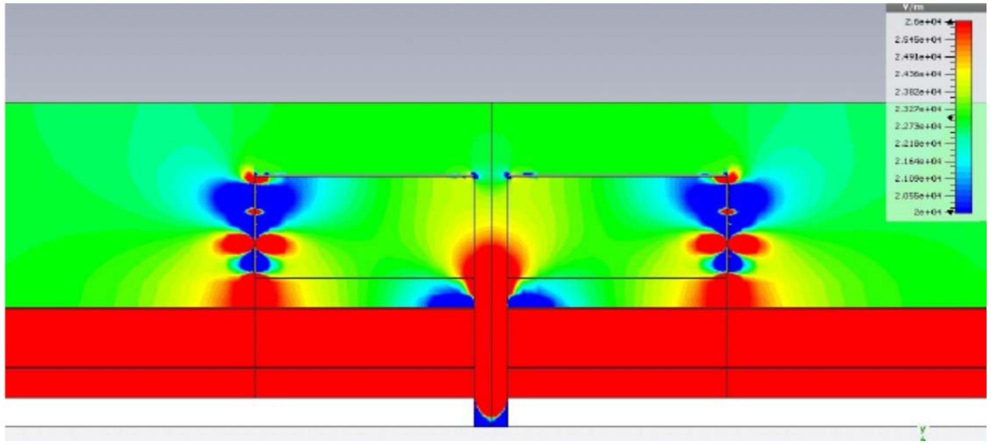
Due to the specific structure around the module. Need to modify the module.





Asian GEM module:

The upper and lower rims the Asian module to stretch GEMs are wide and have 3 field shaping strips in their inner sides.



Remaining Issues

Cooling and Temperature Control of TPC endplate

Two phase CO2 (2PCO2) cooling for ILD TPC endplates:

Installing readout electronics directly on the MPGD module while we keep the pad plane of the module at a given TPC temperature. The temperature control of the pad plane of the module and a proper cooling of electronics become important. 2PCO2 cooling has advantages of constant temperature and high pressure and compact cooling circuit.

(1) Set up two small 2PCO2 cooling units for test at KEK and DESY (currently at NIKHEF) in the beginning of 2014.

(2) The first cooling test of the T2K electronics on the Micromegas module soon. Mock up tests for the S-ALTRO16 electronics in early 2014.

Thermal design of the whole ILD TPC :

ILD TPC design has no thermal jackets on the field cages to minimize the material budget. Addressed in the final design of ILD TPC.

Remaining Issues

Power pulsing and power delivery

Need power pulsing even for low readout electronics at ILD TPC:

(1) Power pulsing of SALTRO16 chip has been demonstrated in the chip test. The reduction factor expected for the ILC bunch structure was around 30.
(2) Power pulsing in LP TPC beam test by SALTRO16 electronics is foreseen.

The power delivery issue has not been addressed so far:

Should be studied together in the design of the final readout electronics for the ILD TPC.

Remaining Issues

Demonstrations in the 3.5T magnetic field

Tests in the 3.5T magnetic field:

(1) Confirmation of performance of MPGD TPC and ion gates,
(2) Measurements of basic parameters of TPC gas, and ,
(3) Engineering issues such as possible mechanical vibration due to the power pulsing .

The problem: A high field solenoid need to be found!

The DESY 5T magnet (KOMAG) has been dismantled from the new He line at DESY for some time. We need either to revive the 5T magnet (by moving it to one of our institutes or by a modification), or to find another high field magnet available for us. With our limited human resource, very preferable to set it up in one of our institutes. A solenoid is preferred.

Remaining Issues

Optimization of ILD TPC

Optimization of the ILD detector in coming few years:

Some specific issues for TPC such as dE/dX performance which we have not addressed very well both in measurement and simulation.

Final specification of ILD TPC before prioritization of different MPGD technologies in TDR:

The final design of the ILD TPC will be given in TDR in 4 - 5 years. We review our specification of the ILD TPC, based on the results and experience from the LP beam tests. It includes pad size, module size, TPC gas, in particular, in the context of the neutron background, Specifications of TPC readout electronics, calibration and operation of ILD TPC, etc. We need to fully utilize our simulation tool for the optimization.

Toward the Final Design of ILD TPC

Readout Electronics

Our history of TPC readout electronics:

ALEPH electronics (for some small prototype tests)
T2K electronics (for LP TPC)
PCA16 + ALTRO electronics (for LP TPC)
SALTRO16 electronics (for LP TPC)
GdSP? (for ILD TPC)

SALTRO16 chip: ***The first analog-digital integrated chip for low noise application satisfies our specification except the packing density and power consumption (ADC).***

Besides, its hard-wired digital processing not optimized for the MPGD TPC, and the SALTRO development team has been resolved.

GdSP: **New development for a high-density (> 64 ch/chip), lower power chip as the successor of the SALTRO. Situation not very clear now. Need to establish our own group of experts and significant budget urgently.**

Schedule: **With the rapid development of technology and our limited resource, may be realistic to start development after establishment of ILC Lab (in 2017, or, 9 years before the installation of ILD TPC in ILD detector).**

Toward the Final Design of ILD TPC

Field cage, endplates and all

R&Ds in LP TPC so far:

- **Construction of the light and thin field cages for the LP TPC**
- **Construction of the two types of Al endplates for the LP TPC**
- **Some simulation study for the field cage and the Al endplate for ILD TPC**
- **Some study of the TPC support.**
- **Thin central cathode (in prep.)**
- **Tool for the installation of LP module (in prep.)**
- **Laser beam calibration (in prep.)**

Many details of the ILD TPC still to be studied for TDR:

- **Details of mechanical design of ILD TPC and its support,**
- **Design of a support structure for the outer silicon detector on the outer field cage**
- **Structures inside the field cage:**
  - **Details of the central cathode electrode and its HV supply, Resistor chains with a cooling and shielding etc.**
- **Thermal design of ILD TPC**
- **Monitoring system**
- **Measures for earthquakes in Japan**

We need to activate and enlarge our mechanical group asap.

Toward the Final Design of ILD TPC

Software

So far:

Software packages for the LP beam test with its core package Marlin TPC for reconstruction of TPC tracks and analysis with tools necessary for the data analysis at LP TPC.

Study of the local distortions has been made using CST^{TM} and Garfield++.

In coming few years: need to perform more simulation

Implementation of the resistive anode,
Tracking code for the digital TPC,
More studies of local distortion and its correction,
Simulation studies for the optimization,
Update of background including the neutrons,
Design and methods of TPC calibrations,
Demonstration of actual track reconstruction of events in one full bunch train
,,,,,,

What is missing here is not ideas, but human resource for simulation!

Toward the Final Design of ILD TPC

The earliest timeline?

2014-15	**R&D on ion gates and a decision on the ion gate:**
2015-17	**Beam tests of new LP modules with the gate**
2017	**Prioritization of the MPGD technology and module**
2017(*)	**ILC LAB & ILD detector proposal**
2017-19	**Final design of the readout electronics for ILD TPC and its verifications** **Design of ILD TPC**
2018-19(*)	**TDR for the ILD tracking system:**
2019-23	**Prototyping and production: Electronics (chips→boards)** **Prototyping and production: Modules** **Production: Field cage/endplate and all others** **All others**
2024-25	**TPC integration and test**
2026(*)	**TPC Installation into the ILD detector**
2027	**ILC commissioning**

(*) In this slide we delayed by one year the ILD-ILC schedule shown at the ILD meeting at Cracow (Sept 2013) to be a bit more realistic.

Conclusions

Through the LP TPC beam tests at DESY, we have demonstrated that the basic performance of the MPGD TPCs, in particular, the pad readout options, satisfy the basic requirements for ILC (ILD) TPC.

It was there demonstrated how to build some major components of the ILD TPC such as the MPGD modules, the thin field cage and the light Al endplates. We have accumulated experiences of the operation of MPGD TPC.

However, still some issues remain to be addressed in coming few years before the detector proposal for ILC.

The schedule of ILC in Japan and ILD detector (presented in the 2013 ILD group meeting at Cracow) is very tight, while the available resource available for the LC TPC collaboration and the ILD group has been very much limited.

The LC TPC collaboration needs to make its best effort to recruit new members. Even though it would not be easy before ILC in Japan is approved officially.