LCTPC needs for Test Beams

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for the LCTPC collaboration

Future Opportunities for Test Beams at DESY
5.-6. October 2017, DESY

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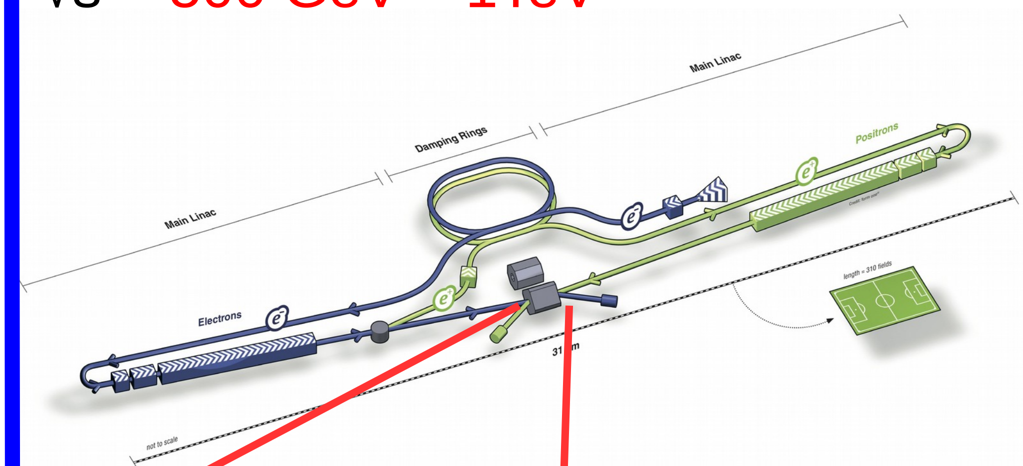
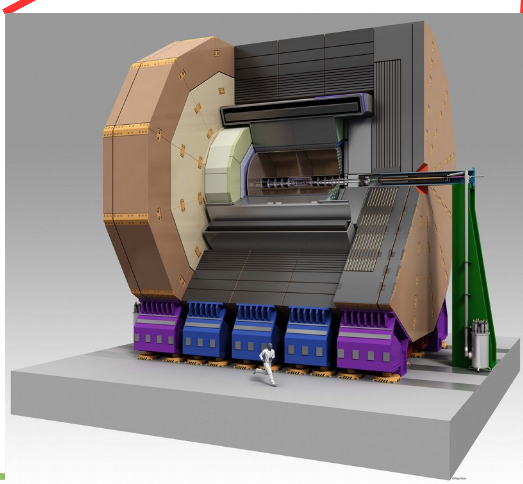
ILC/ILD

International Linear Collider (ILC)
is a linear e^+e^- colliders with
$\sqrt{s}$ = 500 GeV – 1TeV



Requirements of TPC from ILC TDR vol. 4:

Parameter			
Geometrical parameters	r_{in}	r_{out}	z
	329 mm	1808 mm	$\pm$ 2350 mm
Solid angle coverage	up to $\cos\theta \simeq 0.98$ (10 pad rows)		
TPC material budget	$\simeq 0.05\ X_0$ including outer fieldcage in r		
	$< 0.25\ X_0$ for readout endcaps in z		
Number of pads/timebuckets	$\simeq$ 1-2 $\times 10^6$/1000 per endcap		
Pad pitch/ no.padrows	$\simeq 1\times 6$ mm^2 for 220 padrows		
σ_{point} in $r\phi$	$\simeq 60\ \mu$m for zero drift, $< 100\ \mu$m overall		
σ_{point} in rz	$\simeq 0.4 - 1.4$ mm (for zero – full drift)		
2-hit resolution in $r\phi$	$\simeq 2$ mm		
2-hit resolution in rz	$\simeq 6$ mm		
dE/dx resolution	$\simeq 5$ %		
Momentum resolution at B=3.5 T	$\delta(1/p_t) \simeq 10^{-4}$/GeV/c (TPC only)		

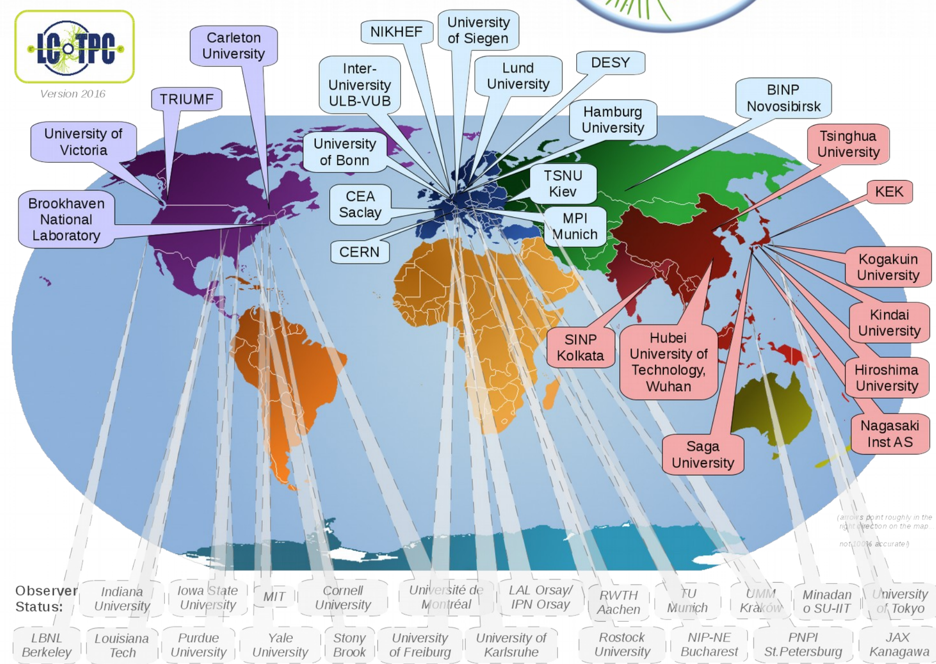


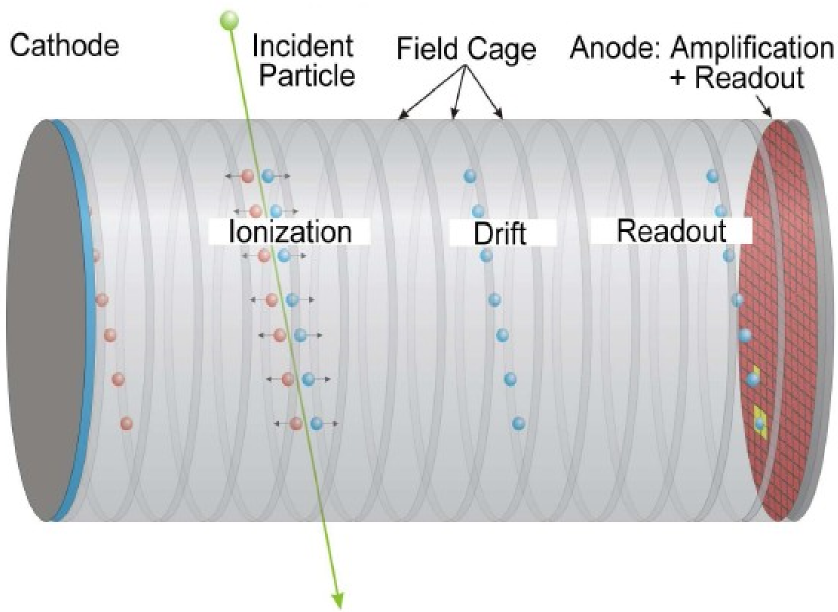
International Large Detector
- Standard HEP detector
- TPC as main tracker

Requirements are driven by benchmark processes, in the case of ILD-TPC the most stringent one is the Higgs-recoil measurement.
For the particle flow concept also a very high efficiency of more than 99 % is required.

LCTPC Collaboration

LCTPC collaboration studies the MPGD detectors for the ILD-TPC:
25 Institutes from 12 countries
+ 22 institutes have an observer status





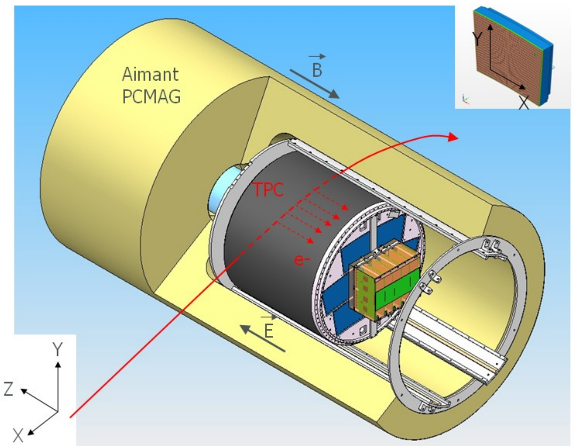
Various gas amplification stages are studied: GEMs, Micromegas, GEMs with double thickness and GridPixes.

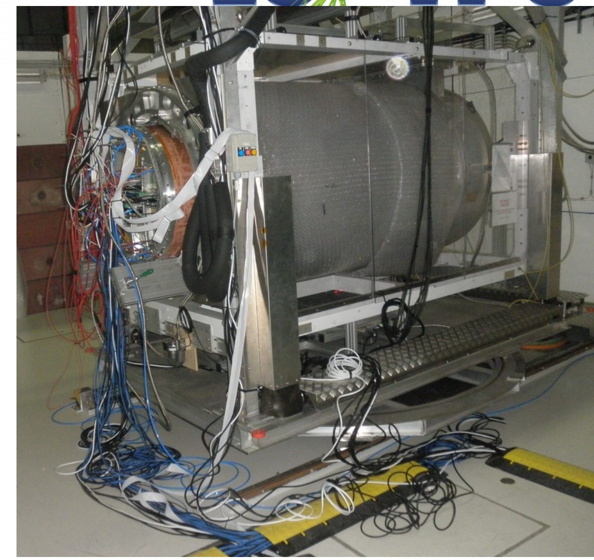
MPGDs in TPCs

- Ion backflow can be reduced significantly
- Small pitch of gas amplification regions => strong reduction of E×B-effects
- No preference in direction => all 2 dim. readout geometries possible

EUDET-AIDA Test Facility

Large Prototype has been built to compare different detector readouts under identical conditions and to address integration issues.





<u>Setup consists of:</u>

PCMAG: B < 1.2 T (prov. KEK)

e^- test beam: E = 1- 6 GeV

2p CO_2 cooling (partly by KEK)

Movable support structure

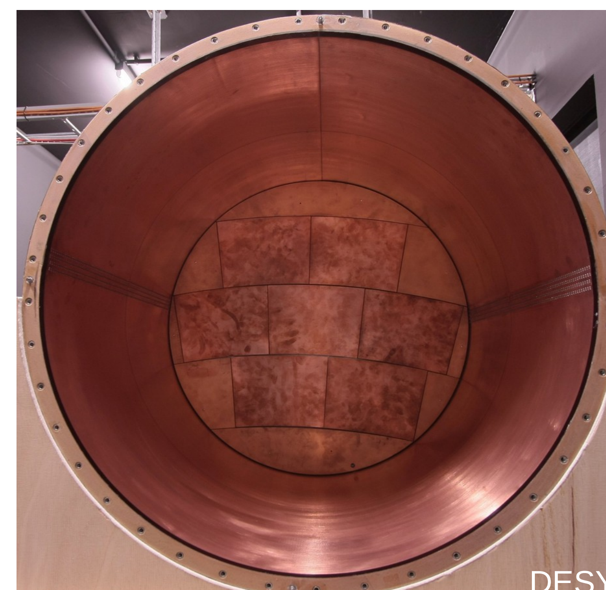
LP Field Cage Parameter:

- length = 61 cm
- inner diameter = 72 cm
- drift field: E ≈ 350 V/cm
- made of composite materials:

Modular End Plate

- 7 module windows,
- size ≈ 22 × 17 cm^2

<u>Ongoing upgrade:</u> external tracking device inside PCMAG



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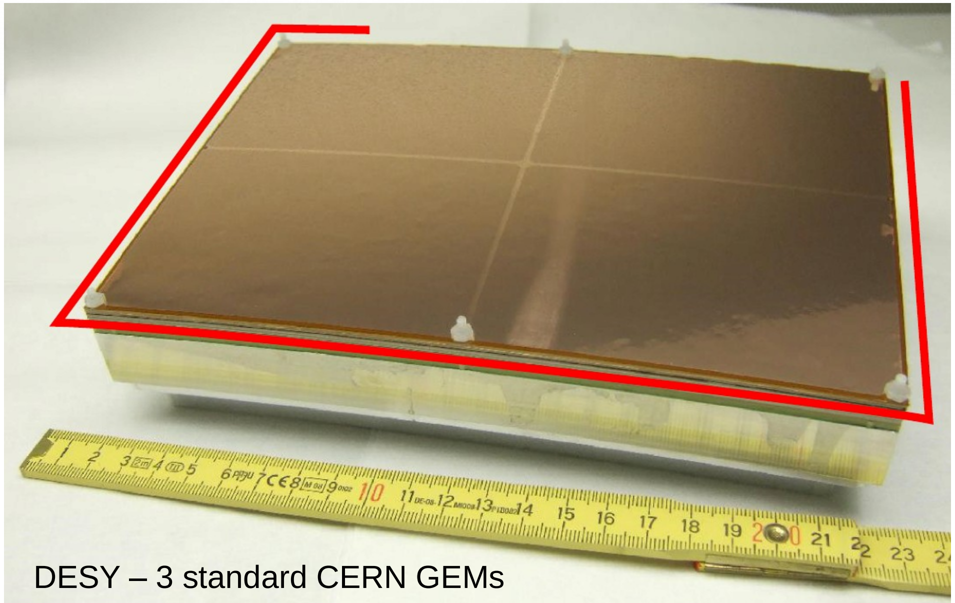
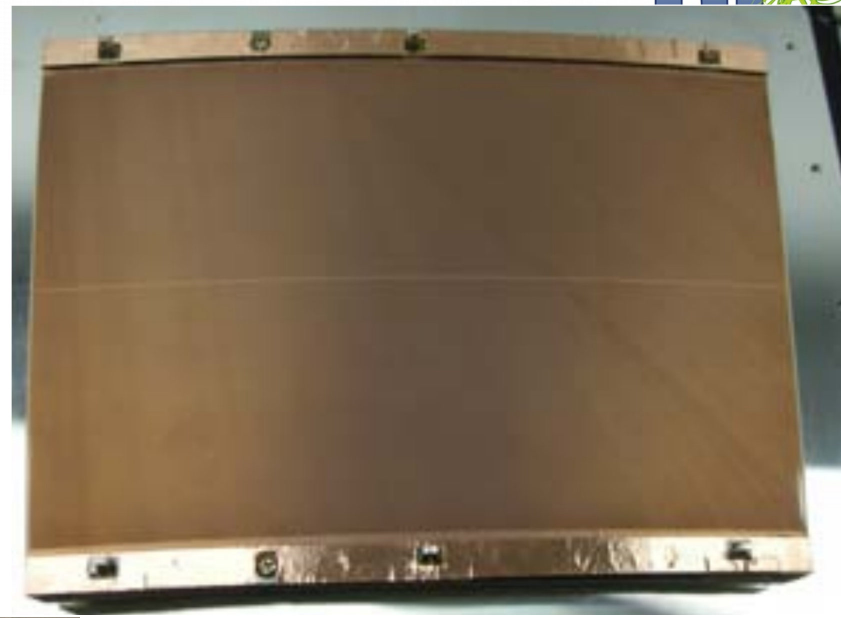
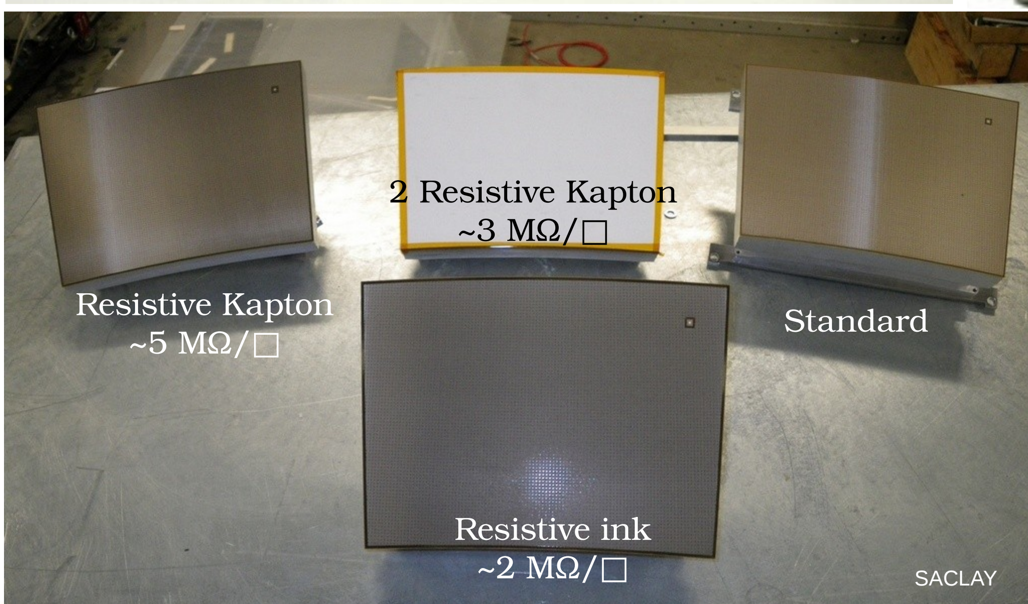
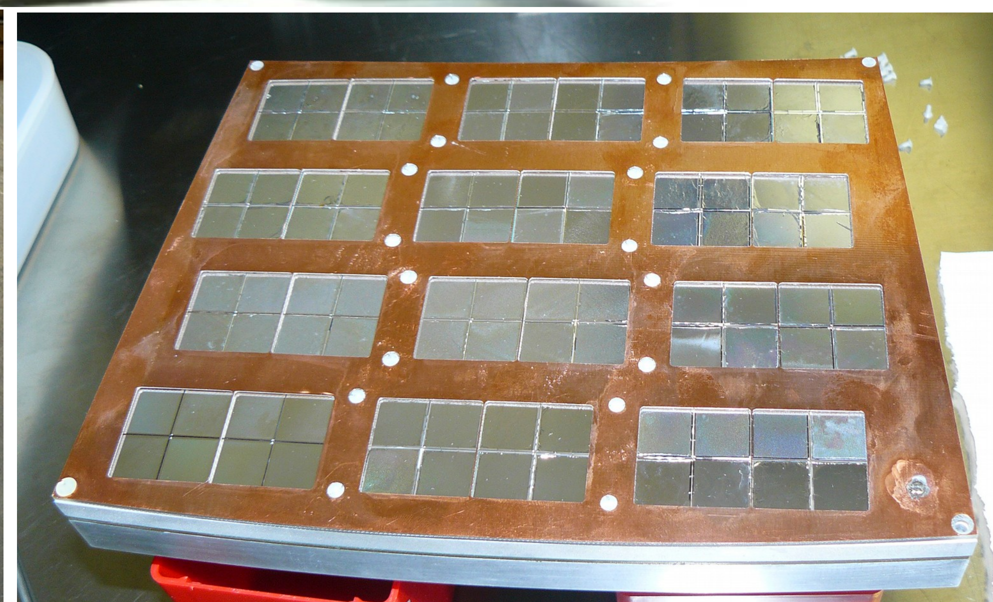
Diverse Modules


DESY – 3 standard CERN GEMs



Asian module
2 LCP GEMs
100µm thick





Aims of Test Beam Measurements

Currently: Verify the performance of the different technologies and study common challenges:

- Compare the performance of GEM, Micromegas and GridPix modules
- Study impact of E-field distortions at the border of the modules
- Develop common parts of modules (Gating, field shaper, pad plane,…)
- Study performance (double track separation, dE/dx,….)

Future: Once the technology choice has been done, construction of the TPC and modules will start.

- Test Final electronics with power pulsing and ILC-type beam
- Test all parts in the test beam before transporting them to ILC site

Infrastructure: We would also need an online monitoring system for beam currents/online trigger counts, which stores the currents or rates in a data base, which can be retrieve later by users. (For us this is important to evaluate the ion backflow into the chamber.)

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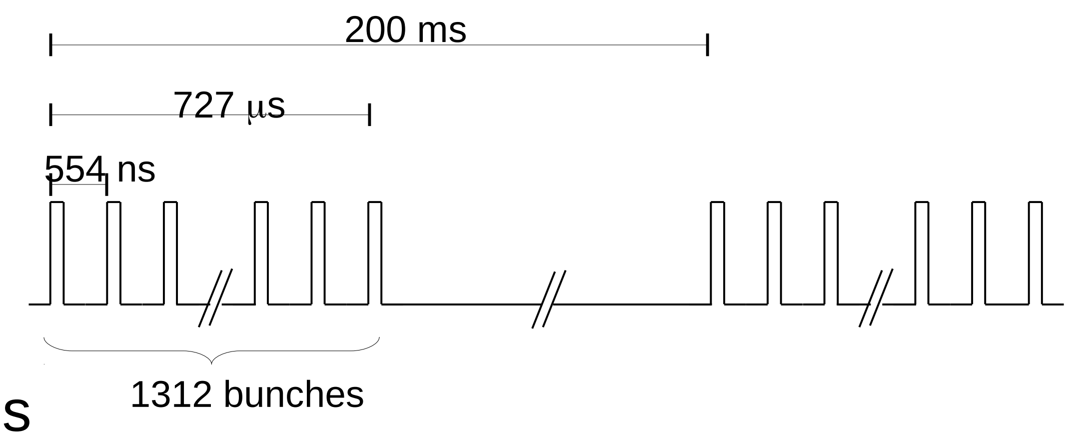
Rate

A higher rate would definitely be necessary:

In particular the ILC beam structure should be simulated to study:

- Power pulsing of electronics
- Gating performance of gating device
- Study how particles generated during different bunches (554 ns spacing) can be Separated => need rates of 1/50ns So about 20 MHz → for short time



Also a different mode with higher rate would be important to study double track resolution. Currently it is done by placing a stainless steel block of 0.5 X_0 in front of PCMAG, but

- Rate is rather low (2-5 % of all events after selection)
- Good overlap is rarely reached (region is outside of LP, i.e. in the PCMAG wall,…)
- Now particles have a significantly lower energy (now: ≲2.5 GeV)

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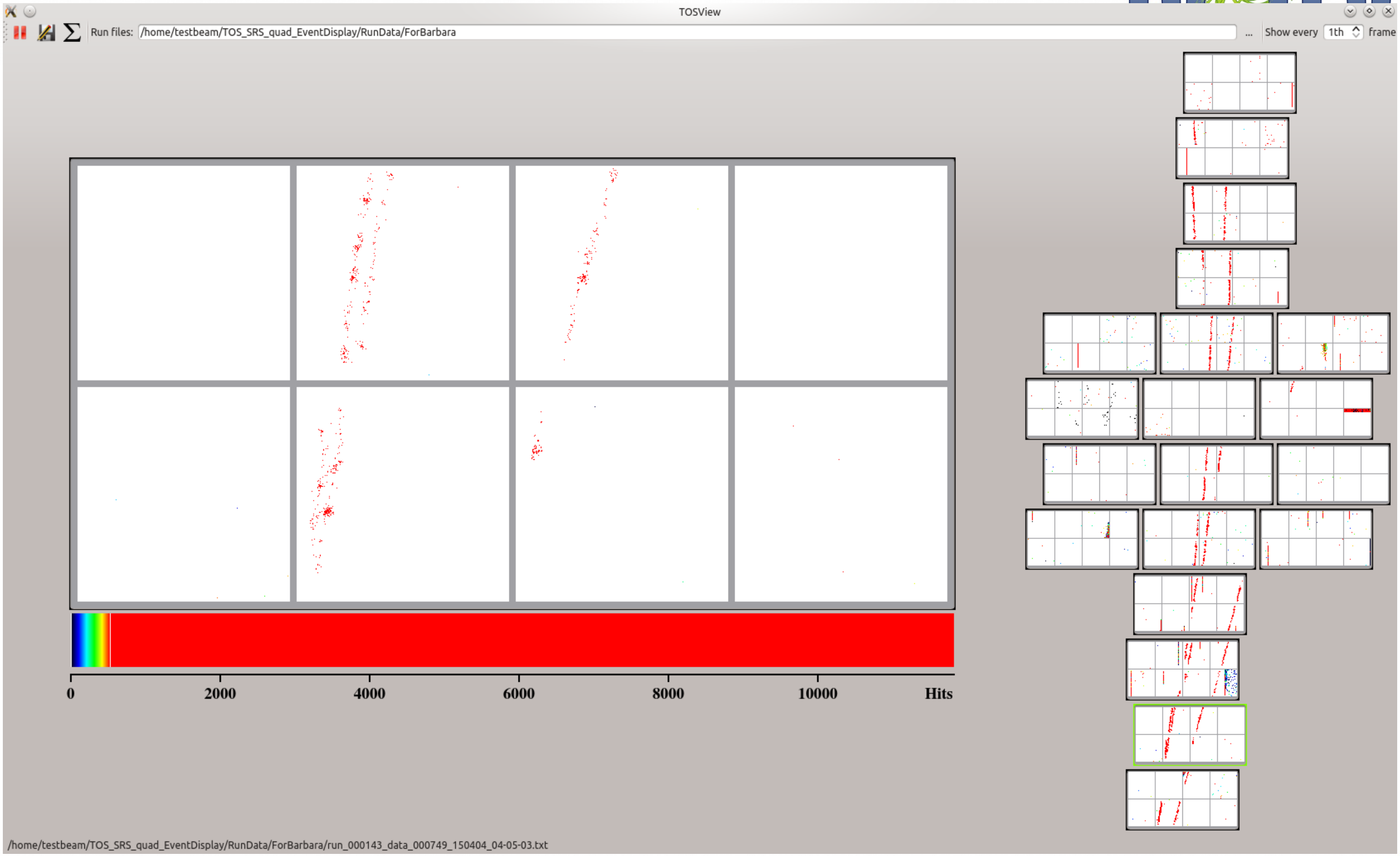
Double Track



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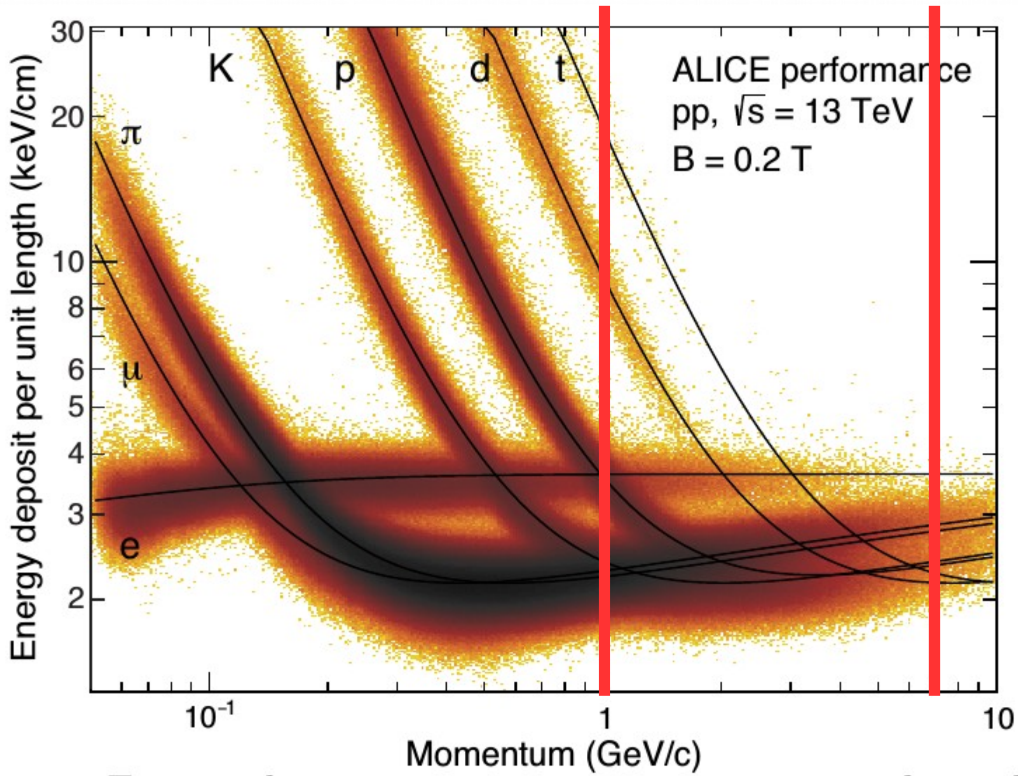
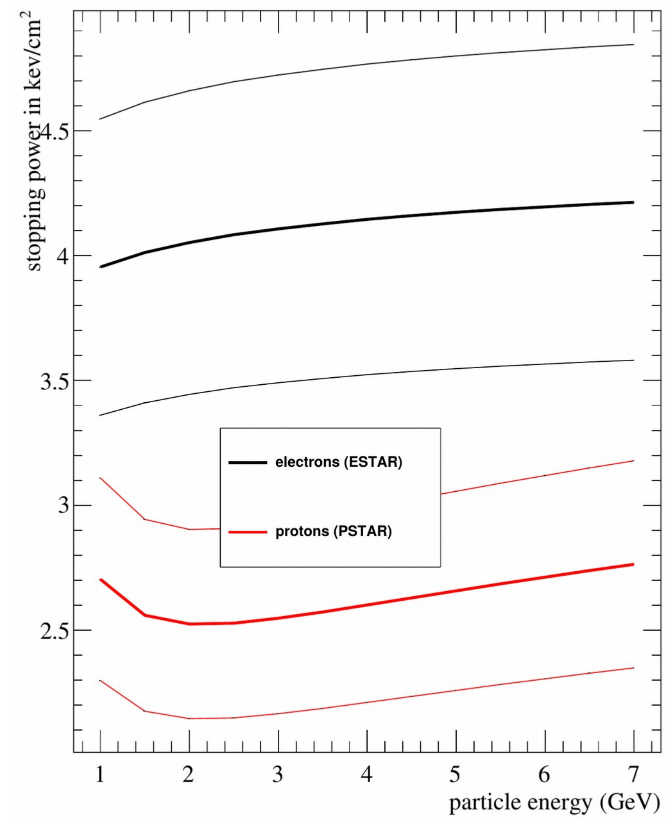
Energy loss dE/dx

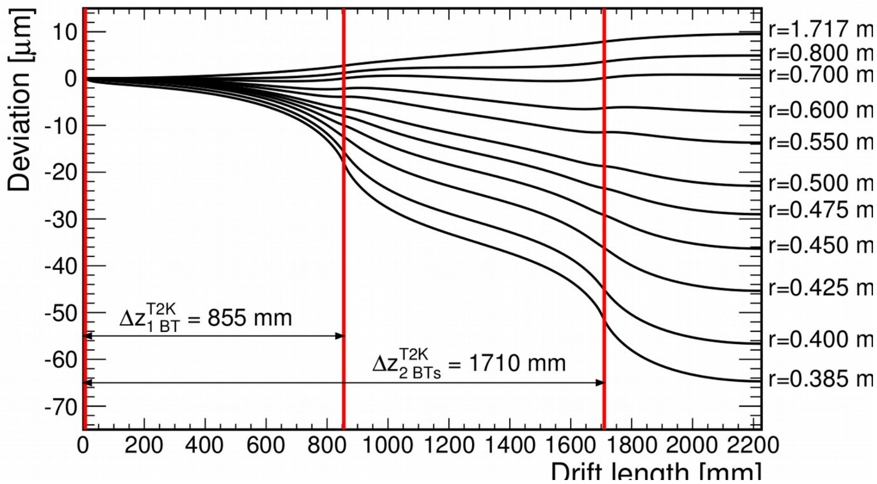


With the ILD-TPC we want to reach an energy (dE/dx) resolution of 5%



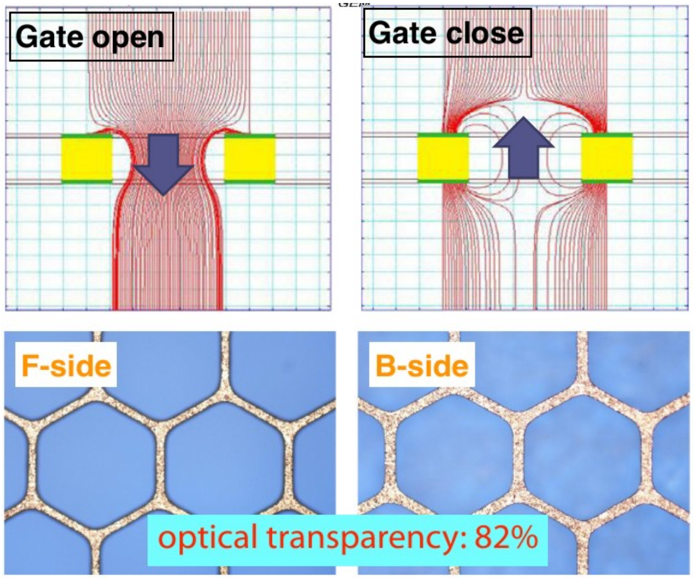
With the LP we have demonstrated an energy resolution (dE/dx) of 10-15%. But only electrons could be tested (on Fermi-plateau). It would
Be important to test also different particles at the minimum of ionization or even at β^2 raise.

Ion Feedback



Primary ions and gas amplifications generate a large space charge in the drift volume → track distortions
TPC needs a gating device to neutralize ions between bunch trains.

Gating GEM
- (Alternatively: wire gate)
- Simulation show:
  Maximum electron transparency is close to optical transparency
- Fujikura Gate-GEM Type 3
  Hexagonal holes: 335 µm pitch, 27/31 µm rim
  Insulator thickness 12.5 µm



This needs to be tested under realistic conditions → time structure of beam, higher rates and magnetic field (B = 3.5 – 4 T)

Higher Magnetic Field

It would be desirable to test the TPC in a B = 3.5-4 T magnetic field.

Drift behavior of electrons and ions have to be tested in the correct environment. Besides, the functionality of the gating GEM and the electronics.

If that is possible with a test beam.

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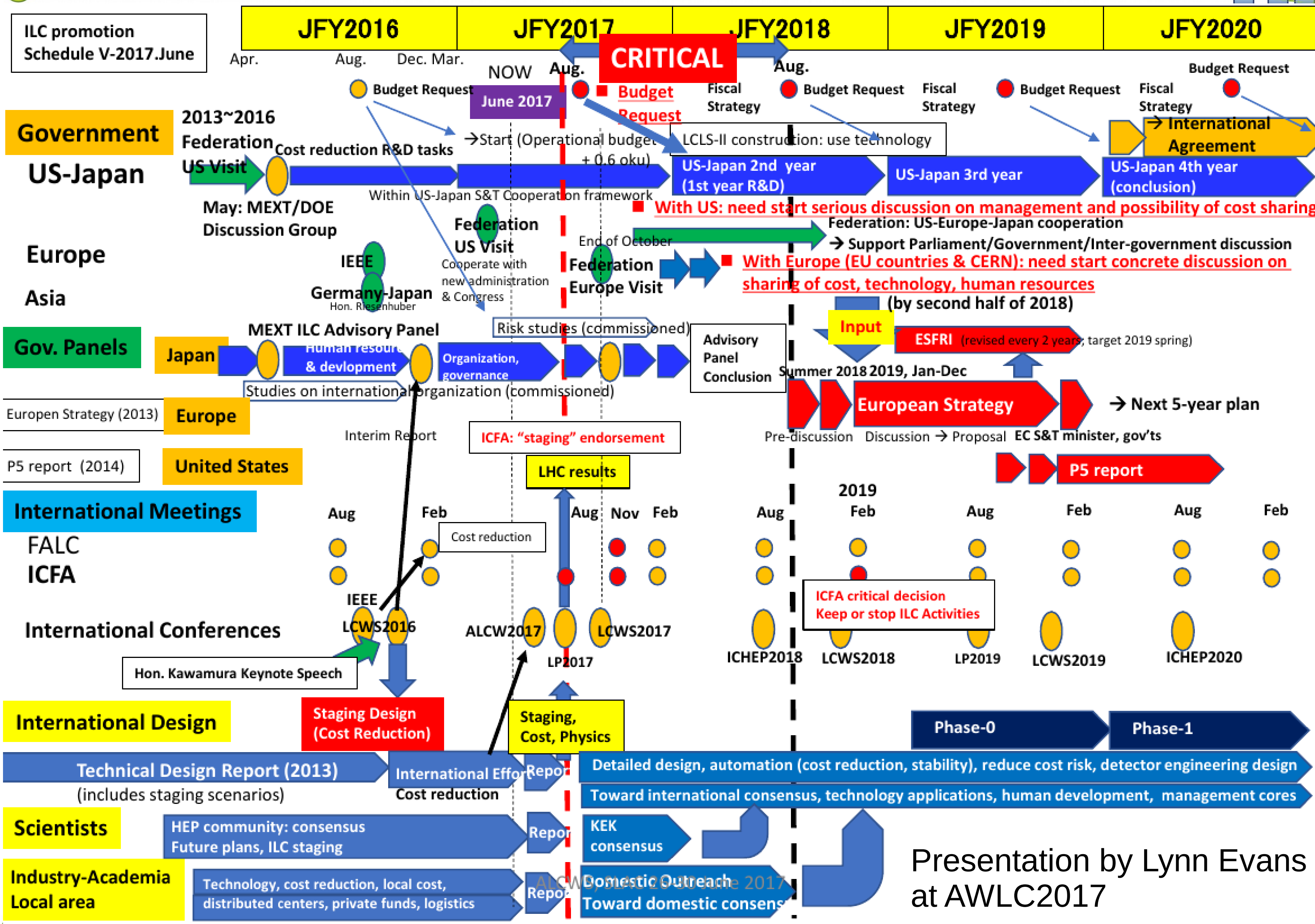
Status of Time Line



Presentation by Lynn Evans at AWLC2017

Development phase up to 1-2 years after t_0.

Component tests until 1-2 years before start of data taking.

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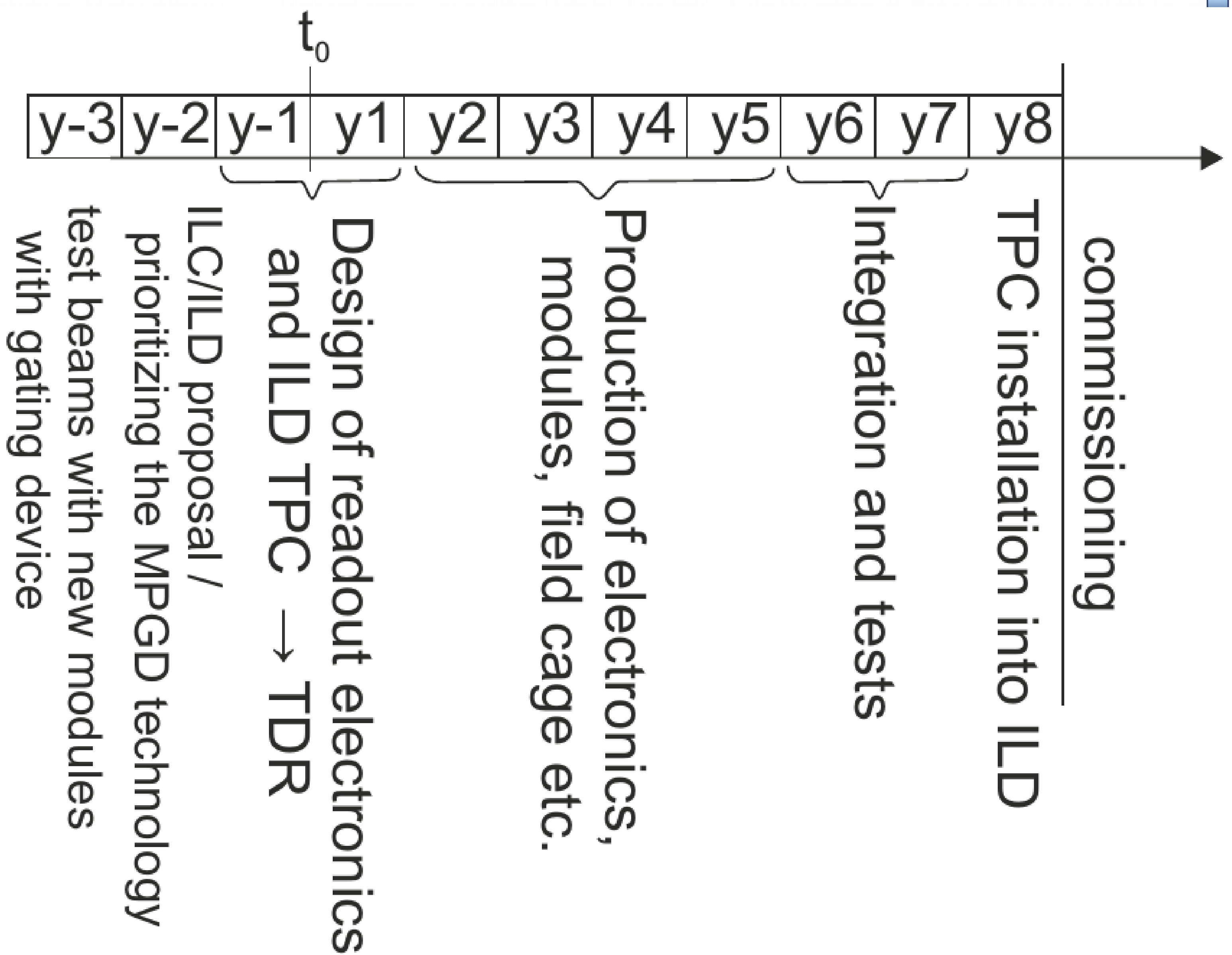

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Summary

DESY test beam is essential for LCTPC because

- Setup (including 2pCO_2 cooling and PCMAG) is too large to move it in and out of beam areas and test beam sites
- For the near future we need an external tracking device inside the PCMAG to track particles with high precision (work has started)

On the somewhat longer time scale we definitely need

- Beam structure simulating the ILC beam structure to study performance of the electronics, power pulsing, the ion backflow suppression by the gatingGEM,
  - → Individual features (554 ns bunch spacing, 5 Hz bunch trains, high luminosity bunches,….) could also be simulated in separate settings
- Higher rates to see and measure double tracks with sufficient rate
- DE/dx measurements with different particles
- Measurements in high magnetic fields

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