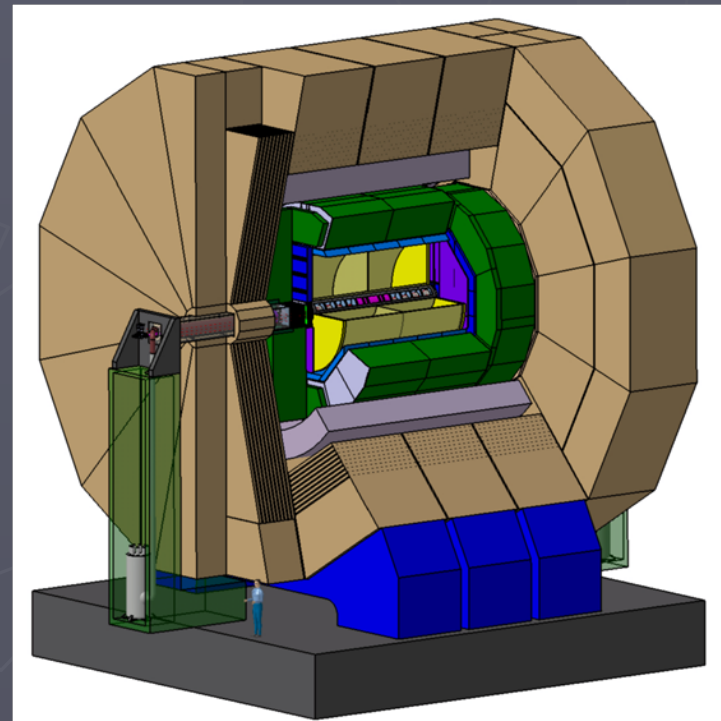


Beam Test Results of a GEM Large TPC Prototype Readout by New ATRLO Electronics

Current Status

LC TPC Collaboration

**Presented by
Takeshi Matsuda
LC TPC Asian Group
(DESY/KEK)
@MPGD2009**



Proposed ILD Detector

Tracking at ILC: Momentum Resolution

1. **Higgs recoil mass: $e^+e^- \rightarrow ZH (Z \rightarrow \mu\mu/ee) + X$:**
 If $\delta M(\mu\mu/ee) \ll \Gamma_Z$ then the beam energy spread dominates when $\delta(1/pt) \leq 5 \times 10^{-5}$.
2. **Slepton and the LSP masses through the end point measurement:**
 σM (Momentum resolution) $\sim \sigma M$ (Parent mass) at 1 ab^{-1}
 when $\delta(1/pt) \leq 5 \times 10^{-5}$
3. E_{cm} determination from $e^+e^- \rightarrow \mu^+\mu^-(\gamma)$:
4. Rare decay $\text{Br}(H \rightarrow \mu\mu)$ in $e^+e^- \rightarrow ZH$ and $H\nu\nu$:



$$\delta(1/pt) \leq 5 \times 10^{-5}$$

ILD example for 1.

$$\Delta M_H \sim 70 \text{ MeV}$$

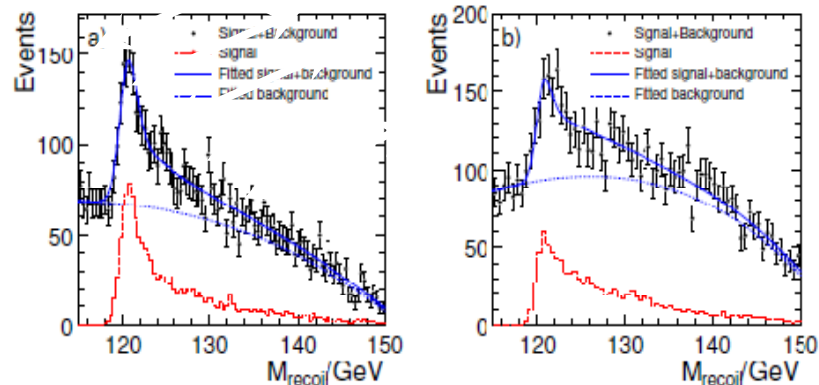
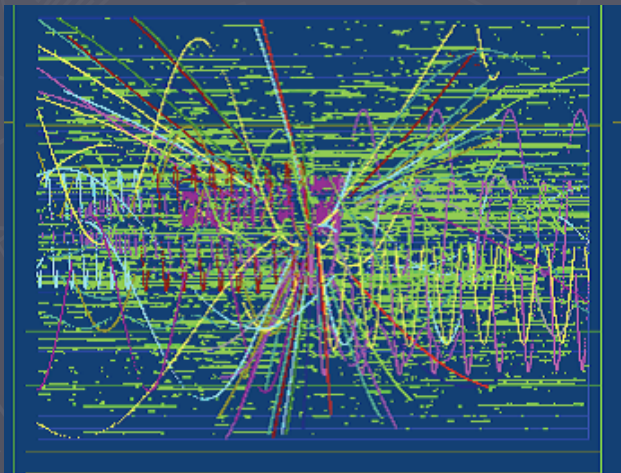


FIGURE 3.3-7. Results of the model independent analysis of the Higgs-strahlung process $e^+e^- \rightarrow HZ$ in which a) $Z \rightarrow \mu^+\mu^-$ and b) $Z \rightarrow e^+e^-$. The results are shown for the $P(e^+, e^-) = (+30\%, -80\%)$ beam polarisation.

Tracking at ILC

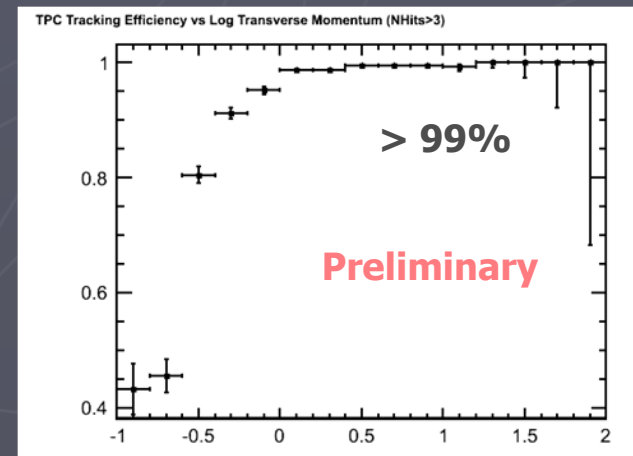
Performance requirement greatly exceeds the achievements of existing trackers for colliders

- High Momentum resolution: $\delta(1/pt) \leq 5 \times 10^{-5}$
 - ~ 200 position measurements along each track with the point resolution of $\sigma_{r\phi} \sim < 100\mu\text{m}$ at 3-4T → TPC
 - ~ a several position measurements with $\sigma_{r\phi} \sim 10\mu\text{m}$ at 5T → SiTR
- High tracking efficiency down to low momentum (for PFA)
- Minimum material of tracker for PFA (→ challenging!)
- dE/dX (also for PFA)



still

ttbar overlaid with 100BX of pair backgrounds

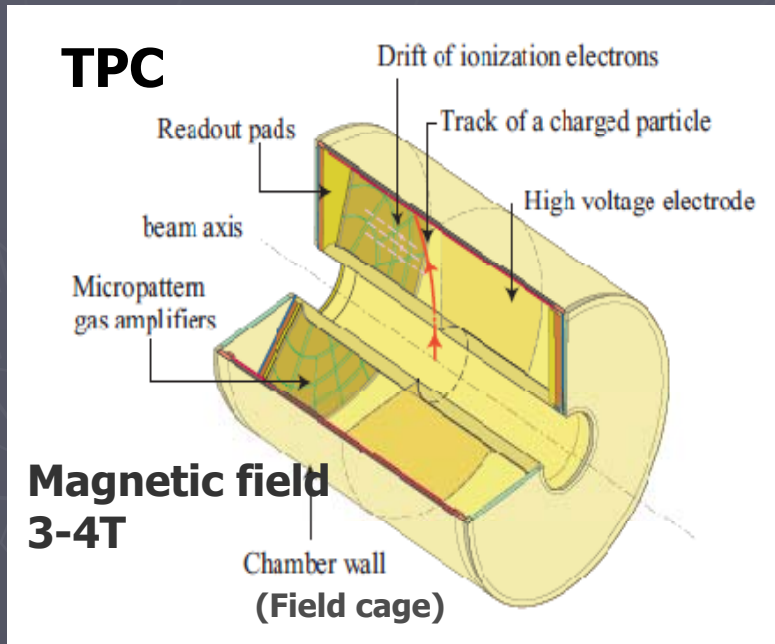


Tracking efficiency w pair background
(S. Aplin & F. Gaede)

TPC with Micro Pattern Gas Detectors (MPGD)

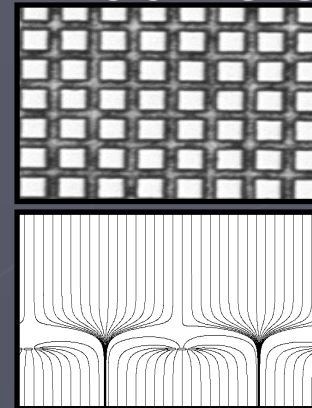
The traditional TPC with MWPC has limited space resolution due to the $E \times B$ effect in high magnetic field. Also the structure to support many wires inevitably introduces significant dead regions and material:

→ MPGD TPC.

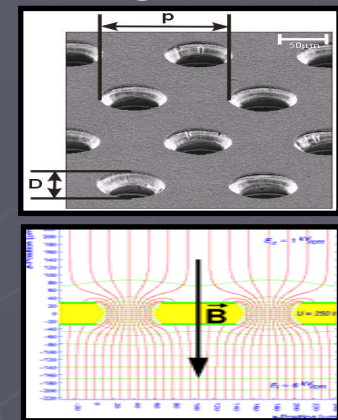


(4 m in outer diameter
and 5 m long)

MicroMEGAS



GEM



● Two gas amplification schemes

● Analog TPC vs. Digital TPC

A: Standard pad readout (need signal broadening)

D: Pixel (TimePix) readout (need to detect all electrons individually)

Candidates of MPGD TPC for ILC (ILD)

(Based on the studies with Small MPGD TPC Prototypes)

Analog TPC:

GEM + narrow pad readout:

Defocusing by multilayer GEM

Narrow (1mm) pads → Large readout channels

MicroMEGAS + resistive anode:

Widening signal by resistive anode

(in space but also in time) → Track separation

With possibly wider (> 2-3 mm) pads

GEM + Timepix:

As an analog TPC with finer “pad = pixel”

Digital TPC:

Ingrid-MicroMEGAS + Timepix: Elegant solution

Free from the gas gain fluctuation

→ More information from primary electrons and thus better point resolution (not yet probed)

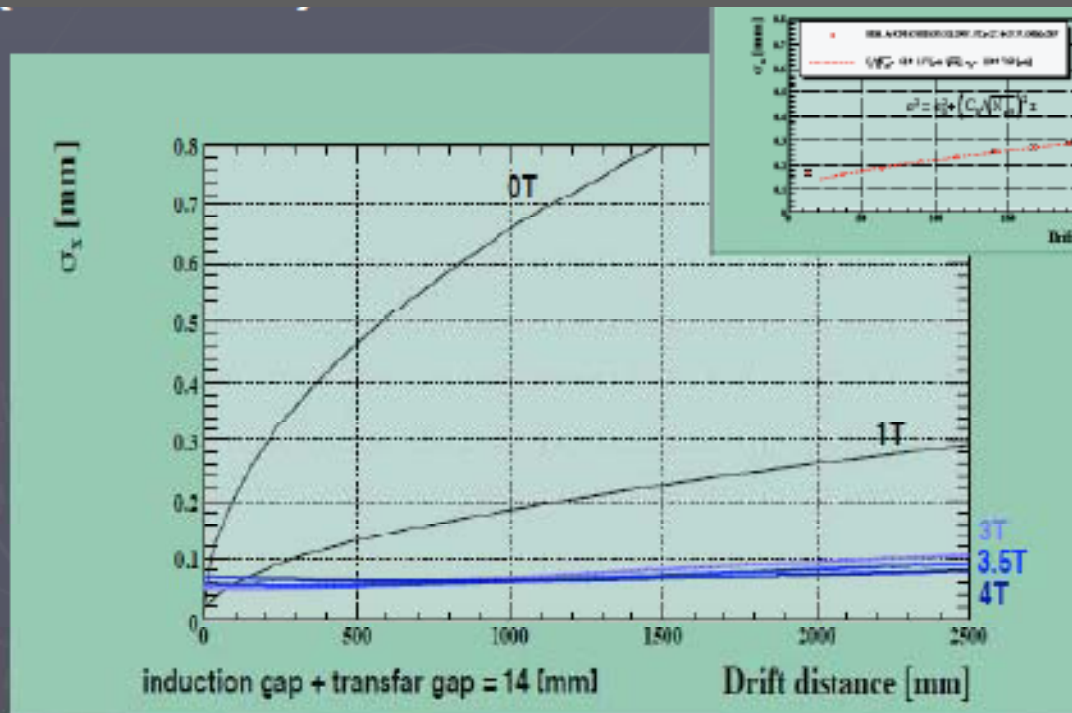
GEM + Timepix:

Need to improve the efficiency for primary electrons

Spatial Resolution of MPGD TPC

The point resolution of $\sigma_{r\phi} \leq 100 \mu\text{m}$ at 3-5T

(A) Extrapolation of Measurements at 1T for a three GEM TPC with narrow (1.17mm) pads (MP-TPC at KEK) to 3-4T using a full analytic formula for TPC point resolution



MP-TPC in its cosmic ray set up with 1T superconducting magnet at the KEK cryogenic center.

Extrapolation to I LC TPC from measurements at 0/1T ($\theta = \phi = 0$: no angular pad effect).

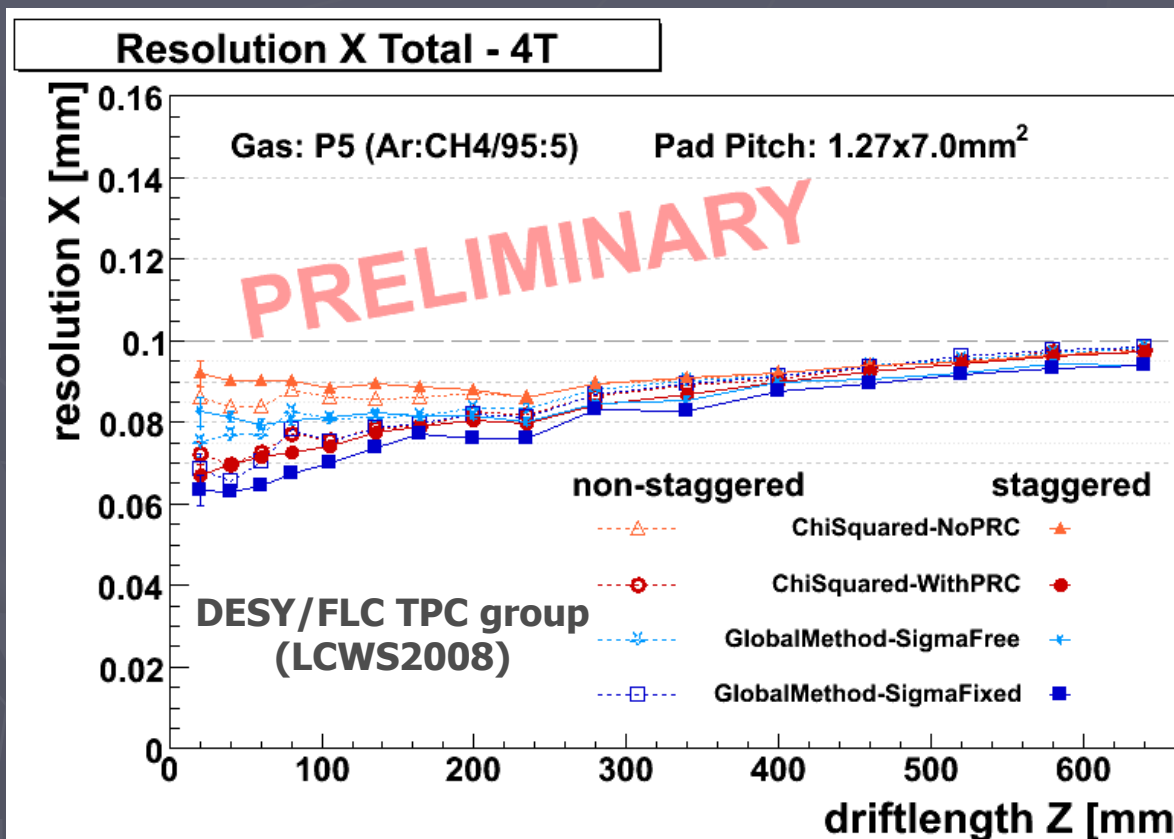
Ar/CF₄(3%)/isobutene (2%) at $E_{\text{drift}} = 200\text{V/cm}$. The number of effective electrons $N_{\text{eff}} = 22$. (R. Yonamine et. al. 2008)

(*) Measurements with DESY Midi-TPC in 5T magnet come soon but so far for P5. Also TU-TPC.

Spatial Resolution of GEM MPGD TPC

$$\sigma_{r\phi} \leq 100\mu\text{m at 3-4T}$$

(B) Measurements in 4T with DESY Midi-TPC with P5 gas (LCSW2008)



Momentum Resolution Expected for ILC (ILD) TPC

Single muon in full simulation with no systematic

TPC point resolution

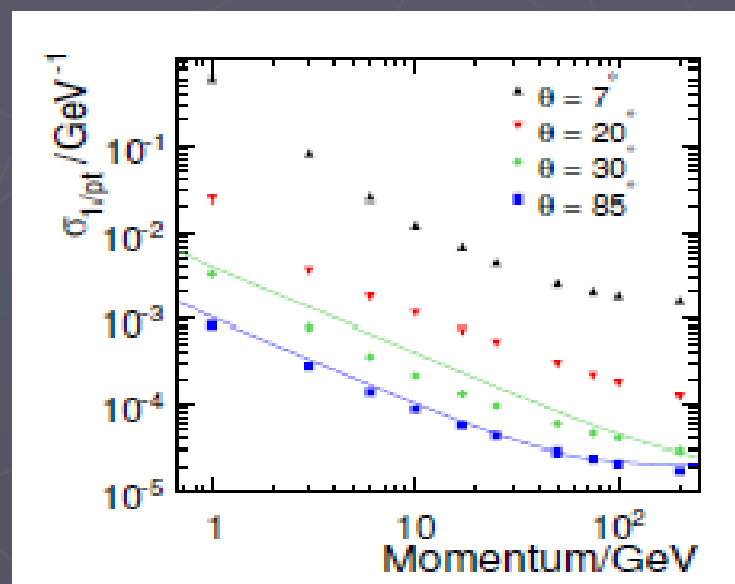
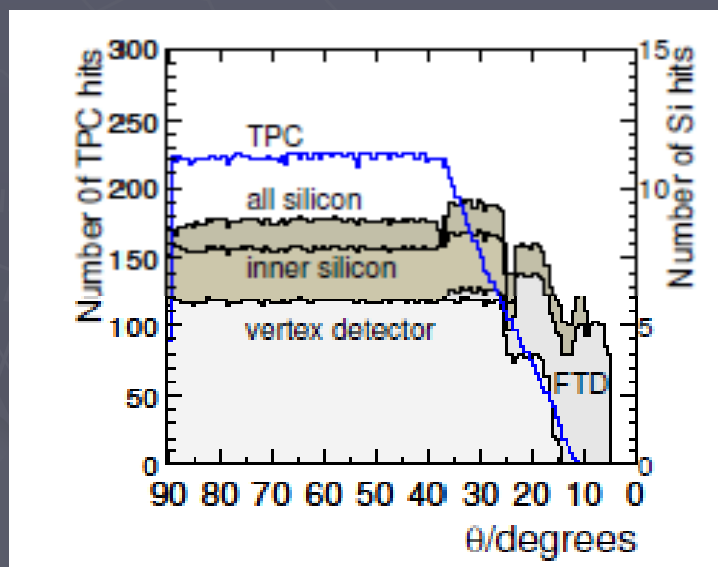
$$\sigma_{r,\phi}^2 (\mu\text{m}^2) = P + QL$$

$$P = 50^2 + 900^2 \sin^2 \varphi : (\mu\text{m})^2$$

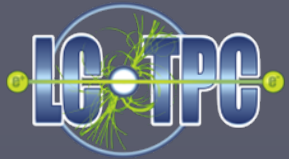
$$Q = (25^2 / 22) \times (4 / B)^2 \sin \theta : (\mu\text{m} / \sqrt{\text{cm}}), B \text{ in Tesla}$$

L : drift length [cm]

$$\sigma_z^2 (\mu\text{m}^2) = 40^2 + 8^2 \times L(\text{cm})$$



Detector model: ILD LOI(00) Model, VTX + Si-tracker + TPC. Magnetic field of 3.5T. With an empirical angular pad effect. By Full simulator using Mokka (and Jupiter for comparison).

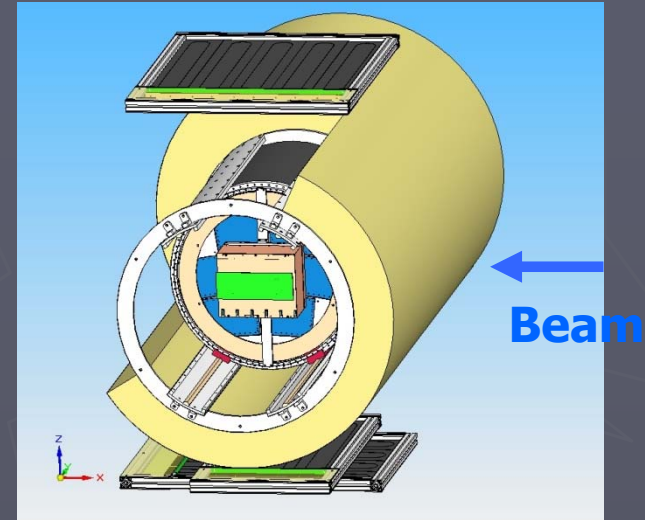


TPC Large Prototype (LP) Beam Test at DESY by LC TPC Collaboration using EUDET Facility

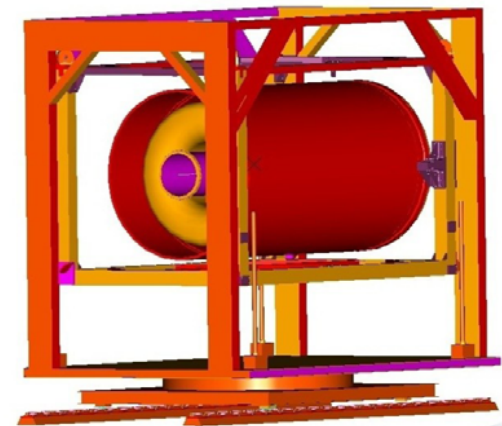
Goals:

- Study, in practice, design and fabrication of all components of MPGD TPC in larger scale; field cage, endplate, detector modules, front-end electronics and field mapping of non uniform magnetic field. (But not yet the engineering stage.)
- **Demonstrate full-volume tracking in non-uniform magnetic field, trying to provide a proof for the momentum resolution at LC TPC.**
- Demonstrate dE/dX capability of MPGD TPC.
- Study effects of detector boundaries.
- Develop methods and software for alignment, calibration, and corrections.
(Beijing tracker review, Jan 2007)

We are still far away from the goals!



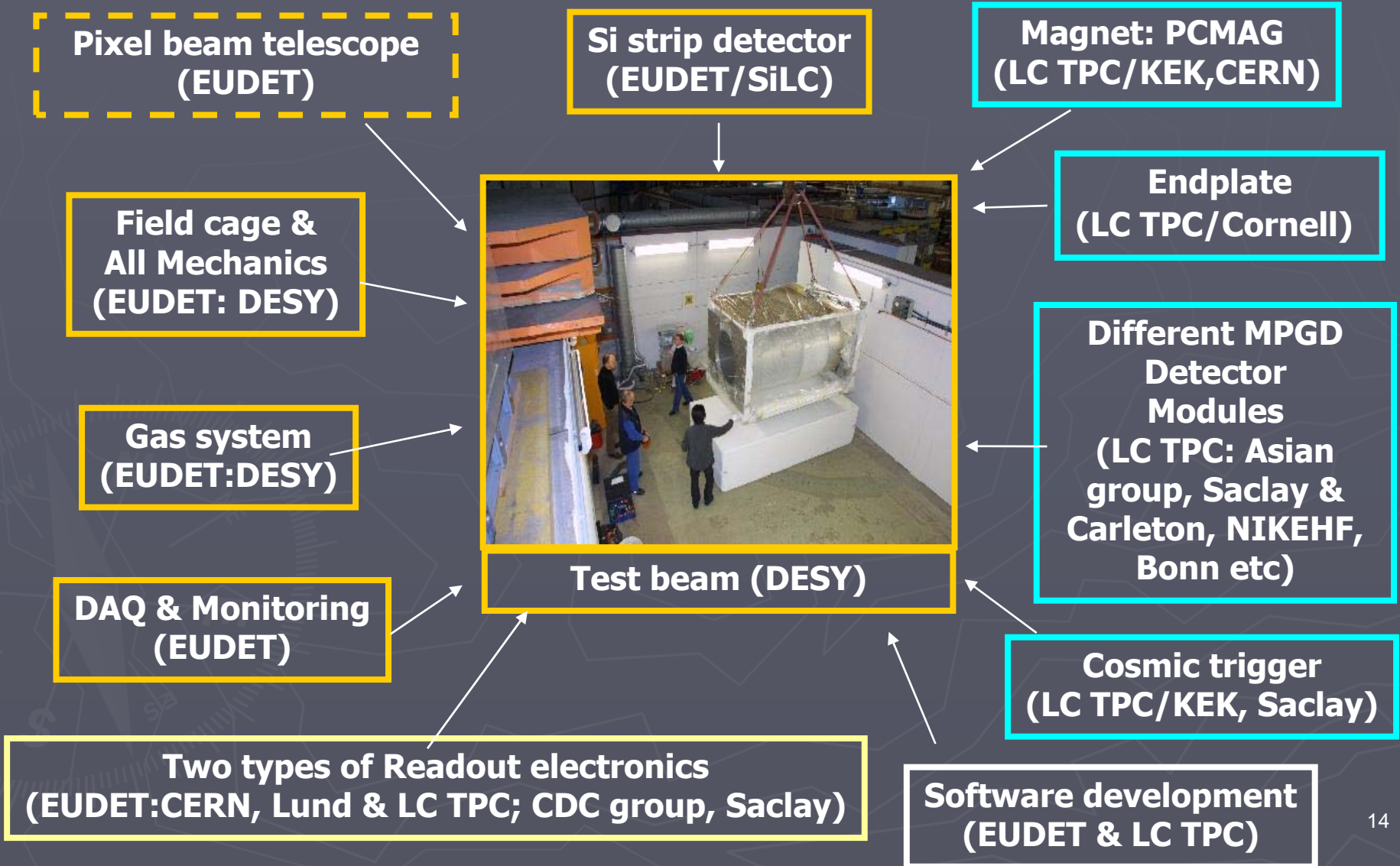
Design Study of the Magnetmovementtable



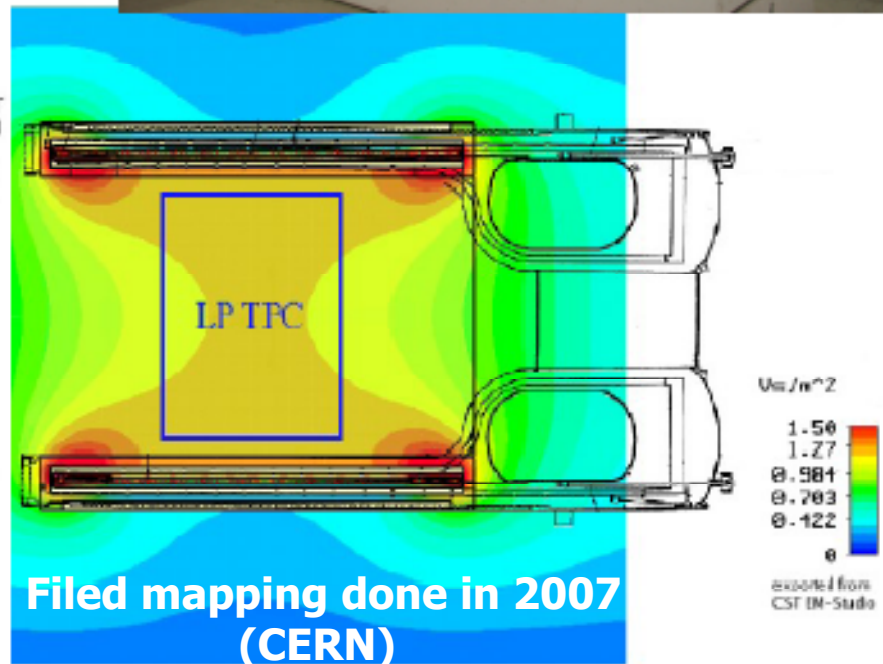
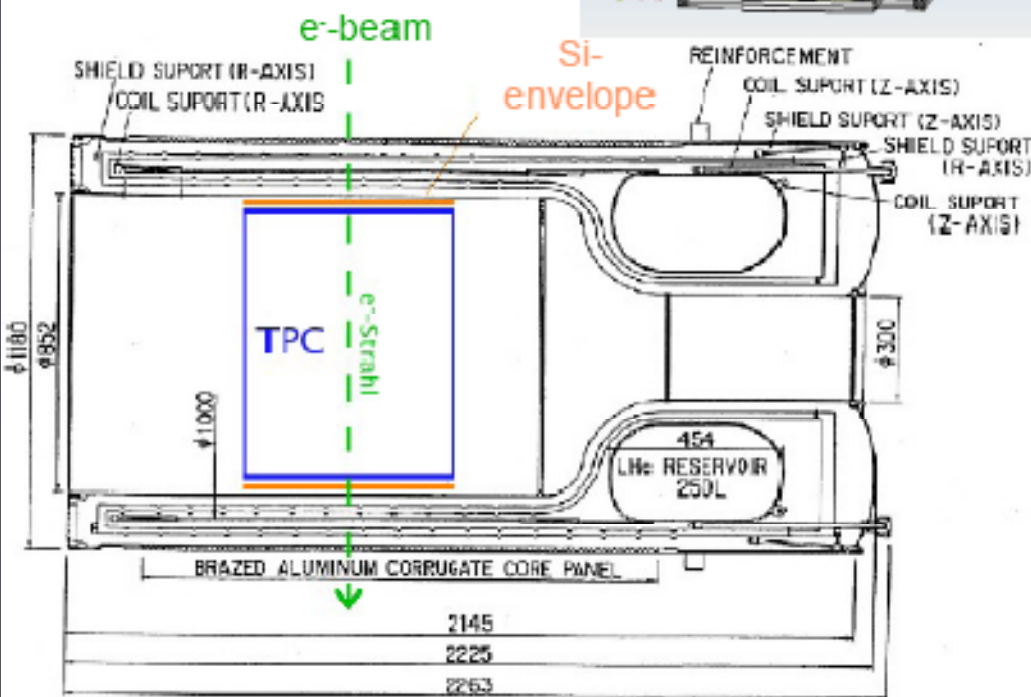
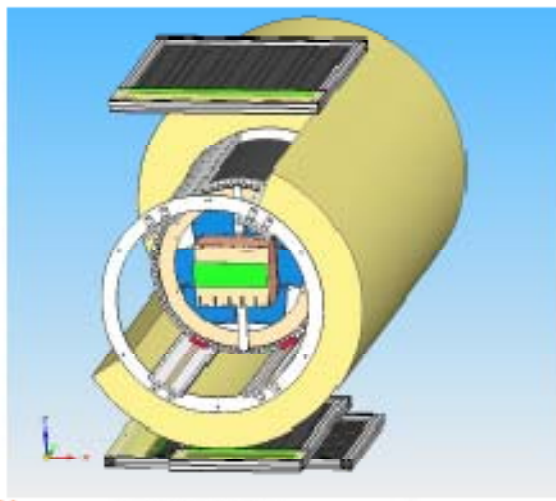
Bear

LC TPC Large Prototype Beam Test at DESY

LC TPC Collaboration with EUDET Facility



- e^- test beam @DESY
- PCMAG



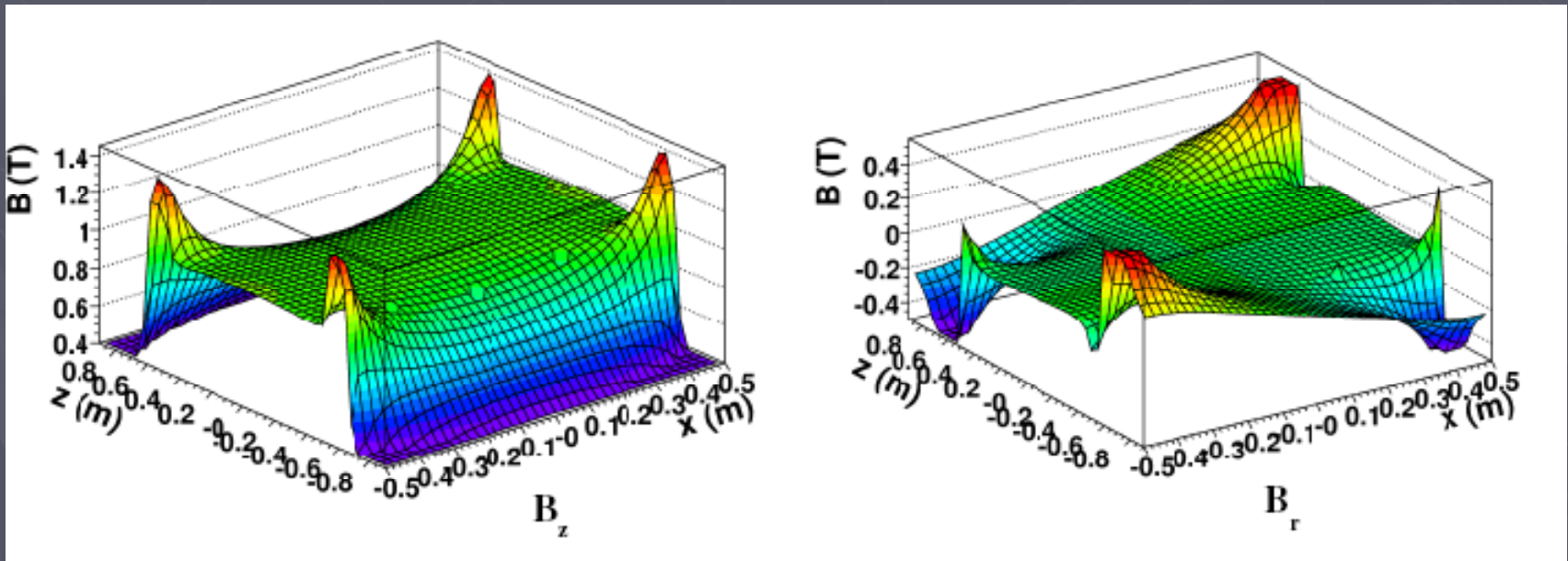
Filed mapping done in 2007 (CERN)

PCMAG

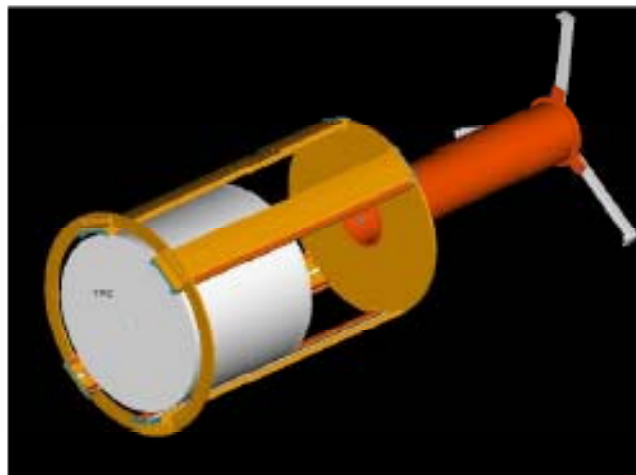
Magnetic Field Measurement and Field Models

Our claim: Correction for non-uniform magnetic field can be done when the field is mapped down to $O(1G)$ a la ALEPH (Settles & Wiedemann)

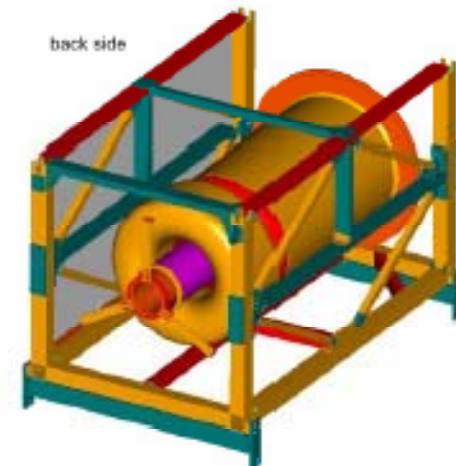
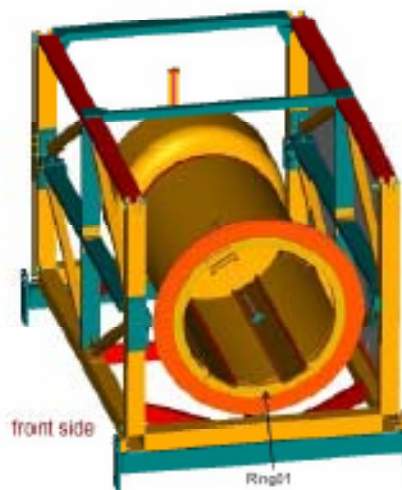
Precision field measurement done by CERN group (Lucie). The precision is down to 5-10 gauss in 3D components. Field model is implemented in Marlin TPC and is ready to be used.



We are better to make use of them performing full tracking in TPC Large Prototype!



(installed in 2008)



Design Study of the Magnetmovementtable

Support structures:

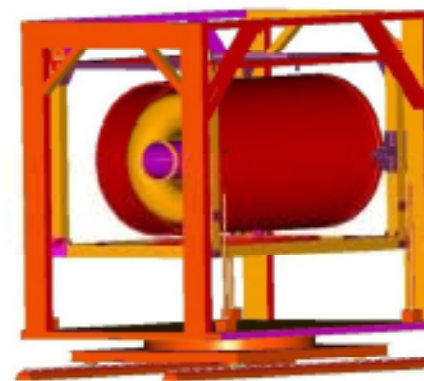
- TPC
- PCMAG



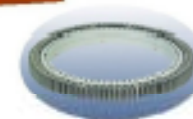
Power Jack



Linear guiding



Bearing



(In Summer 2009)

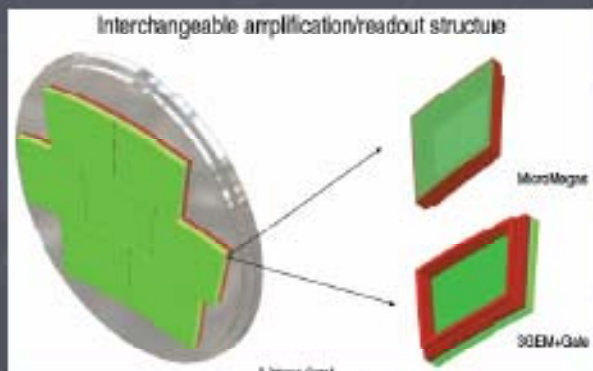
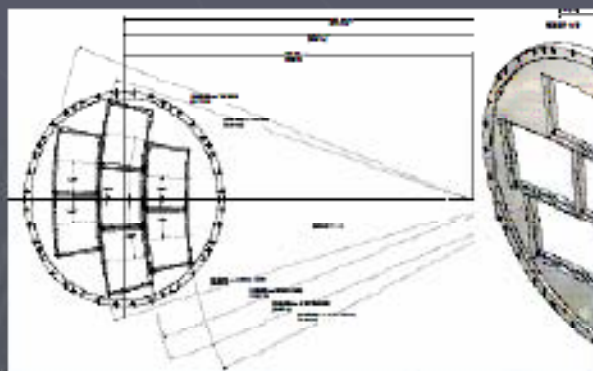
F. Hegner, V. Prah, R. Volkenborn, DESY

TPC Large Prototype (LP1) Endplate

Cornell University

LP1 endplate made of Al, accommodates 7 detector modules. The diameter of the endplate is about 770 mm.

The shape and size of the detector module was decided to simulate one at LC TPC of the size of GEM widely available. All 7 detector modules have the same outer shape so that they are interchangeable on the endplate. However, we do not plan to mix the detector modules of different MPGD since they are normally in different operation conditions (such as the voltage applied to their front face). The endplate is designed at Cornell Univ. The endplate has arrived at DESY. Need design R&D for a light structure.



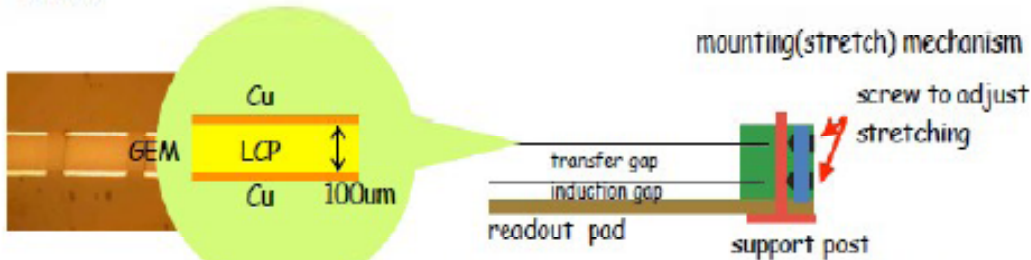
LP1 GEM Module by LC TPC Asian Group

Two layers of thick GEMs + Gating GEM

LC TPC Asian group

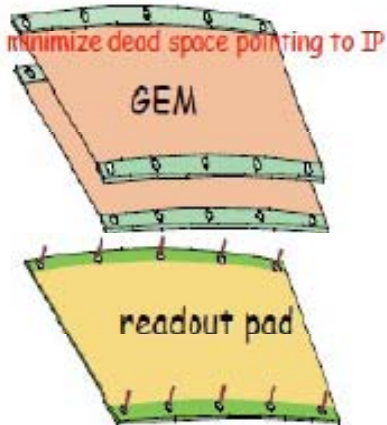
GEM Module (w/o Gating GEM)

GEMs



Transfer gap ~ 4mm : enlarge signal distribution (+2mm) width > 0.3* pad pitch

frame : top & bottom frame.
no side frame



A. Sugiyama, Saga Univ.

- 28 pad-rows of 176 -194 pads
- Pad size ~ 1.1 x 5.4 mm²
- Total 5152 pads/modules
- GEMs: 2 layers of GEM (100µm) (w/o Gating GEM this time.)
Electrically divided in 2
Transfer gap = 4 mm
Induction gap = 2 mm
(Gating = 10 mm)
- 4 modules made and 3 modules installed to cover full length of beam
- GEMs from SiEnergy & PCB layout/fabricated by Tsinghua University

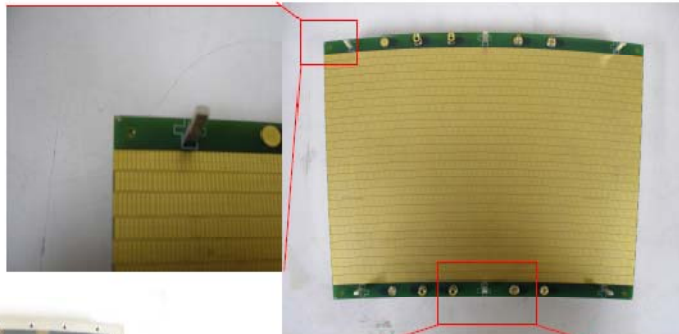
LP1 GEM Module by LC TPC Asian Group

Some details

LC TPC Asian group

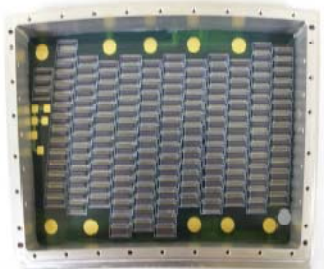
PCB on BackFrame

- 2 pieces



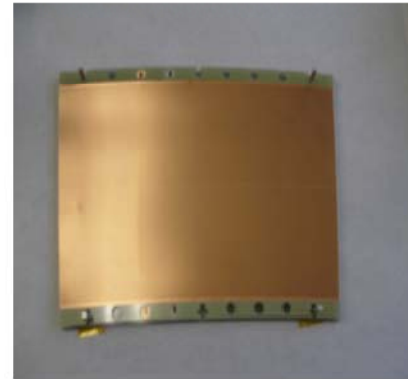
electrode

for GEM stretch

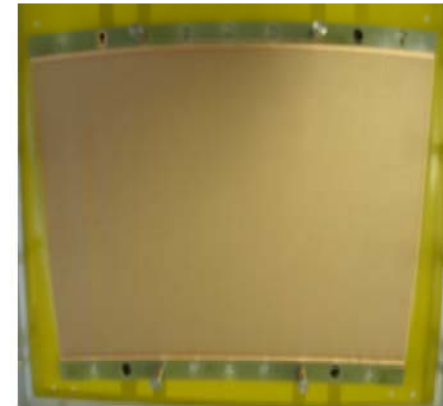


readout plane

- Amp. GEM
 - 100 μm -thick
 - 70 μm ϕ , 140 μm pitch
 - Insulator : LCP
 - 12 pieces



- Gate GEM
 - 14 μm -thick
 - 90 μm ϕ , 140 μm pitch
 - 3 pieces



Current module structure: Minimize dead area in $R\phi$ but tolerate those in R
Easy to replace each GEM layer.
Problem of bias voltage contact (once in LP test)
Open to consider other solutions to hold/bias GEMs.

Ion in ILC TPC

V. Lepeltier,
TILC08 March 2008

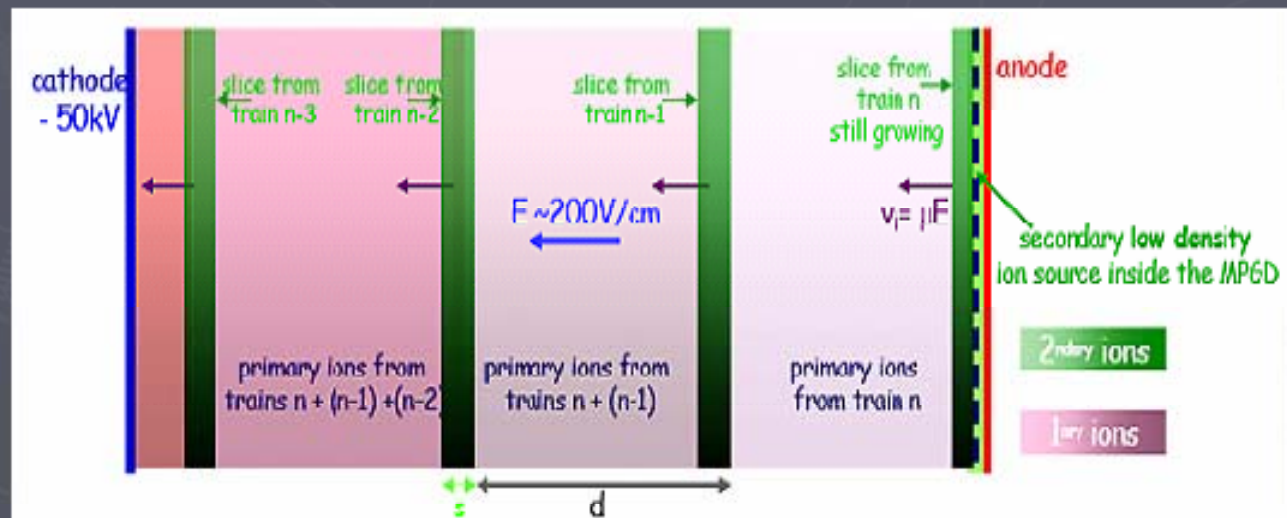
- Ions in the TPC drift volume, if its density is high, introduce the E-field distortion.
- Two sources of ions; primarily ions and feed back ions from the amplification region.
- The collection time of ions is slow: 600ms for the drift field of 200V/cm compared to the electron drift time of about 40 micro sec.
- If the ion feedback ration β is height, the feed back ions build up the a few ion sdisks in the TPC drift volume.
- $G \times \beta$ is the key factor for the secondary ions. If > 1 , we need an ion gating device.

Ion density

mean charge density in the slice: $\rho_s = \rho_p \times G \times \beta \times 3/8 \times 200$
 total secondary ion charge $Q_s = Q_p \times G \times \beta \times 4/7$

primary ionisation
 MPGD gain
 MPGD ion backflow
 pile-up factor
 time ratio intertrain/train

Ion disks



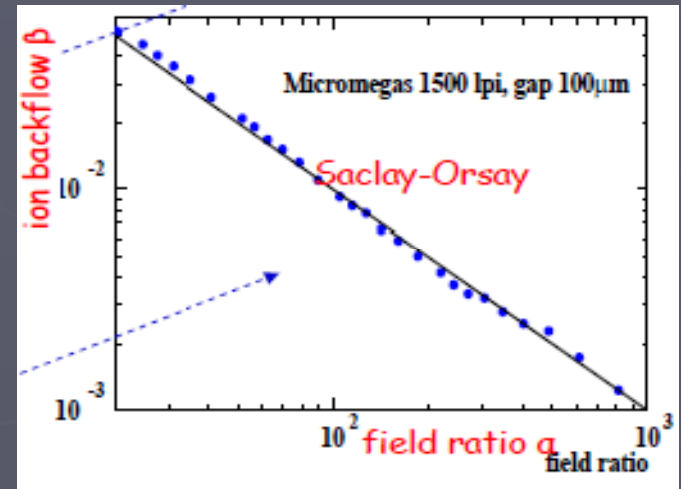
Detailed simulation underway using Marlin TPC (Bonn)

(L. HALLINIAN / LUISO)

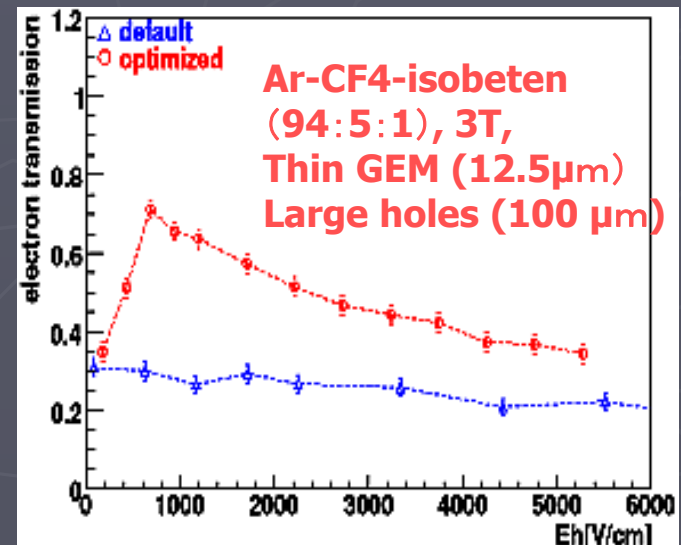
LP1 GEM Module by LC TPC Asian Group

Gating with special GEM

- The ion feedback ratios of MicroMEGAS and triple GEM can be $O(0.1)$ %. If the gas gain of the MPGD system is $< 1,000$, the total amount of the feed back ions is in the same order of the primary ions. Still the charge density in the ion disks may be 200 times of that of primary ions.
- With the two layers of (thick) GEMs, a gating device may be mandatory.
- **GEM Gating:** The wire gating is efficient but introduces a mechanical complication. GEM gating can stop the feed back ions. But electron transmission through gating GEM may be 70 % at the best, thus introduces some degradation of the spatial resolution. Between the gating device and MPGD, there will be still an ion dick.



Ion feedback ratio MicroMEGAS



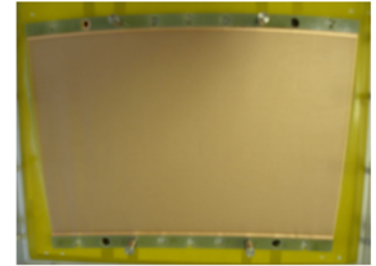
Electron transmission of gating GEM
(Simulation: Saga/CDC group)

LP1 GEM Module by LC TPC Asian Group

Gating with special GEM

Measured transmission of the thin (14 μm) gating GEM is measured to be around 50% or less (Saga University/LC PC Asian group). The point resolution with the gating GEM will be deteriorated accordingly. Still tolerable?

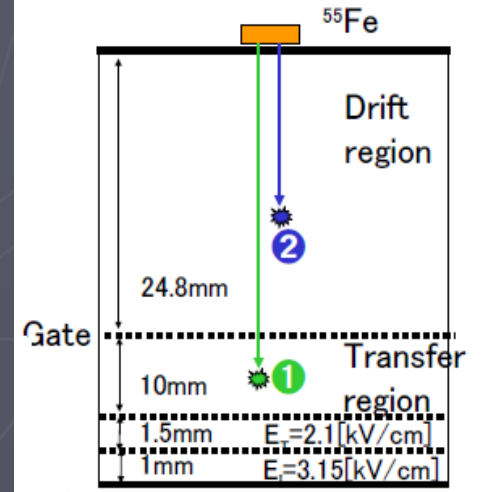
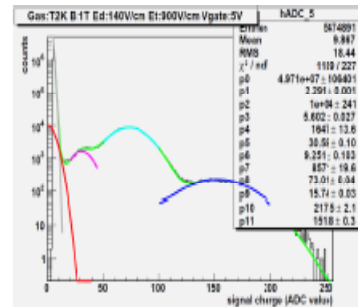
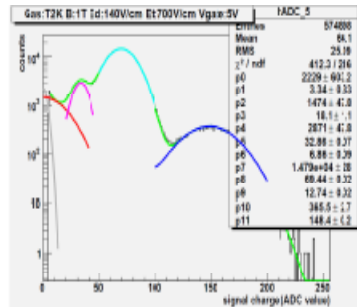
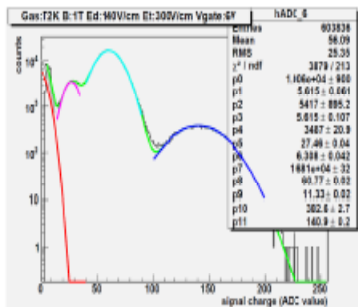
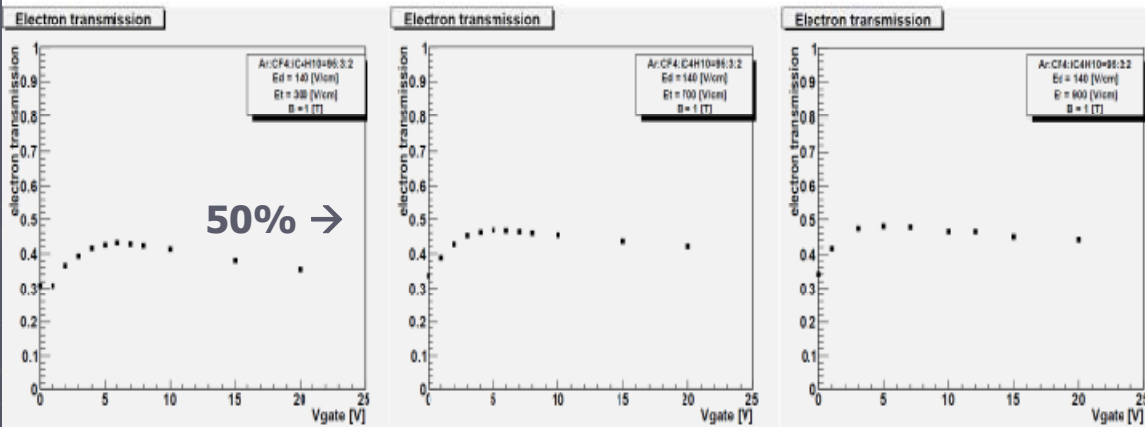
- Gate GEM
 - 14 μm -thick
 - 90 μm ϕ , 140 μm pitch
- 3 pieces



Gating GEM for LP test

Transmission

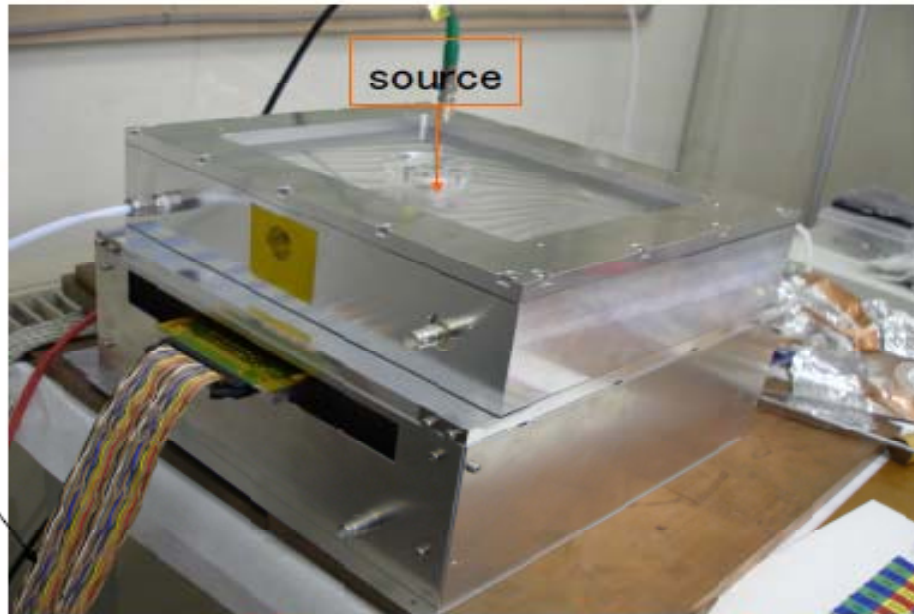
Very preliminary
Saga University/C TPC Asian group



Compare the pulse height for conversions in the drift region and the transfer region.

LP1 GEM Module by LC TPC Asian Group Laboratory test

Test Box



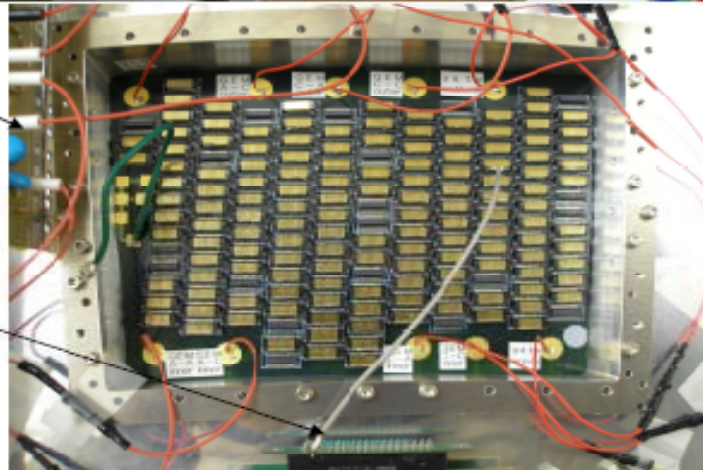
Sygiyama
Kuroiwa
@Saga

to post amp.
and oscilloscope

H.V. distribution board

readout elec.
16 pads*2 layers
(other pads are grounded)

readout plane



Without Gate

LP1 GEM Module by LC TPC Asian Group **The First Beam Test at DESY in Spring 2009**

The first beam test in spring 2009 at DESY with 5GeV/c electron beam
With 3 GEM modules mounted
Without the gating GEM
Readout with 3,000ch ALTRO electronics
Next beam test before April 2010:
With the gating GEM
With 10,000ch ALTRO electronics



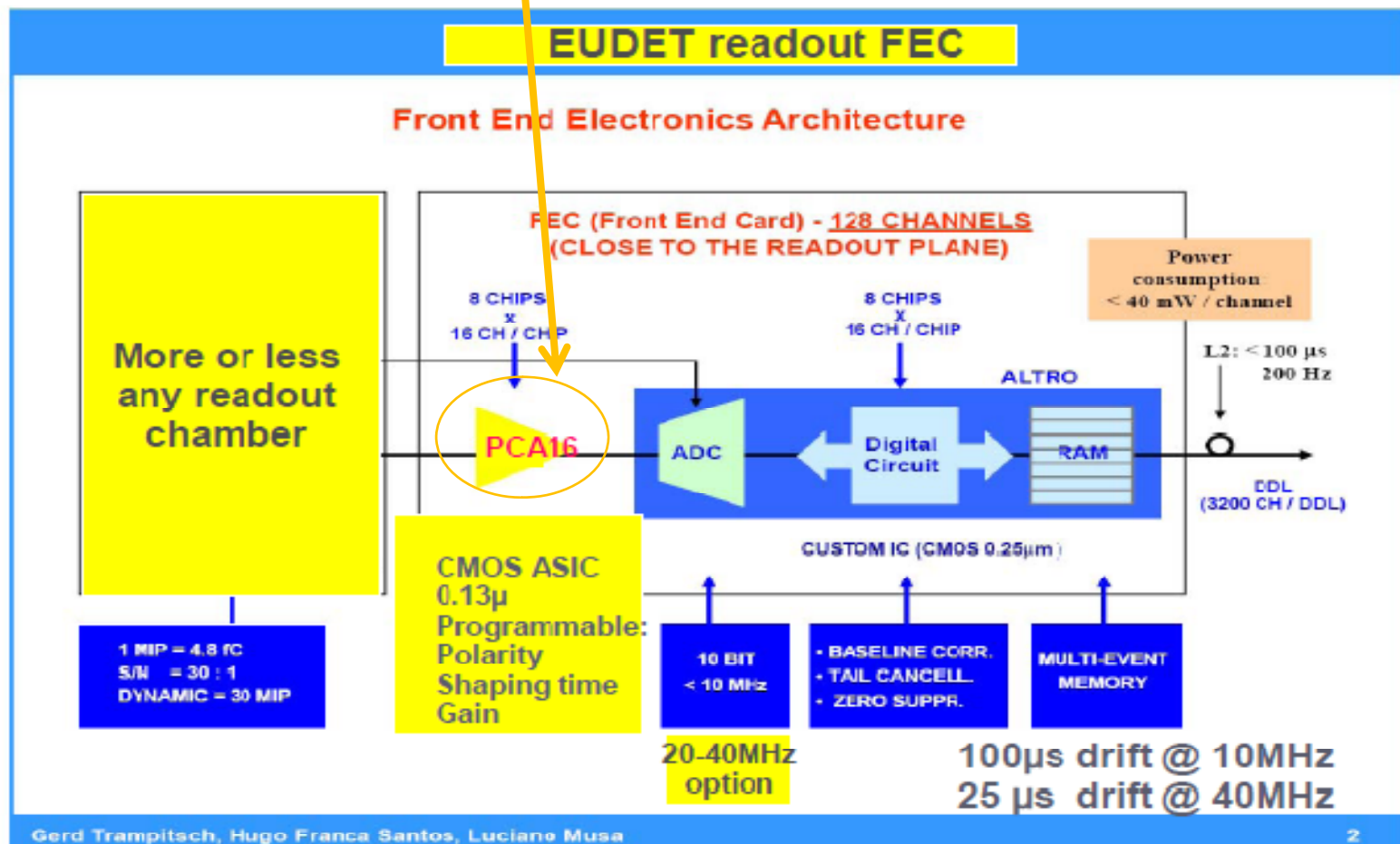
LP1 GEM Module by LC TPC Asian Group

Readout Electronics

ALTRO GEM Electronics: S-ALTRO

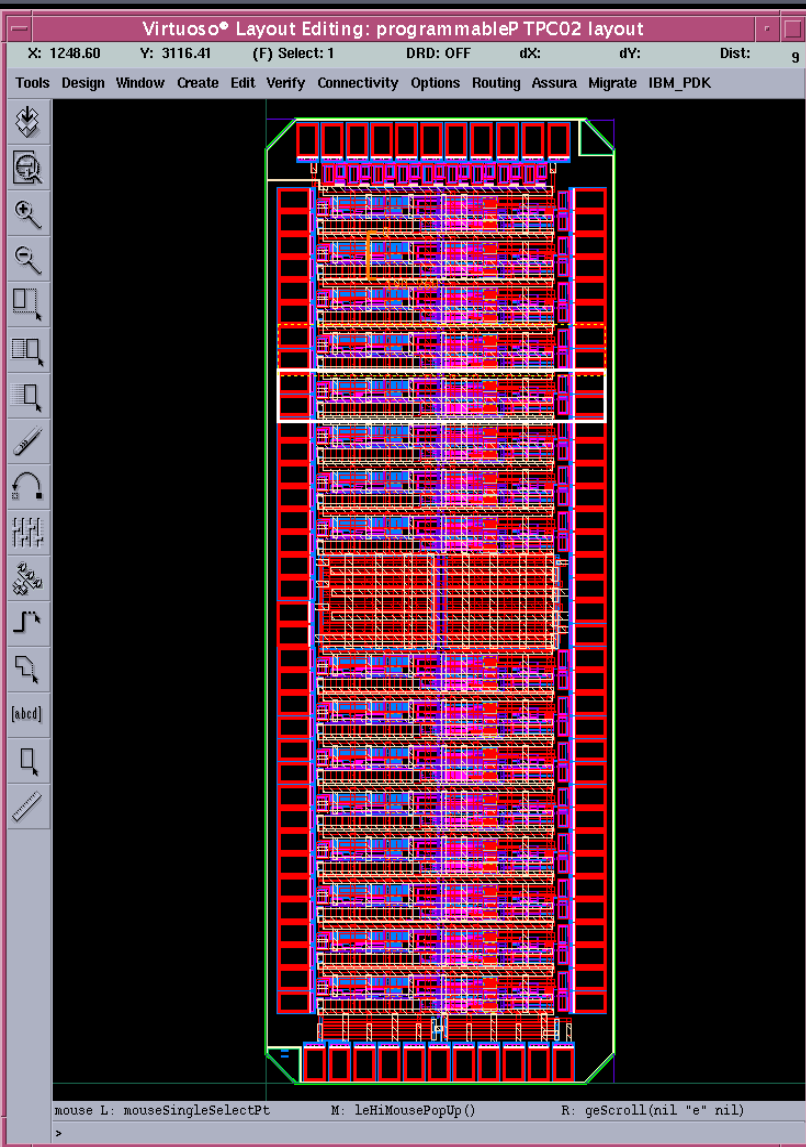
CERN/Lund

Based on the existing PASA + ALTRO electronics designed for the Alice TPC
PASA is replaced by PCA16 for MPGD readout.



ALTRO Electronics

New Programmable Charge Amplifier (PCA 16)



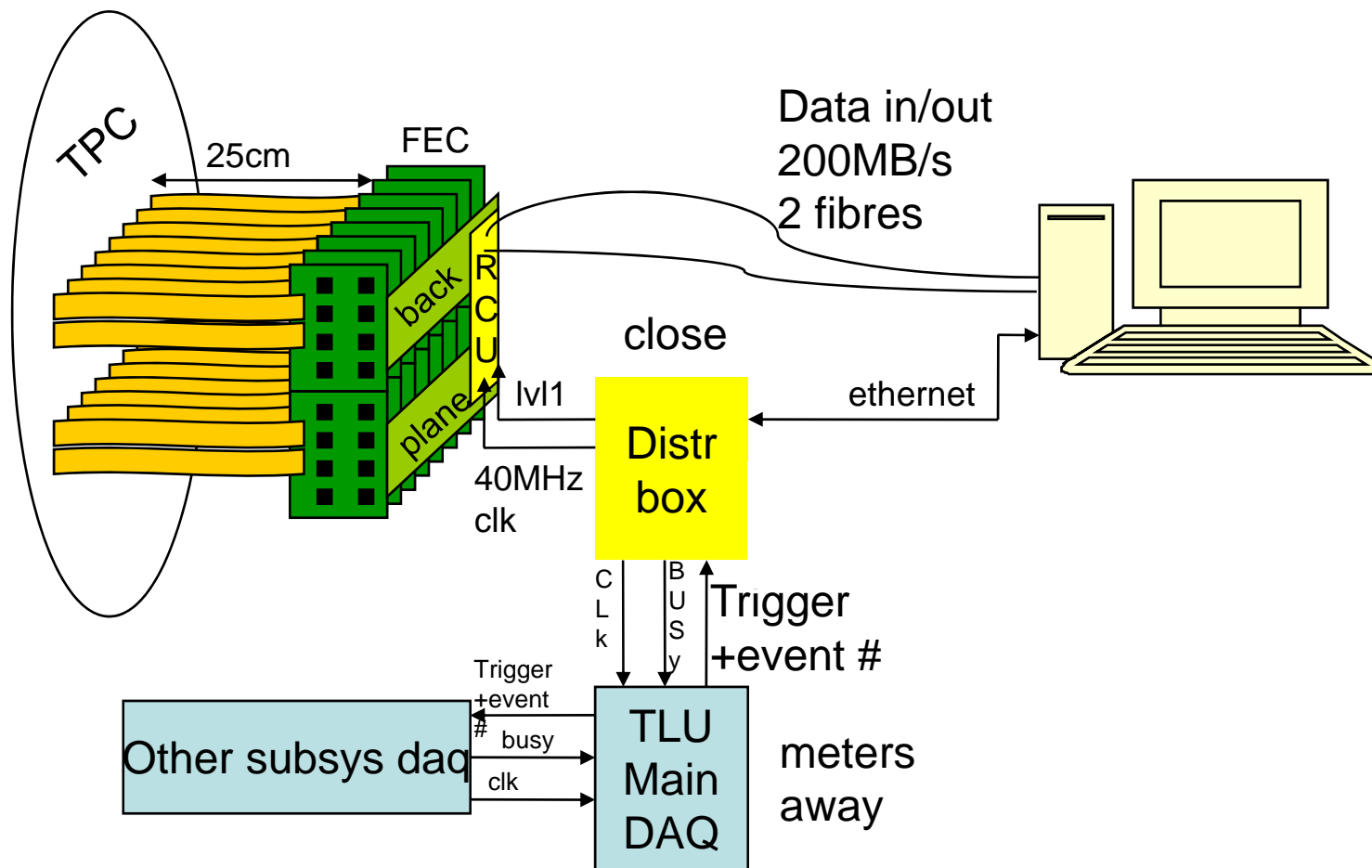
Both for MPGD & MWPC

- 1.5 V Supply,
- power consumption < 8 mW/channel
- 16 channel charge amplifier + anti-aliasing filter
- Single ended preamplifier
- Fully differential output amplifier
- Both signal polarities
- Power down mode (wake-up time = 1 ms)
- Programmable peaking time (30 ns – 120 ns) – 3rd order semi Gaussian pulse shape
- Programmable gain in 4 steps (12 – 27 mV/fC)
- Pre-amp-out mode (by pass shaper)
- Tunable time constant of the preamplifier
- Pitch 190.26um, Channel length 1026um,
- Chip dimensions = 1.5mm x 4mm

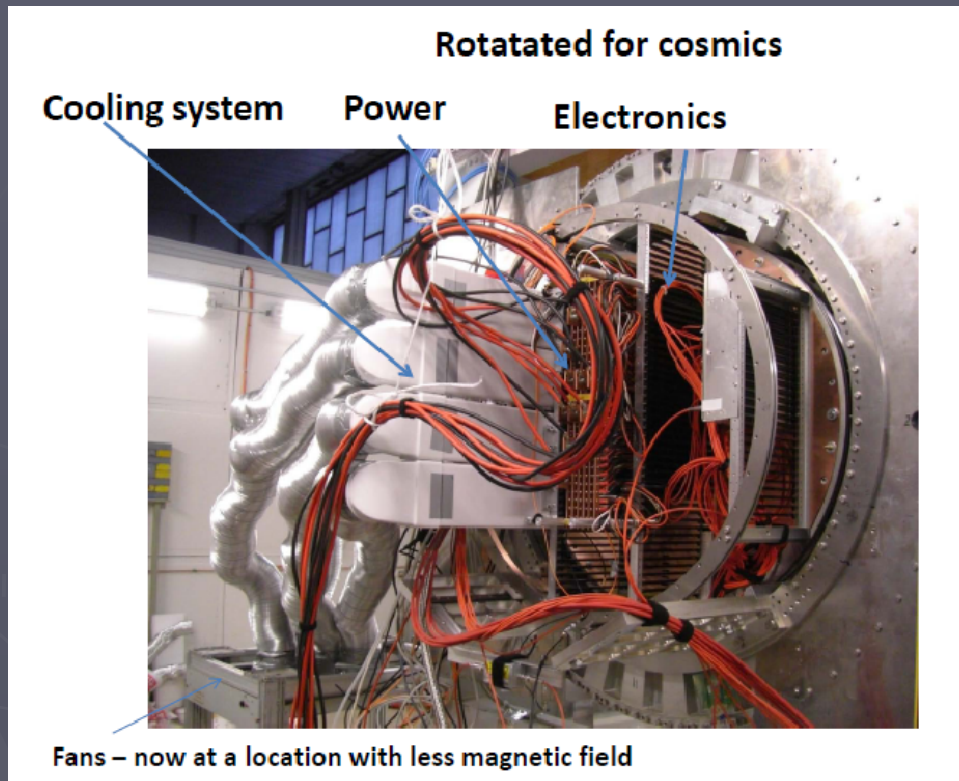
Most of data were taken with 120ns peaking time and With the highest gain.

ALTRO GEM Electronics

2048ch (16 FEC) (EUDET) → 10,000ch (LP test)



LP1 GEM Module by LC TPC Asian Group 3,000ch S-ALRO Electronics: Installation



Full installation of readout DAQ system for the ALRO TPC
Commissioning started with the ALRO TPC on 10th March 2010

ALRO

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| 100 | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 | 111 | 112 | 113 | 114 | 115 | 116 | 117 | 118 | 119 | 120 | 121 | 122 | 123 | 124 | 125 | 126 | 127 | 128 | 129 | 130 | 131 | 132 | 133 | 134 | 135 | 136 | 137 | 138 | 139 | 140 | 141 | 142 | 143 | 144 | 145 | 146 | 147 | 148 | 149 | 150 | 151 | 152 | 153 | 154 | 155 | 156 | 157 | 158 | 159 | 160 | 161 | 162 | 163 | 164 | 165 | 166 | 167 | 168 | 169 | 170 | 171 | 172 | 173 | 174 | 175 | 176 | 177 | 178 | 179 | 180 | 181 | 182 | 183 | 184 | 185 | 186 | 187 | 188 | 189 | 190 | 191 | 192 | 193 | 194 | 195 | 196 | 197 | 198 | 199 | 200 | 201 | 202 | 203 | 204 | 205 | 206 | 207 | 208 | 209 | 210 | 211 | 212 | 213 | 214 | 215 | 216 | 217 | 218 | 219 | 220 | 221 | 222 | 223 | 224 | 225 | 226 | 227 | 228 | 229 | 230 | 231 | 232 | 233 | 234 | 235 | 236 | 237 | 238 | 239 | 240 | 241 | 242 | 243 | 244 | 245 | 246 | 247 | 248 | 249 | 250 | 251 | 252 | 253 | 254 | 255 | 256 | 257 | 258 | 259 | 260 | 261 | 262 | 263 | 264 | 265 | 266 | 267 | 268 | 269 | 270 | 271 | 272 | 273 | 274 | 275 | 276 | 277 | 278 | 279 | 280 | 281 | 282 | 283 | 284 | 285 | 286 | 287 | 288 | 289 | 290 | 291 | 292 | 293 | 294 | 295 | 296 | 297 | 298 | 299 | 300 | 301 | 302 | 303 | 304 | 305 | 306 | 307 | 308 | 309 | 310 | 311 | 312 | 313 | 314 | 315 | 316 | 317 | 318 | 319 | 320 | 321 | 322 | 323 | 324 | 325 | 326 | 327 | 328 | 329 | 330 | 331 | 332 | 333 | 334 | 335 | 336 | 337 | 338 | 339 | 340 | 341 | 342 | 343 | 344 | 345 | 346 | 347 | 348 | 349 | 350 | 351 | 352 | 353 | 354 | 355 | 356 | 357 | 358 | 359 | 360 | 361 | 362 | 363 | 364 | 365 | 366 | 367 | 368 | 369 | 370 | 371 | 372 | 373 | 374 | 375 | 376 | 377 | 378 | 379 | 380 | 381 | 382 | 383 | 384 | 385 | 386 | 387 | 388 | 389 | 390 | 391 | 392 | 393 | 394 | 395 | 396 | 397 | 398 | 399 | 400 | 401 | 402 | 403 | 404 | 405 | 406 | 407 | 408 | 409 | 410 | 411 | 412 | 413 | 414 | 415 | 416 | 417 | 418 | 419 | 420 | 421 | 422 | 423 | 424 | 425 | 426 | 427 | 428 | 429 | 430 | 431 | 432 | 433 | 434 | 435 | 436 | 437 | 438 | 439 | 440 | 441 | 442 | 443 | 444 | 445 | 446 | 447 | 448 | 449 | 450 | 451 | 452 | 453 | 454 | 455 | 456 | 457 | 458 | 459 | 460 | 461 | 462 | 463 | 464 | 465 | 466 | 467 | 468 | 469 | 470 | 471 | 472 | 473 | 474 | 475 | 476 | 477 | 478 | 479 | 480 | 481 | 482 | 483 | 484 | 485 | 486 | 487 | 488 | 489 | 490 | 491 | 492 | 493 | 494 | 495 | 496 | 497 | 498 | 499 | 500 | 501 | 502 | 503 | 504 | 505 | 506 | 507 | 508 | 509 | 510 | 511 | 512 | 513 | 514 | 515 | 516 | 517 | 518 | 519 | 520 | 521 | 522 | 523 | 524 | 525 | 526 | 527 | 528 | 529 | 530 | 531 | 532 | 533 | 534 | 535 | 536 | 537 | 538 | 539 | 540 | 541 | 542 | 543 | 544 | 545 | 546 | 547 | 548 | 549 | 550 | 551 | 552 | 553 | 554 | 555 | 556 | 557 | 558 | 559 | 560 | 561 | 562 | 563 | 564 | 565 | 566 | 567 | 568 | 569 | 570 | 571 | 572 | 573 | 574 | 575 | 576 | 577 | 578 | 579 | 580 | 581 | 582 | 583 | 584 | 585 | 586 | 587 | 588 | 589 | 590 | 591 | 592 | 593 | 594 | 595 | 596 | 597 | 598 | 599 | 600 | 601 | 602 | 603 | 604 | 605 | 606 | 607 | 608 | 609 | 610 | 611 | 612 | 613 | 614 | 615 | 616 | 617 | 618 | 619 | 620 | 621 | 622 | 623 | 624 | 625 | 626 | 627 | 628 | 629 | 630 | 631 | 632 | 633 | 634 | 635 | 636 | 637 | 638 | 639 | 640 | 641 | 642 | 643 | 644 | 645 | 646 | 647 | 648 | 649 | 650 | 651 | 652 | 653 | 654 | 655 | 656 | 657 | 658 | 659 | 660 | 661 | 662 | 663 | 664 | 665 | 666 | 667 | 668 | 669 | 670 | 671 | 672 | 673 | 674 | 675 | 676 | 677 | 678 | 679 | 680 | 681 | 682 | 683 | 684 | 685 | 686 | 687 | 688 | 689 | 690 | 691 | 692 | 693 | 694 | 695 | 696 | 697 | 698 | 699 | 700 | 701 | 702 | 703 | 704 | 705 | 706 | 707 | 708 | 709 | 710 | 711 | 712 | 713 | 714 | 715 | 716 | 717 | 718 | 719 | 720 | 721 | 722 | 723 | 724 | 725 | 726 | 727 | 728 | 729 | 730 | 731 | 732 | 733 | 734 | 735 | 736 | 737 | 738 | 739 | 740 | 741 | 742 | 743 | 744 | 745 | 746 | 747 | 748 | 749 | 750 | 751 | 752 | 753 | 754 | 755 | 756 | 757 | 758 | 759 | 760 | 761 | 762 | 763 | 764 | 765 | 766 | 767 | 768 | 769 | 770 | 771 | 772 | 773 | 774 | 775 | 776 | 777 | 778 | 779 | 780 | 781 | 782 | 783 | 784 | 785 | 786 | 787 | 788 | 789 | 790 | 791 | 792 | 793 | 794 | 795 | 796 | 797 | 798 | 799 | 800 | 801 | 802 | 803 | 804 | 805 | 806 | 807 | 808 | 809 | 810 | 811 | 812 | 813 | 814 | 815 | 816 | 817 | 818 | 819 | 820 | 821 | 822 | 823 | 824 | 825 | 826 | 827 | 828 | 829 | 830 | 831 | 832 | 833 | 834 | 835 | 836 | 837 | 838 | 839 | 840 | 841 | 842 | 843 | 844 | 845 | 846 | 847 | 848 | 849 | 850 | 851 | 852 | 853 | 854 | 855 | 856 | 857 | 858 | 859 | 860 | 861 | 862 | 863 | 864 | 865 | 866 | 867 | 868 | 869 | 870 | 871 | 872 | 873 | 874 | 875 | 876 | 877 | 878 | 879 | 880 | 881 | 882 | 883 | 884 | 885 | 886 | 887 | 888 | 889 | 890 | 891 | 892 | 893 | 894 | 895 | 896 | 897 | 898 | 899 | 900 | 901 | 902 | 903 | 904 | 905 | 906 | 907 | 908 | 909 | 910 | 911 | 912 | 913 | 914 | 915 | 916 | 917 | 918 | 919 | 920 | 921 | 922 | 923 | 924 | 925 | 926 | 927 | 928 | 929 | 930 | 931 | 932 | 933 | 934 | 935 | 936 | 937 | 938 | 939 | 940 | 941 | 942 | 943 | 944 | 945 | 946 | 947 | 948 | 949 | 950 | 951 | 952 | 953 | 954 | 955 | 956 | 957 | 958 | 959 | 960 | 961 | 962 | 963 | 964 | 965 | 966 | 967 | 968 | 969 | 970 | 971 | 972 | 973 | 974 | 975 | 976 | 977 | 978 | 979 | 980 | 981 | 982 | 983 | 984 | 985 | 986 | 987 | 988 | 989 | 990 | 991 | 992 | 993 | 994 | 995 | 996 | 997 | 998 | 999 | 1000 |
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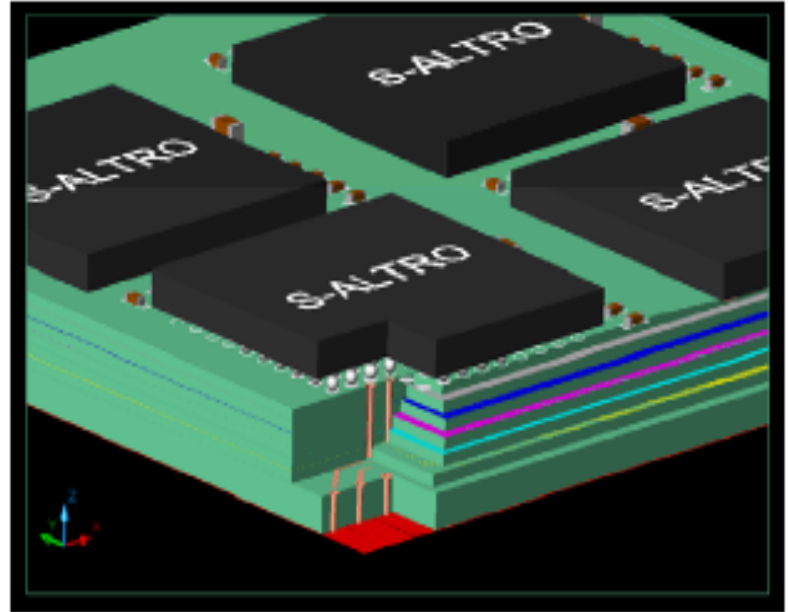
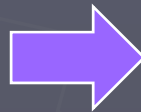
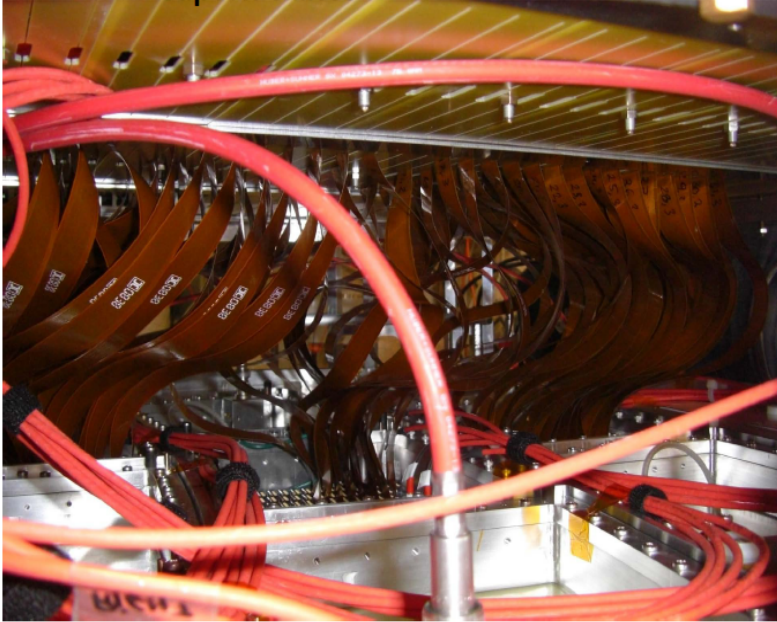
Only parts (red) of the modules were equipped with the electronics.

The status of the readout DAQ system was satisfactory from the time of commissioning:

- 3% of all events corrupted due to problem with zero-suppression. (now known to be a software problem)
- 16 (1chip) channels dead..
- 1 channel has an offset of 12,50 ADC counts in every event.
- A few channels have noise, roughly 130 kHz (due to near by HV cables).
- Some channels saturate (gain=3).

LP1 GEM Module by LC TPC Asian Group S-ALTRO Project and Advanced Endplate

Capton cables

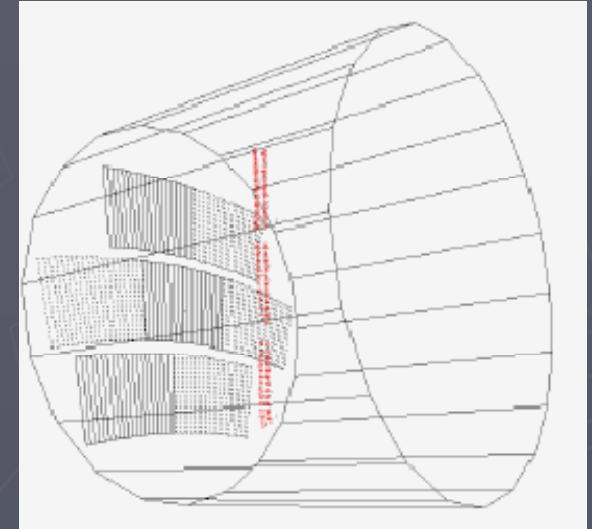
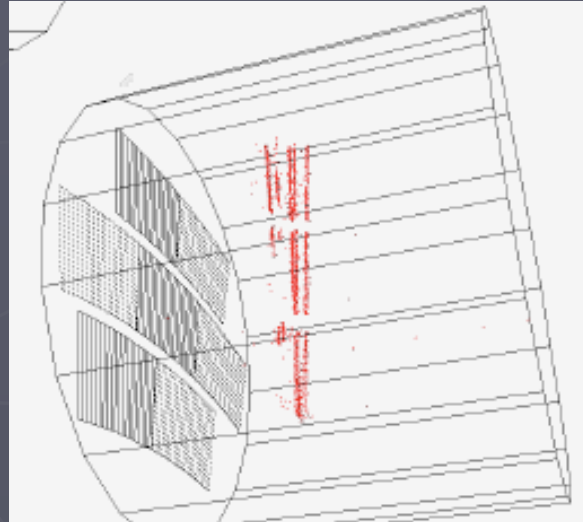
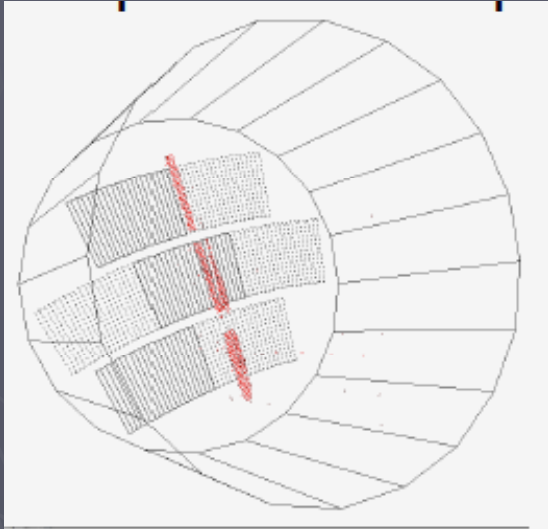


Advanced Endplate

**10,000ch with the flexible cable connections may still be manageable but not more.
S-ALTRO project (and also a similar project for the T2K electronics) is underway.**

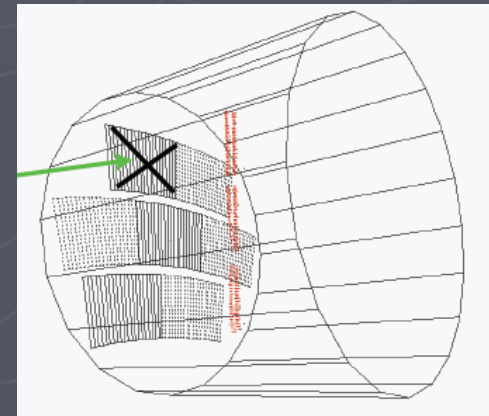
LP1 GEM Module by LC TPC Asian Group **The First Beam Test at DESY in Spring 2009**

3,000ch ALTRO electronics were distributed along beam in the most of data taking.



One of the modules started to draw current due to the provisional electrode on the frame of the top GEM in the absence of the gating GEM.

The rest (most) of the data taking was performed only with two modules.



LP1 GEM Module by LC TPC Asian Group

Some Preliminary Results

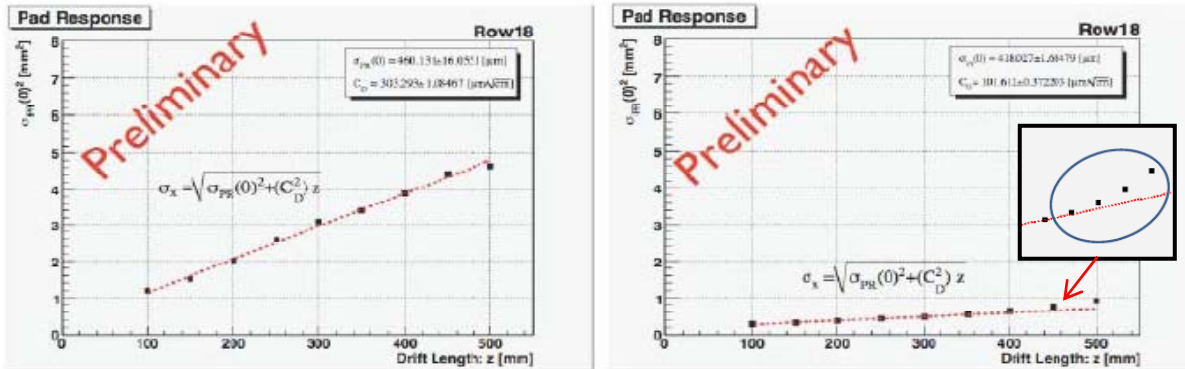
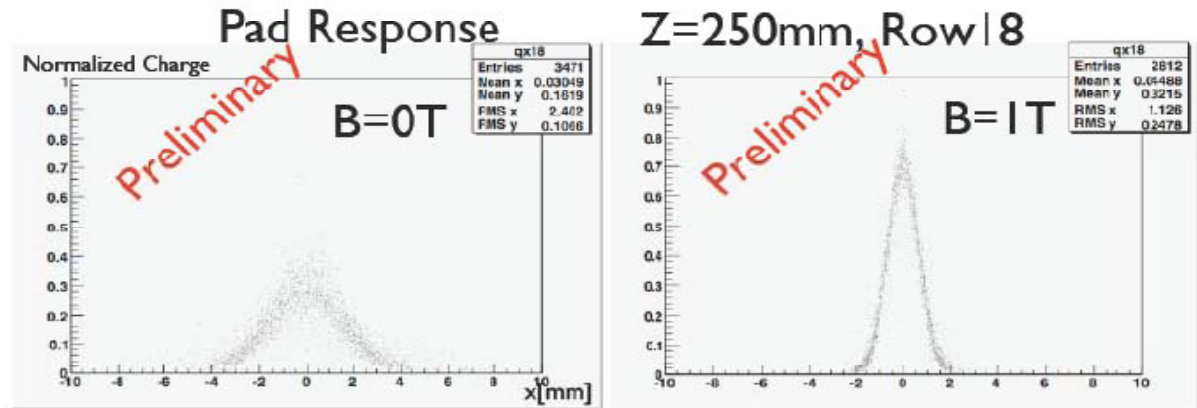
- Analysis: (1) Confirm the results from small prototype test
 (2) Full volume (length) tracking (now starting)

(A) Pad response

Deviation from the expectation at large drift distances at 1T are due to the change of PCMAG at its end.

Need the PCMAG movable table soon.

Charge spread (pad response function)



LP1 GEM Module by LC TPC Asian Group

Some Preliminary Results

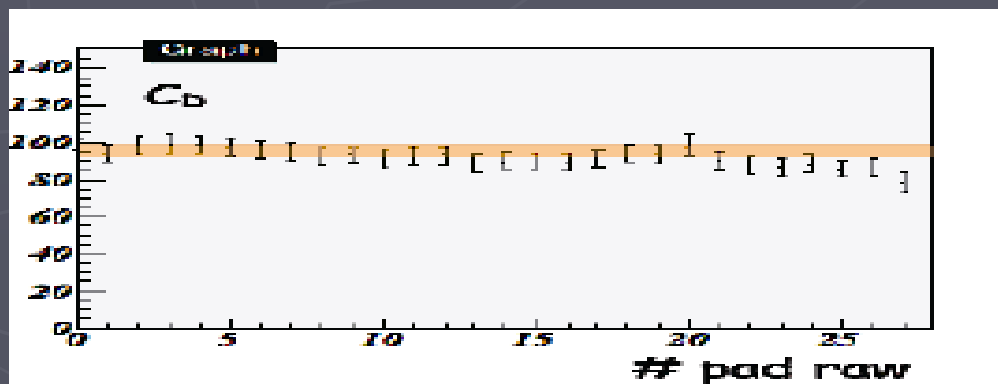
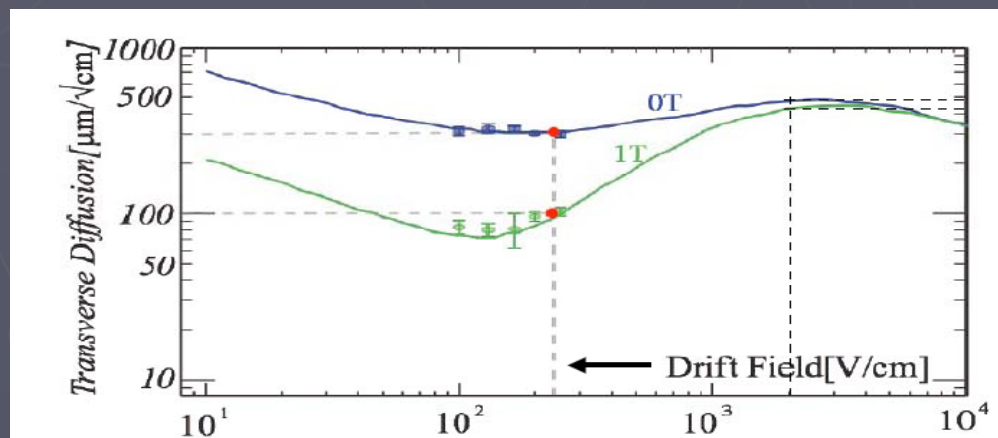
(B) Drift velocity

Agree well to our expectation (MagBoltz simulation) and Our previous measurements.

The green and bleu points are from the small TPC (MP-TPC) prototype.

Pad row dependence of measured C_D .

| Raw 18 | B = 0 T | B = 1 T |
|--|---------|---------|
| C_D [$\mu\text{m}/\sqrt{\text{cm}}$] | 303 | 102 |
| error | 1 | 1 |



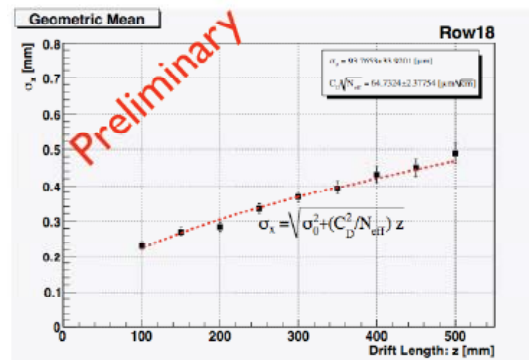
LP1 GEM Module by LC TPC Asian Group

Some Preliminary Results

(C) Point resolution

Confirmed the results from the small TPC (MP-TPC) prototype test.

Neff consistent with that (21 +/- 2) from the small TPC (MP-TPC) prototype considering the differences of pad length (5.7mm vs. 6.4mm) and beams (5GeV/c electrons vs. cosmic muons).



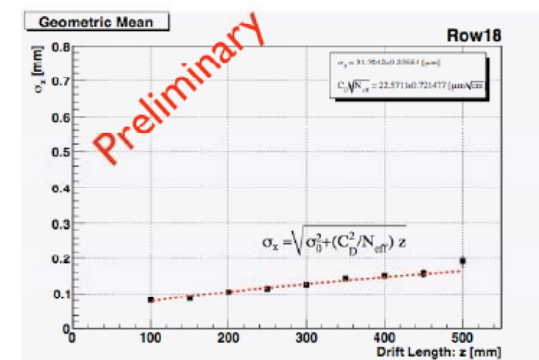
B=0T

fitting result

$$\frac{C_D}{\sqrt{N_{eff}}} = 65 \pm 2 [\mu m / \sqrt{cm}]$$

$$\begin{cases} C_D = 303 \pm 1 [\mu / \sqrt{cm}] \\ \frac{C_D}{\sqrt{N_{eff}}} = 65 \pm 2 [\mu m / \sqrt{cm}] \end{cases}$$

$$\longrightarrow N_{eff} \sim 22 \pm 1$$



B=1T

fitting result

$$\frac{C_D}{\sqrt{N_{eff}}} = 22.6 \pm 0.7 [\mu m / \sqrt{cm}]$$

$$\begin{cases} C_D = 101.6 \pm 0.4 [\mu / \sqrt{cm}] \\ \frac{C_D}{\sqrt{N_{eff}}} = 22.6 \pm 0.7 [\mu m / \sqrt{cm}] \end{cases}$$

$$\longrightarrow N_{eff} \sim 20 \pm 1$$

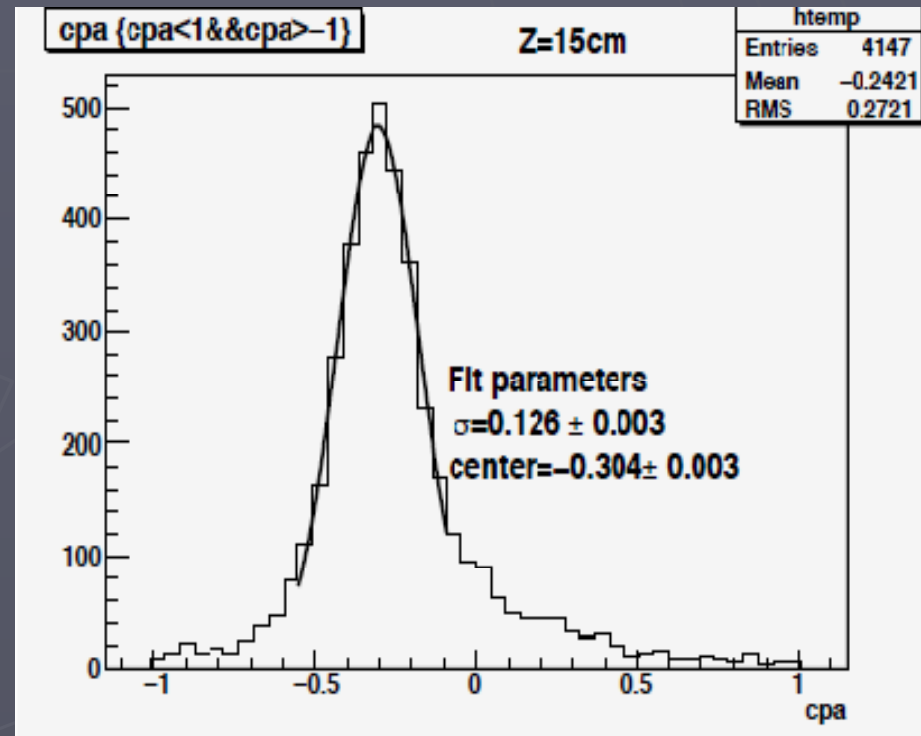
LP1 GEM Module by LC TPC Asian Group Toward Full Volume Tracking

(D) Momentum measurement (One/central module)

Fit all tracks by Kalman Filter.
No selection of events/tracks.
The peak momentum of around 3GeV/c
instead of 5GeV/c (due to the
shower events).
Now need to understand the width of
distribution.

(E) Tracking with multiple modules:

Still provisional tool now available.
Need to work with the non-uniform
magnetic field and to correct/remove
the effect of E-field distortion if any.



1/p distribution for the central module

Conclusions

MPGD provides a new TPC with large number of space points and the excellent point resolution of 100 microns or less over 2.5m drift distance, a truly-visual 3D tracker works in high magnetic field providing the performance necessary for the experimentation at ILC.

The TPC Large Prototype test has started. The full volume tracking is still to be demonstrated (in 2010).

The GEM modules with thick GEM were tested in the Large Prototype . The results confirmed those from the small prototype tests (point resolution).

The issue of ion feed back still remains.

There are important engineering issues to realize MPGD TPC, in particular, the surface mounting of electronics on the endplate (modules). R&D's for the advanced endplate design for all options are urgent.