JLC Central Tracker R&D

Keisuke Fujii, KEK
Representing JLC CDC Group

Plan of Talk

Introduction

What We Have Done Since Sitges

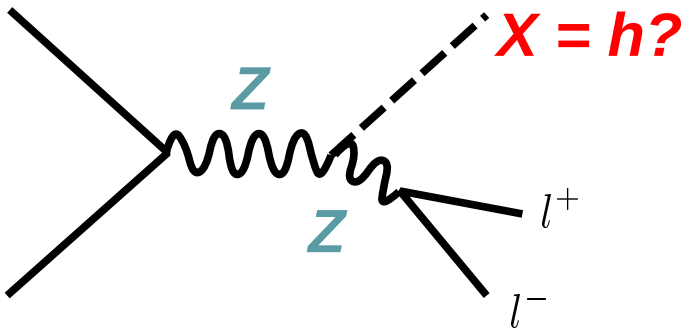
Future Direction

Introduction

Physics Requirements

1. Recoil Mass Resolution

$$\sigma^{\rm meas}_{M_{\rm recoil}} \lesssim \sigma^{\Delta E_{\rm beam}}_{M_{\rm recoil}}$$



$$M_{\rm recoil} = \sqrt{(P_{CM} - (p_{l^+} + p_{l^-}))^2}$$

$$\sigma_{p_{l\pm}}/p_{l\pm} \lesssim 0.4\% \text{ at } p_{l\pm}\ 50\ \text{GeV}$$

2. Jet Invariant Mass Resolution

$$\sigma_{M_{JJ}} \simeq \Gamma_{W/Z}/2$$

Good track-cluster matching $\quad \sigma_z = \sigma_{xy}/\tan\alpha_{\rm stereo} \simeq 1mm$

2-track separtion better than $\quad 2mm$

(<10% loss of hits at the innermost layer for 250 GeV W's)

3. Time Stamping Capability to Reject Mini-Jet BG

$$\sigma_{T_0} = \sigma_{t/wire}/\sqrt{n} \lesssim \text{Bunch Spacing } (1.4/2.8 \text{ nsec})$$

$$\sigma_{t/wire} \lesssim 1.4\text{ns} \times \sqrt{100} \simeq 10\text{ns}$$

Current CDC Parameters

$$\frac{\sigma_{p_T}}{p_T^2} \simeq \sqrt{\left(\frac{\alpha'\sigma_{xy}}{Bl^2}\right)^2\left(\frac{720}{n+4}\right) + \left(\frac{\alpha' C}{BlP_T}\right)^2\left(\frac{10}{7}\left(\frac{X}{X_0}\right)\right)}$$

$$\begin{cases} \sigma_{xy} = 85\mu m \longrightarrow \begin{pmatrix}\text{cool gas}\\ \text{mini-jet cell}\end{pmatrix} \\ l = R_{out} - R_{in} \\ \quad = 230(\text{outer cylinder}) - 45(\text{support tube}) = 185cm \\ n = 80 \\ B = 2T \\ L = 460cm \quad (\text{full lever arm above } 45^\circ) \end{cases}$$

$$\sigma_z = \sigma_{xy}/\tan\alpha_{stereo} \simeq 1mm$$

$$\tan\alpha_{stereo} \simeq 0.1 \longrightarrow \text{mini-jet cell}$$

$$\sigma_{T_0} \simeq \frac{\sigma_{xy}}{v_{drift}\sqrt{n}} \lesssim 1.4\text{nsec}$$

5 sense wires/cell

14k cells

~100k field wires

R&D Items

1. *Can we control gravitational and electrostatic wire sags for 4.6m-long wires?*
2. *Can we achieve a spatial resolution of 85 microns everywhere in this big chamber?*
3. *Can we achieve 2-track separation better than 2mm?*
4. *Can we stably operate 4.6m-long stereo cells?*
5. *Is Lorentz angle small enough to allow straight cells?*
6. *Is gas gain saturation observed for cool gas mixtures no problem?*
7. *Is tension drop controlable for Al wires?*
8. *Is neutron BG no problem?* *(~3k hits/train for B=2T)*
   - *How big is the signal charge for a single neutron hit?*
   - *Any dead time?*

Publication Plan

http://www-jlc.kek.jp/subg/cdc/Paper-e.html

1. Gravitational and Electrostatic Sags (4.6m Test Chamber) : NIM A383(96)391
2. Cosmic Ray Tests (4.6m Test Chamber) :NIM A441(00)393
3. Two-Track Separation (Baby Chamber) (in preparation)
4. Designing of Stereo-Wire Geometry for a Long CDC :NIM A428 (99)403

5. Lorentz Angle Measurement: KEK Preprint 2000-113, to be submitted to NIM

6. Gas Gain Measurement:NIM A447(00)459
7. Wire Tension Measurement
8. BG Studies
9. Gas Properties

KEK Preprint 99-50
July 1999
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Cosmic Ray Tests of a 4.6m-long Test Drift Chamber for JLC

Y.Kurihara[a], *A.Yamaguchi*[b], *S.Sudo*[b], *T.Abe*[c1], *K.Fujii*[a], *N.Ishihara*[a], *N.Khalatyan*[a], *T.Matsui*[a], *O.Nitoh*[b], *T.Ohama*[a], *H.Okuno*[a], *A.Sugiyama*[c], *K.Takahashi*[b], *T.Watanabe*[d], *T.Yoshida*[a],

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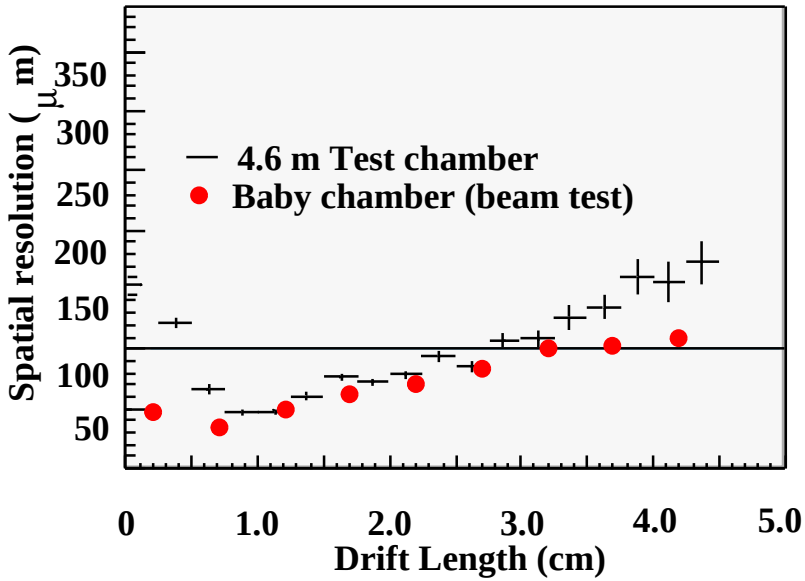
[b]Tokyo University of Agriculture and Technology, Tokyo 184-8588, Japan
[c]Department of Physics, Nagoya University, Nagoya 464-8602, Japan
[d]Kogakuin University, Tokyo 163-8677, Japan
[e]Kinki University, Osaka, 577-8502, Japan

Abstract

Performance of a 4.6 m-long drift chamber filled with a CO_2 iso-butane (90 : 10) mixture was studied using cosmic ray data, in the course of detector R&D's for JLC. After correcting the data for wire displacements due to gravitational and electrostatic forces, a spatical resolution of 100 μm per wire was achieved over the full length of the chamber. The relation between wire efficiency and oxygen remnant in the chamber gas is also discussed.

Momentum Resolution



For a 4.6m-long test chamber

$$\langle \sigma_{xy} \rangle \simeq 100 \mu m$$

has been achieved!

KEK Preprint 99-74
TUAT-HEP 99-01
KINDAI-HEP 99-01
September 1999
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To supplement stero wire study

$CO_2/isoC_4H_{10}$

Very special
..... Quickly saturating!

Gas Gain Study for CO_2/Isobutane Mixtures

H.Okuno[a], *N.Khalatyan*[a], *Y.Nakamura*[b], *K.Fujii*[a], *K.Hoshina*[b], *Y.Kato*[e], *Y.Kurihara*[a], *H.Kuroiwa*[b], *O.Nitoh*[b]

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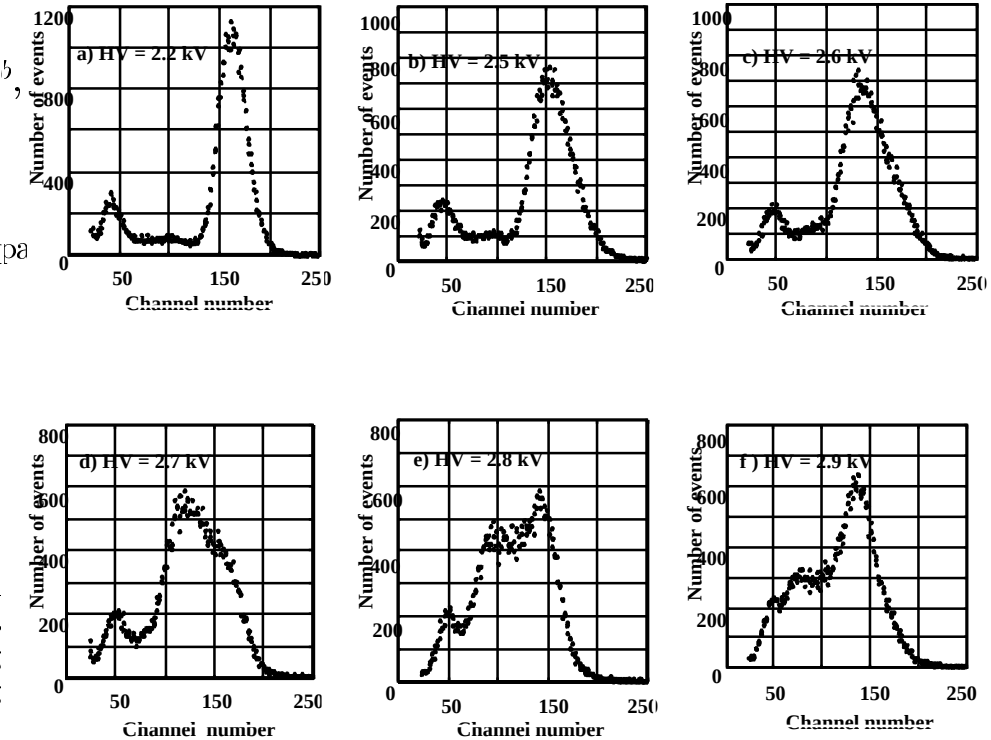
[b]Tokyo University of Agriculture and Technology, Koganei, 184-8588, Japan
[e]Kinki University, Osaka, 577-8502, Japan



Abstract

We have studied gas amplification properties of a proportional tube filled with CO_2/Isobutane gas mixtures. The gas gain was measured for X-rays and β-rays as a function of the anode-wire surface field and was used to estimate gain variation along 4.6 m-long stereo anode wires of our proposed central drift chamber for JLC. During the gas gain study, we observed a strong saturation effect for point ionizations.

KEK Preprint 2000-113
KUDP 2000-001
TUAT-HEP 2000-04
KINDAI-HEP 00-01
October 2000
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Lorentz Angle Measurement for CO_2/Isobutane Gas Mixtures

K.Hoshina[b], *K.Fujii*[a], *N.Khalatyan*[c], *O.Nitoh*[b], *H.Okuno*[a], *Y.Kato*[e], *M.Kobayashi*[a], *Y.Kurihara*[a], *H.Kuroiwa*[b], *Y.Nakamura*[b], *K.Sakieda*[b], *Y.Suzuki*[b], *T.Watanabe*[d]

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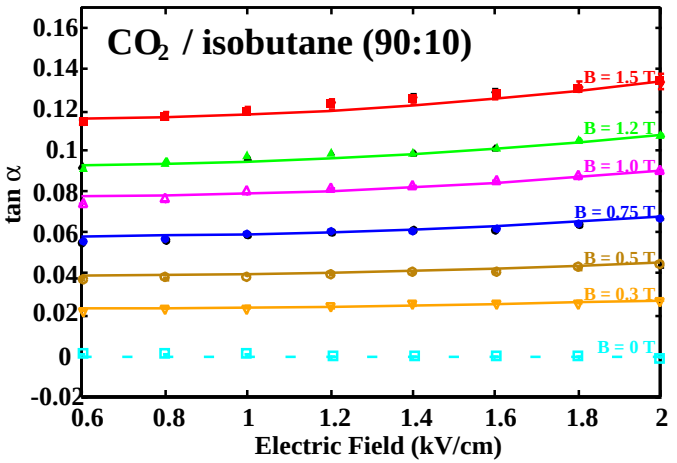
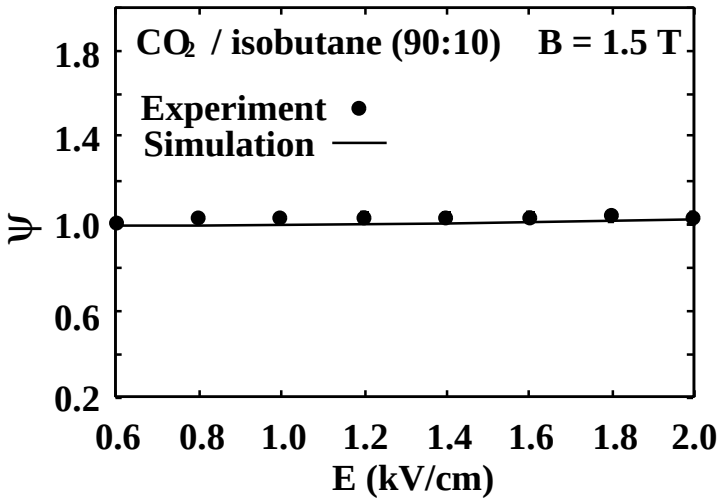
Abstract

We have developed a Lorentz angle measurement system for cool gas mixtures in the course of our R&D for a proposed JLC central drift chamber (JLC-CDC). The measurement system is characterized by the use of two laser beams to produce primary electrons and flash ADCs to read their signals simultaneously. With this new system, we have measured Lorentz angles for CO_2/isobutane gas mixtures with different proportions (95:5, 90:10, and 85:15), varying drift field from 0.6 to 2.0 kV/cm and magnetic field up to 1.5 T. The results of the measurement are in good agreement with GARFIELD/MAGBOLTZ simulations.

To Justify Our Cell Design



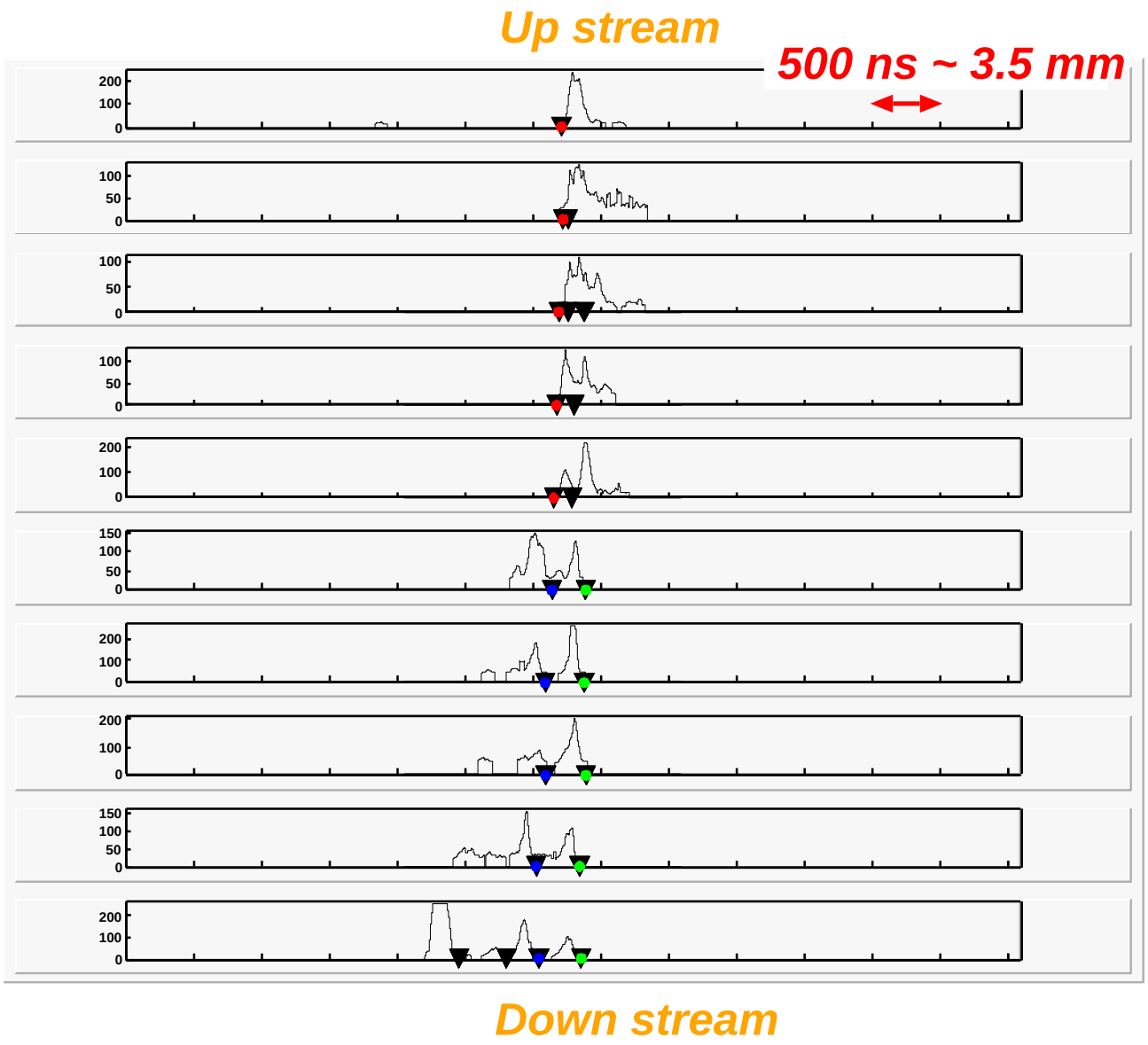
Good agreement with GARFIELD/MAGBOLTZ simulation

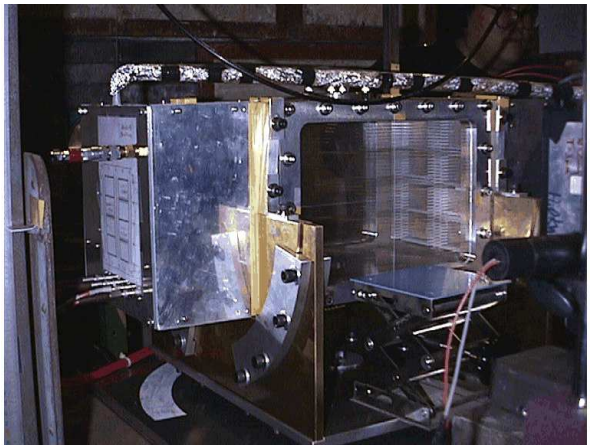


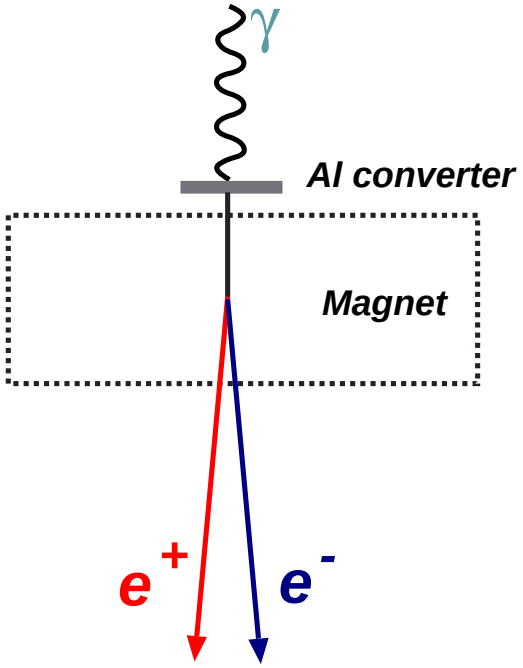
$$\tan\alpha = \left(\frac{B}{E}\right) v_D^0$$

$$\Psi \simeq 1$$

2-Track Separation



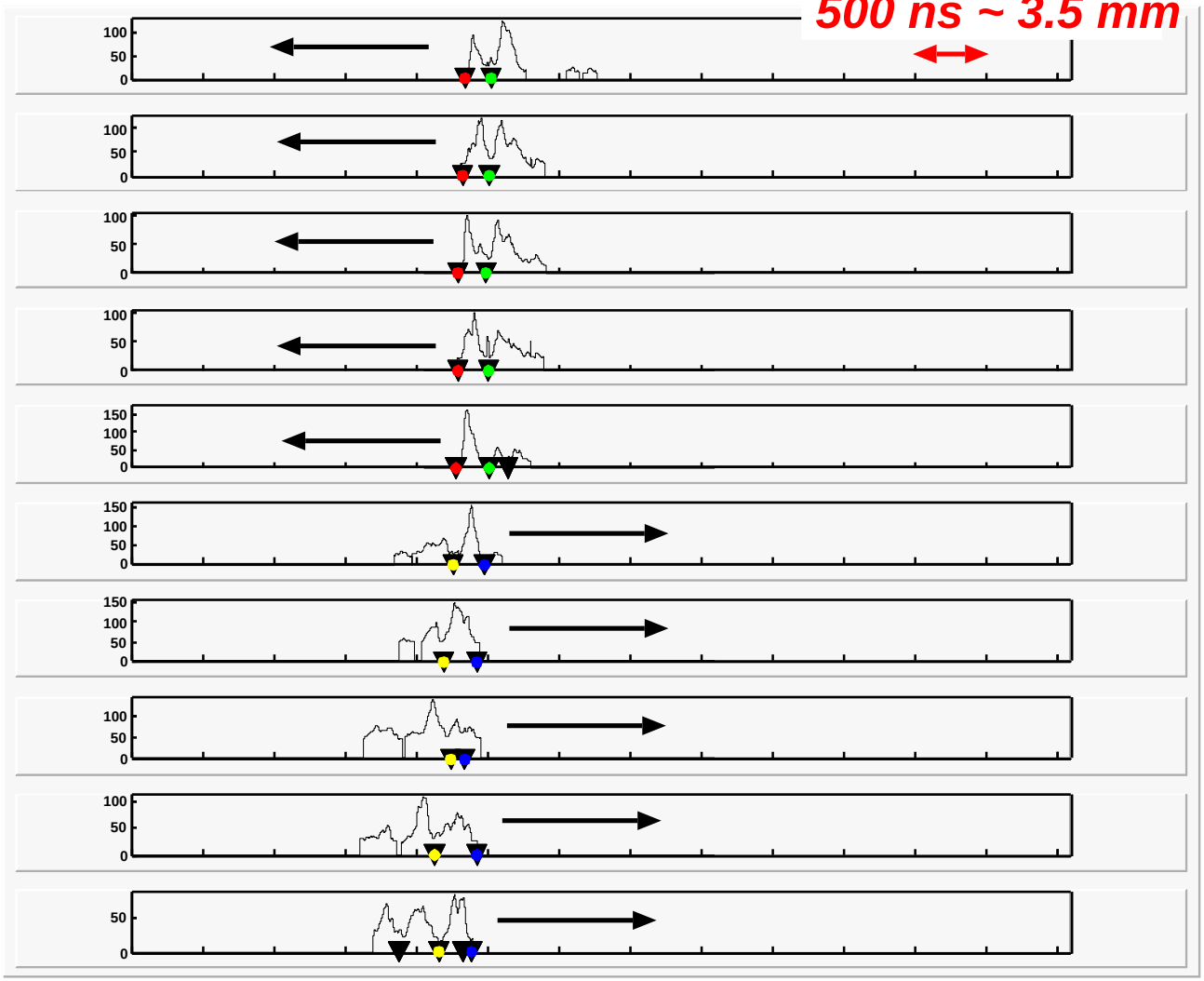




2-Track Separation

Up stream

500 ns ~ 3.5 mm



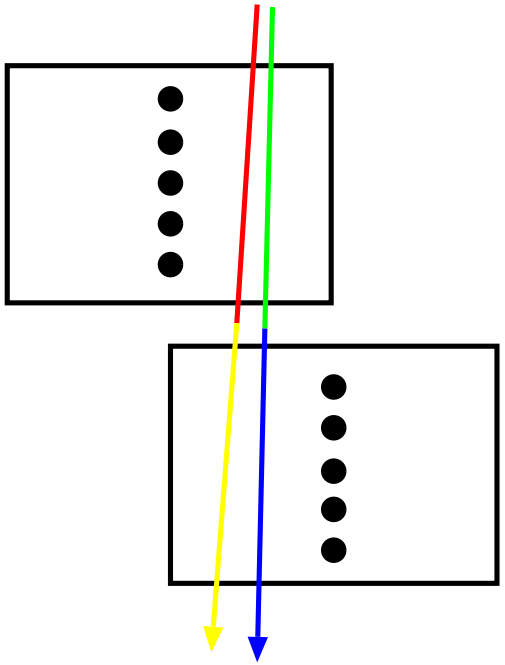
Down stream

Normal Incidence

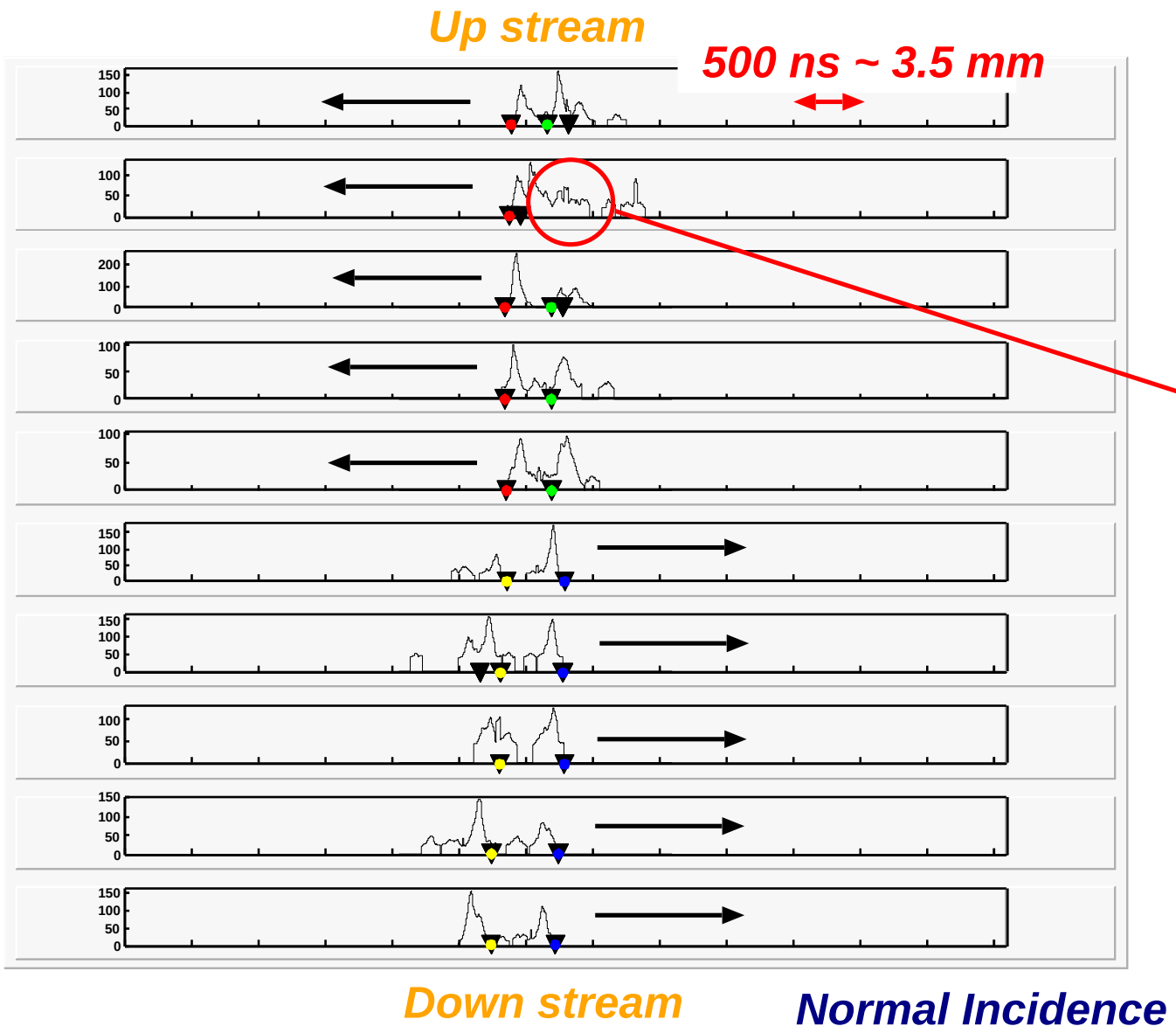
Example 1

Successful Case

It looks possible to separate 2 tracks as close as 1mm to each other



2-Track Separation



Example 2

Our Gas Mixture

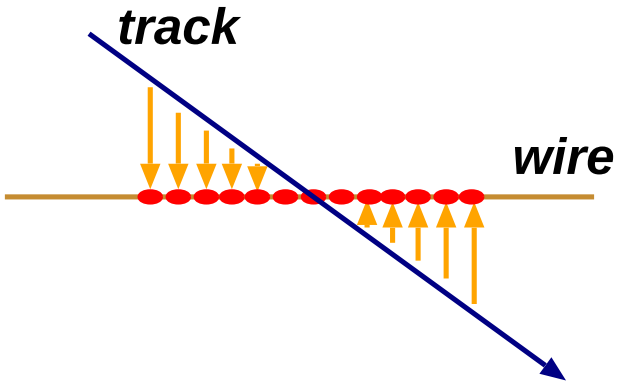
$$CO_2/isoC_4H_{10}$$

Small diffusion

Big space charge effect

2nd hit often significantly smaller than the 1st

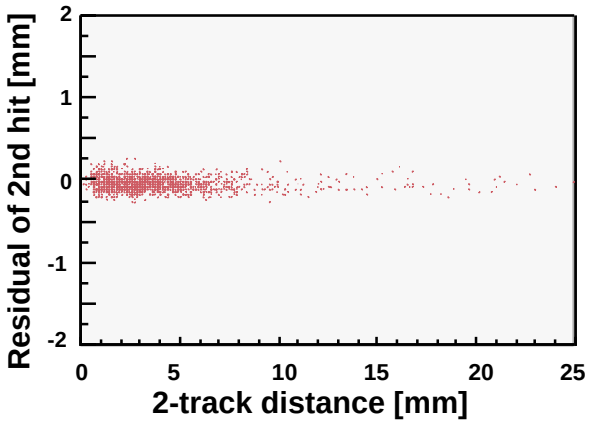
Space charge effect is track angle dependent

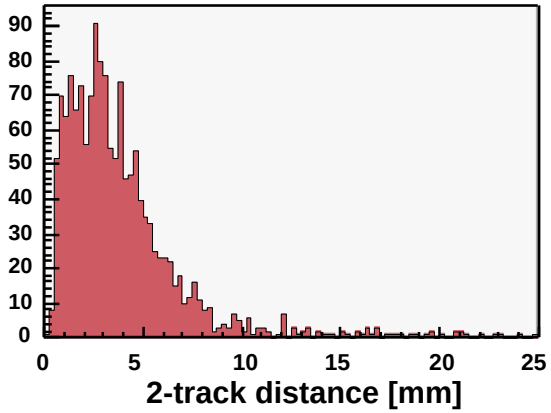


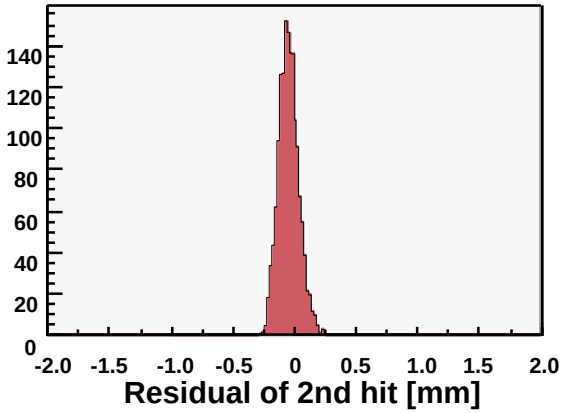
2-Track Separation

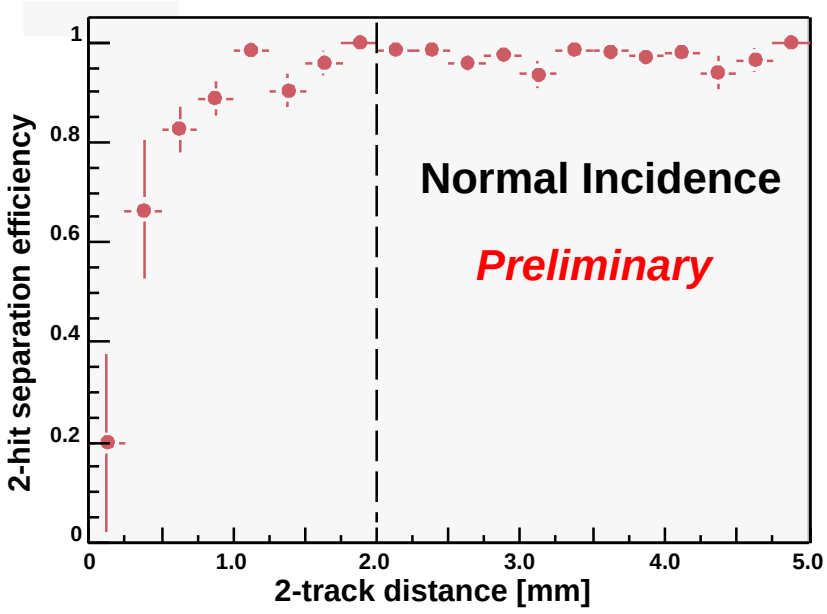
JLC CDC Group

Preliminary Results









Preliminary results look promising!

Short Term Plan

	R & D Item	Location	Means
✔	Improvement of DAQ system	Kogakuin Univ., Tokyo	Baby chamber
✔	Two track separation w/ e^+e^- pairs	KEK Tanashi, Tokyo	
★	w/ laser beams	REFER, Hiroshima KEK, Ibaraki	
★	dE/dx - measurement	KEK, Ibaraki	
✔	Gas gain re-measurement	KEK Tanashi, Tokyo	
✔	Lorentz angle re-measurement with two laser beams which can provide us with more accurate tan α	KEK, Ibaraki	Lorentz - chamber
★	Diffusion coefficient measurement	NoKoDai Univ., Tokyo	Diffusion - chamber
★	New material of potential wire	Kinki Univ., Osaka	Tension measurement

Future Direction

Need to reconcile chamber parameters taking into account new external constraints

B=2T ⟶ 3T

Impossible/difficult to scale

- Wire spacing — if we keep the same cell structure
- σ_{xy} — may need to decrease maximum drift length
- R_{in} — constrained by support tube

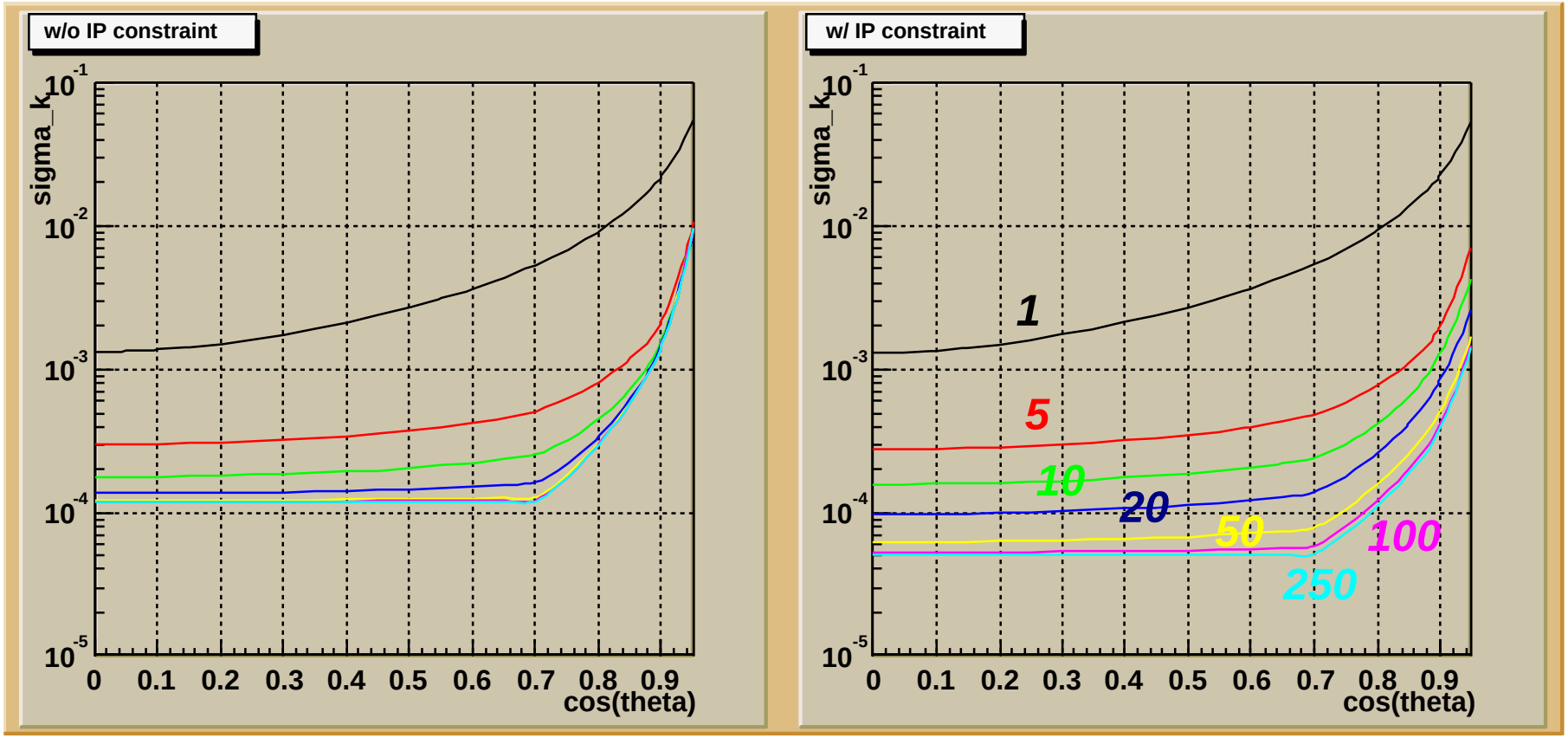
$$\begin{cases} B = 2T \longrightarrow 3T & \\ l = 185\ cm \longrightarrow 110\ cm & \text{same } R_{in} \\ \sigma_{xy} = 85\ \mu m \longrightarrow 85\ \mu m & \text{same} \\ L = 460\ cm \longrightarrow 310\ cm & \text{scaled by } 2/3 \\ n = 80 \longrightarrow 50 & \text{same wire spacing} \end{cases}$$

Then what happens to chamber performance?

$$\begin{cases} \sigma_\kappa^{meas} \propto \frac{\sigma_{xy}}{l^2 B\sqrt{n}} & \uparrow \ \text{☹ How much? c.f.) Miyamoto} \\ \sigma_\kappa^{MS} \propto \frac{\sqrt{(X/X_0)}}{lBp} & \downarrow \ \text{☺} \\ \tan\alpha_{stereo} = \frac{r\Delta\phi}{L} \uparrow \text{ for a given r} \longrightarrow \sigma_z & \downarrow \ \text{☺} \\ \sigma_{T_0} \propto \frac{\sigma_{xy}}{v_{drift}\sqrt{n}} & \uparrow \ \text{☹ Is it OK?} \\ \text{required 2-track separation} \propto \text{track distance} & \downarrow \ \text{☹ Open question} \\ \text{Lorentz angle} \propto B & \uparrow \ \text{☹} \end{cases}$$

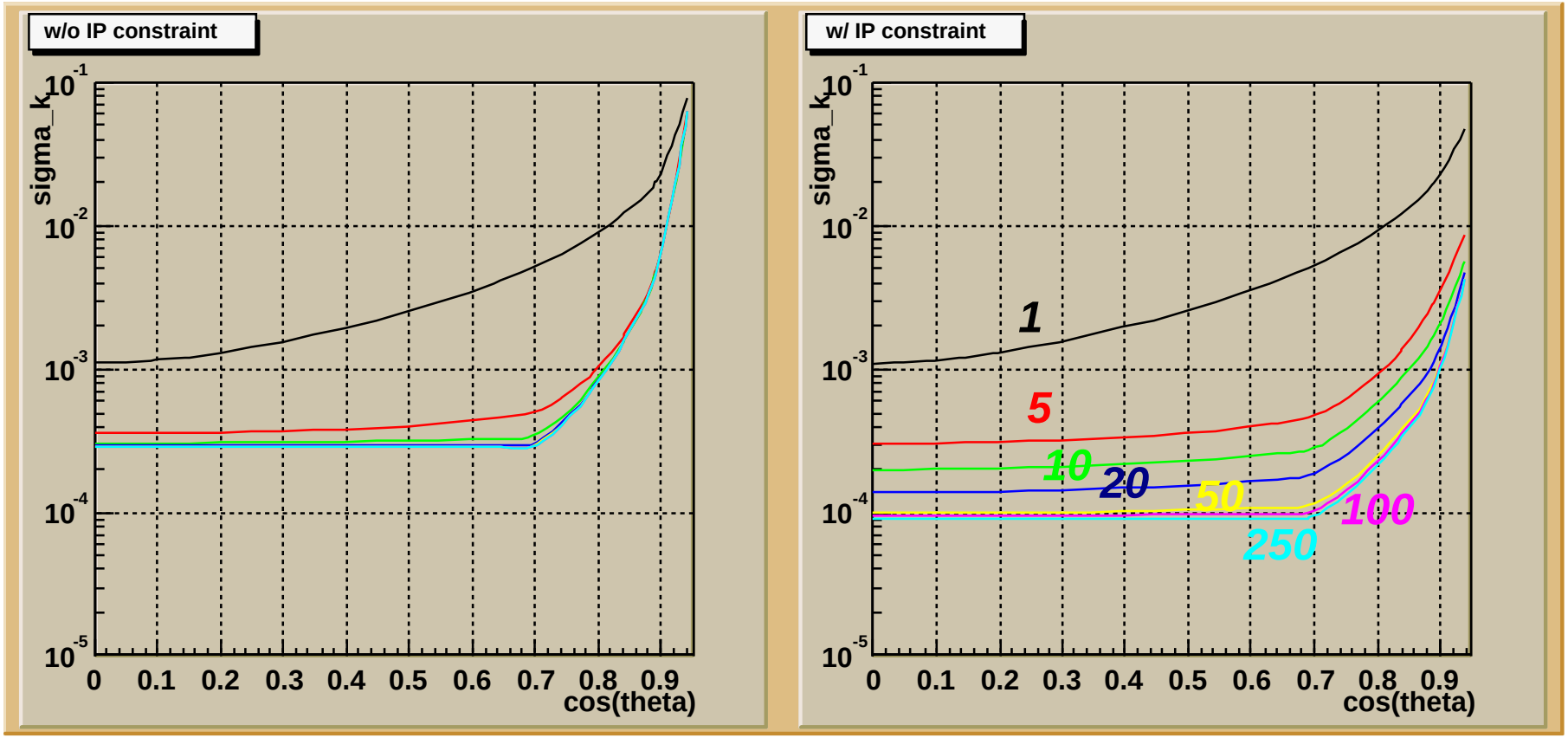
Future Direction

CDC Momentum Resolution (2T Design)



Future Direction

CDC Momentum Resolution (3T Design)

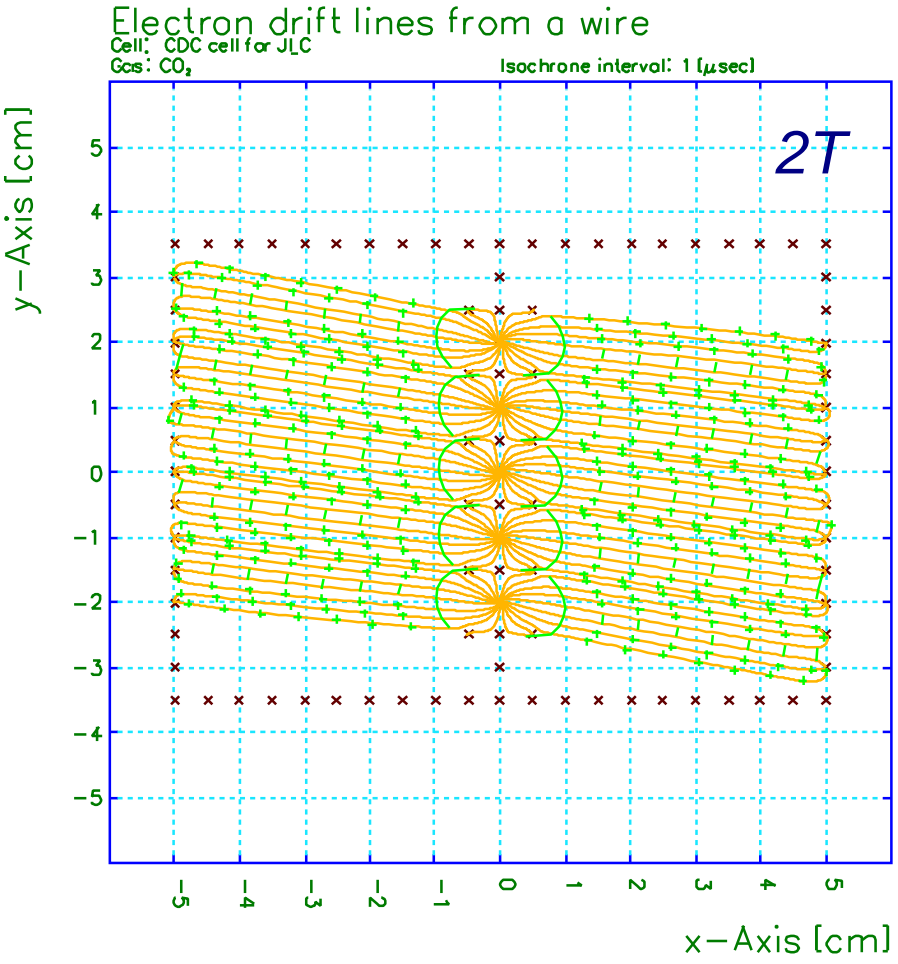


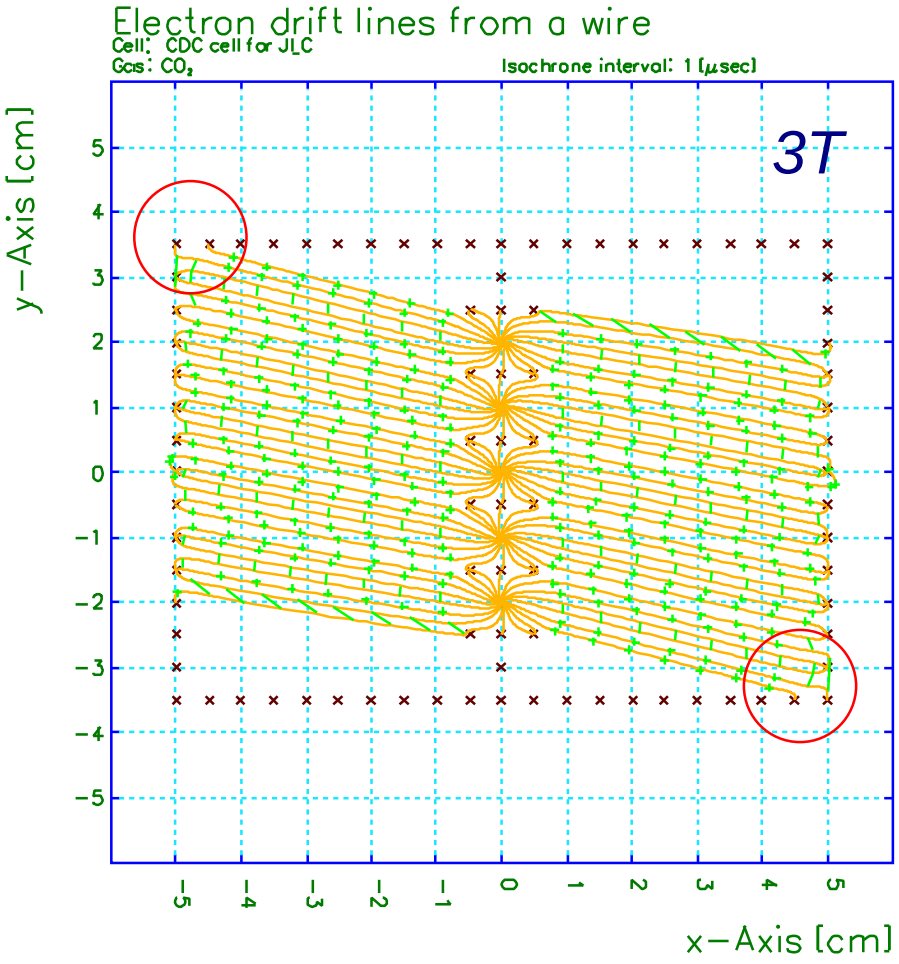
Further improvement expected from combined fit with IMT and VTX

A.Miyamoto's talk

Future Direction

Lorentz Angle





Almost OK

We can make the drift length shorter if necessary.

R&D Status (Score Sheet)

1. Can we control gravitational and electrostatic wire sags for 4.6m-long wires? — Yes

2. Can we achieve a spatial resolution of 85 microns everywhere in this big chamber? — Yes

3. Can we achieve 2-track separation better than 2mm? — Promising

4. Can we stably operate 4.6m-long stereo cells? — Yes

5. Is Lorentz angle small enough to allow straight cells? — Yes

6. Is gas gain saturation observed for cool gas mixtures no problem?
   Test with particle & laser beams in progress

7. Is tension drop controlable for Al wires? — Study on going

8. Is neutron BG no problem? ~3(0.2)k hits/train for B=2(3)T
   How big is the signal charge for a single neutron hit?
   Any dead time?
   Planning G4-based simulation studies for various optimizations for 3T option

→ Final Chamber Desgin