# JLC Central Tracker R&D



***Keisuke Fujii, KEK***
***Representing JLC CDC Group***

## *Plan of Talk*

*Introduction*

*What We Have Done Since Beijing*

*Future Direction*

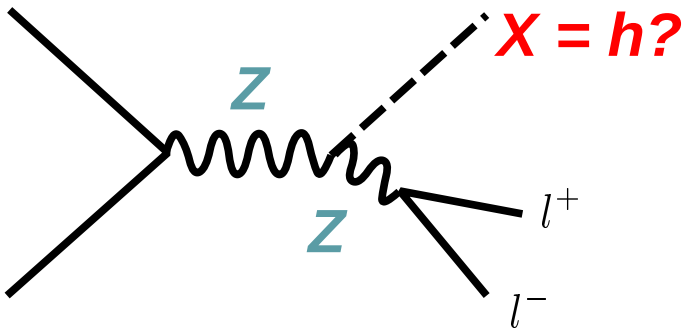
# Introduction



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

2-track separtion better than $2mm$

( <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



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

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

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

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

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

*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?* *(~2k 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

New 2. Cosmic Ray Tests (4.6m Test Chamber)

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 (almost ready)

New 6. Gas Gain Measurement

7. Wire Tension Measurement

8. BG Studies

9. Gas Properties

KEK Preprint 99-50
July 1999
H

# 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
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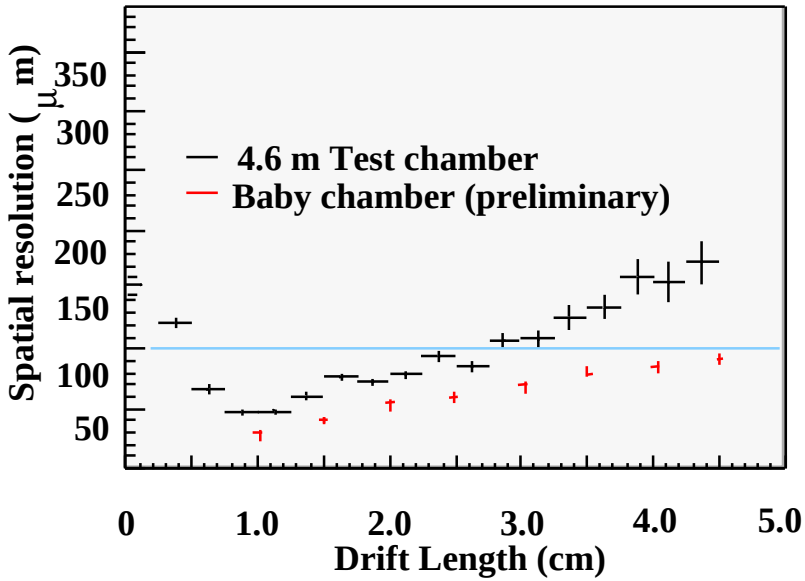
[e]Kinki University, Osaka, 577-8502, Japan

**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 $\mu$m 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
H

*To supplement stero wire study*

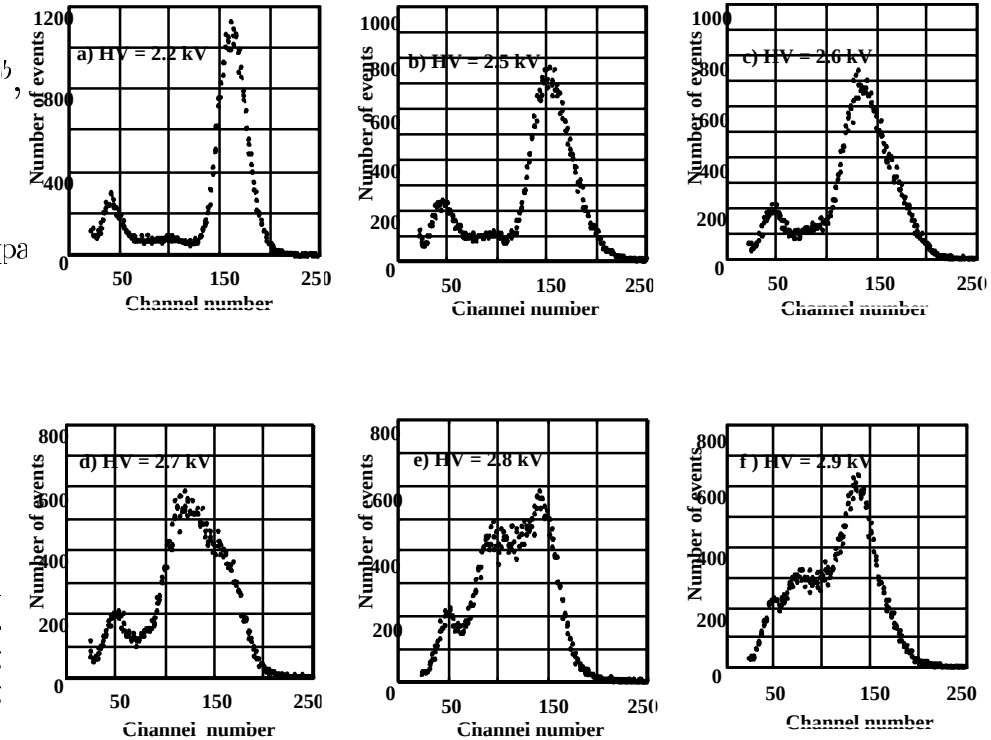
$CO_2/isoC_4H_{10}$

*Very special*
*..... Quickly saturating!*

# Gas Gain Study for $CO_2$/Isobutane Mixtures

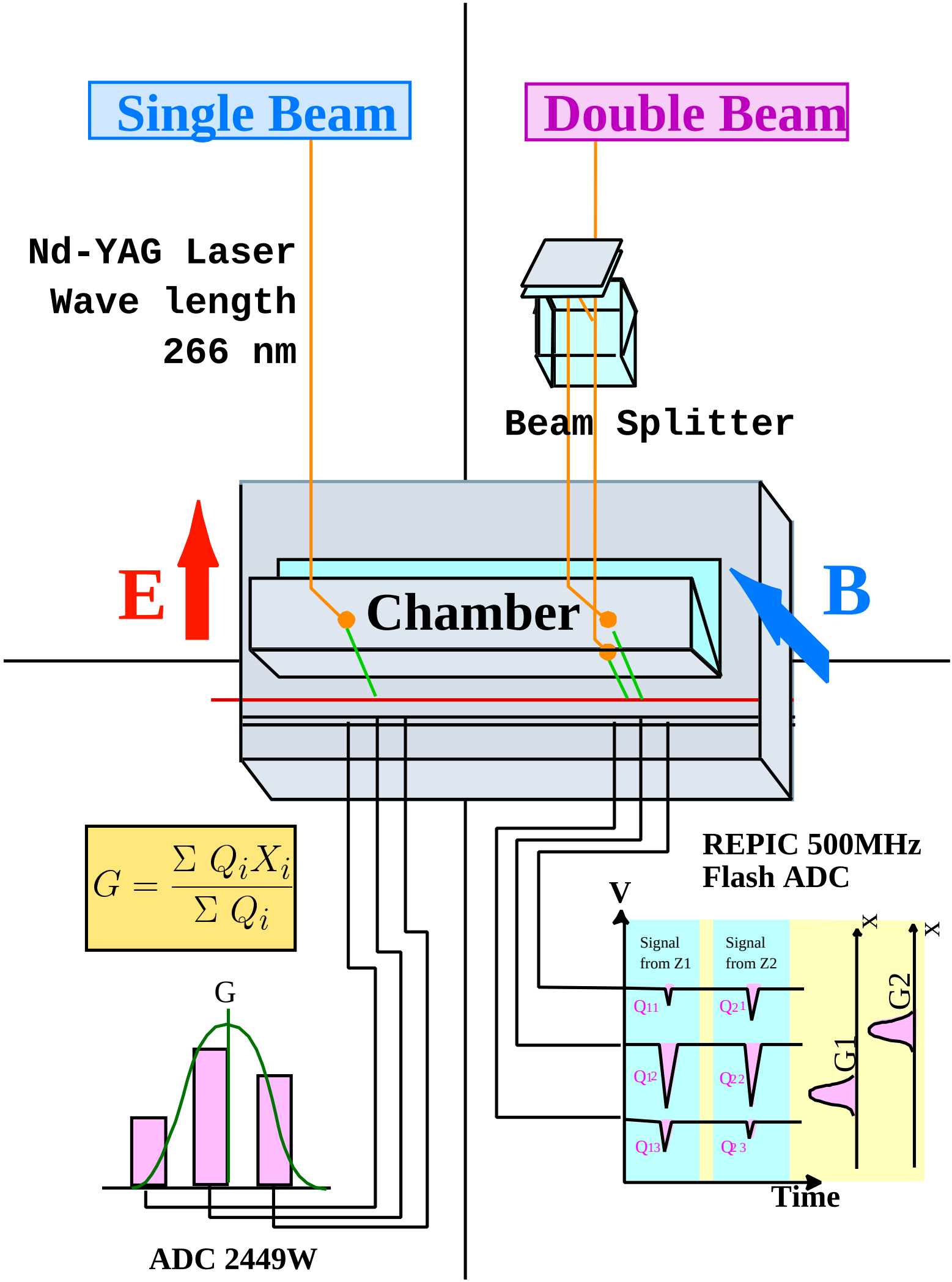
*H.Okuno*[a], *N.Khalatyan*[a], *Y.Nakamura*[b], *K.Fujii*[a], *K.Hoshina*[b], *Y.Kato*[e], *Y.Kurihara*[a], *H.Kuroiwa*[b], *O.Nitoh*[b]

[a] High Energy Accelerator Research Organization(KEK), Tsukuba, 305-0801, Japa
[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 $\beta$-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.

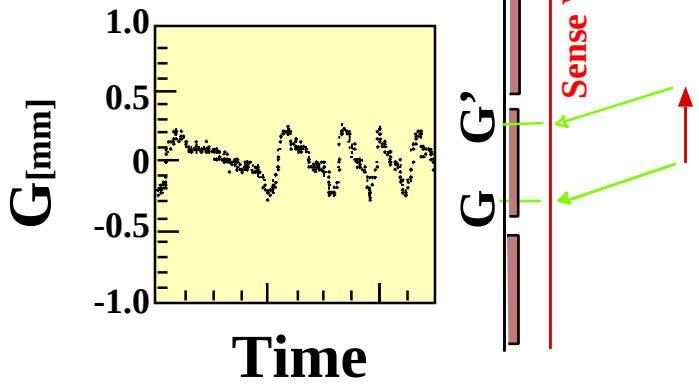

Single Beam
Double Beam
Nd-YAG Laser
Wave length
266 nm
Beam Splitter
E
Chamber
B
$G = \frac{\Sigma\, Q_i X_i}{\Sigma\, Q_i}$
G
ADC 2449W
REPIC 500MHz
Flash ADC
V
Signal
from Z1
Signal
from Z2
Q11
Q12
Q13
Q21
Q22
Q23
G1
G2
X
X
Time

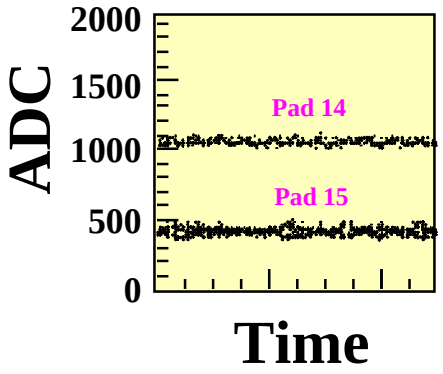
# Principle and Setup of the Measurement



## Single Beam

B=1.5T




Beam Position: unstable

↓

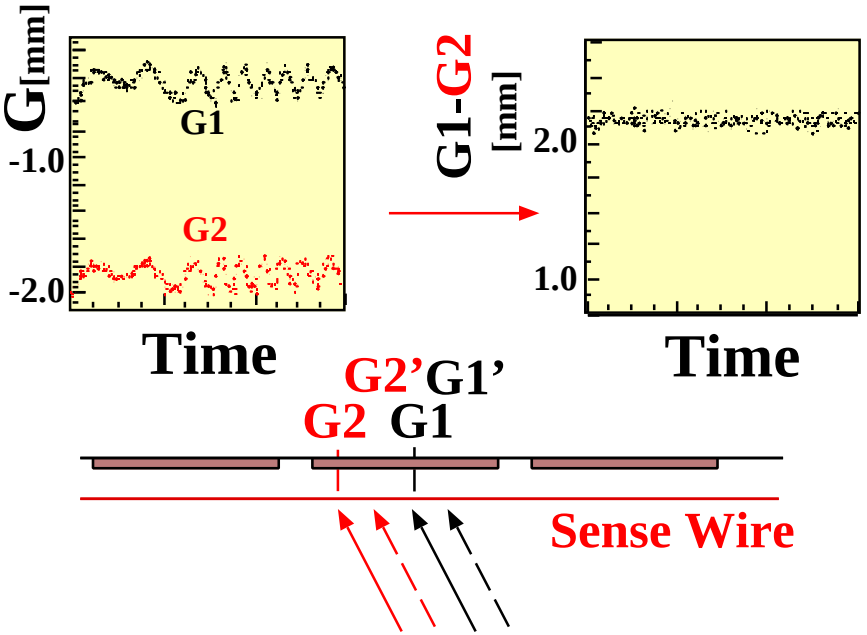
(G1-G2):unstable

↓

tanα: unstable

## Double Beam

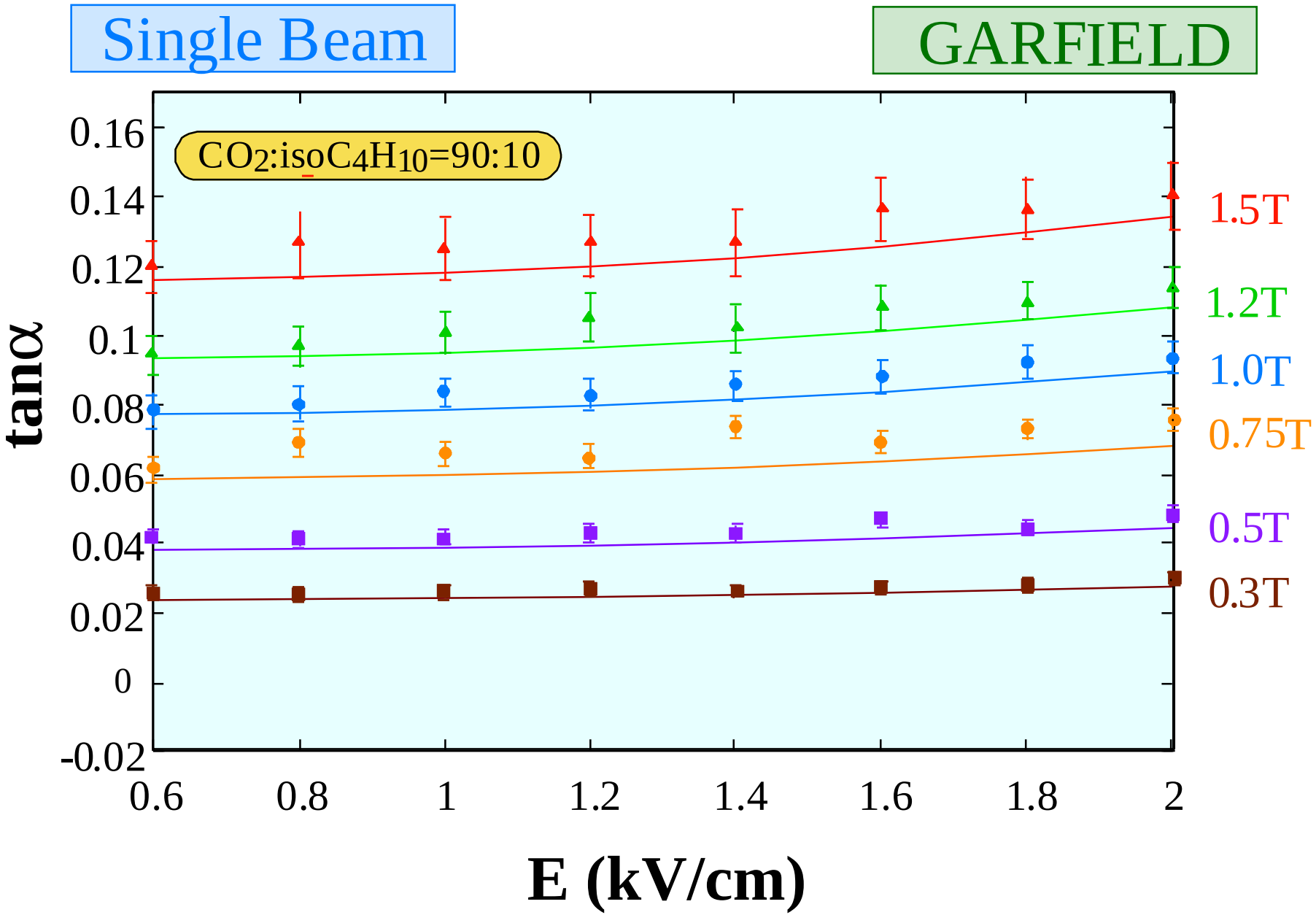
B=1.5T



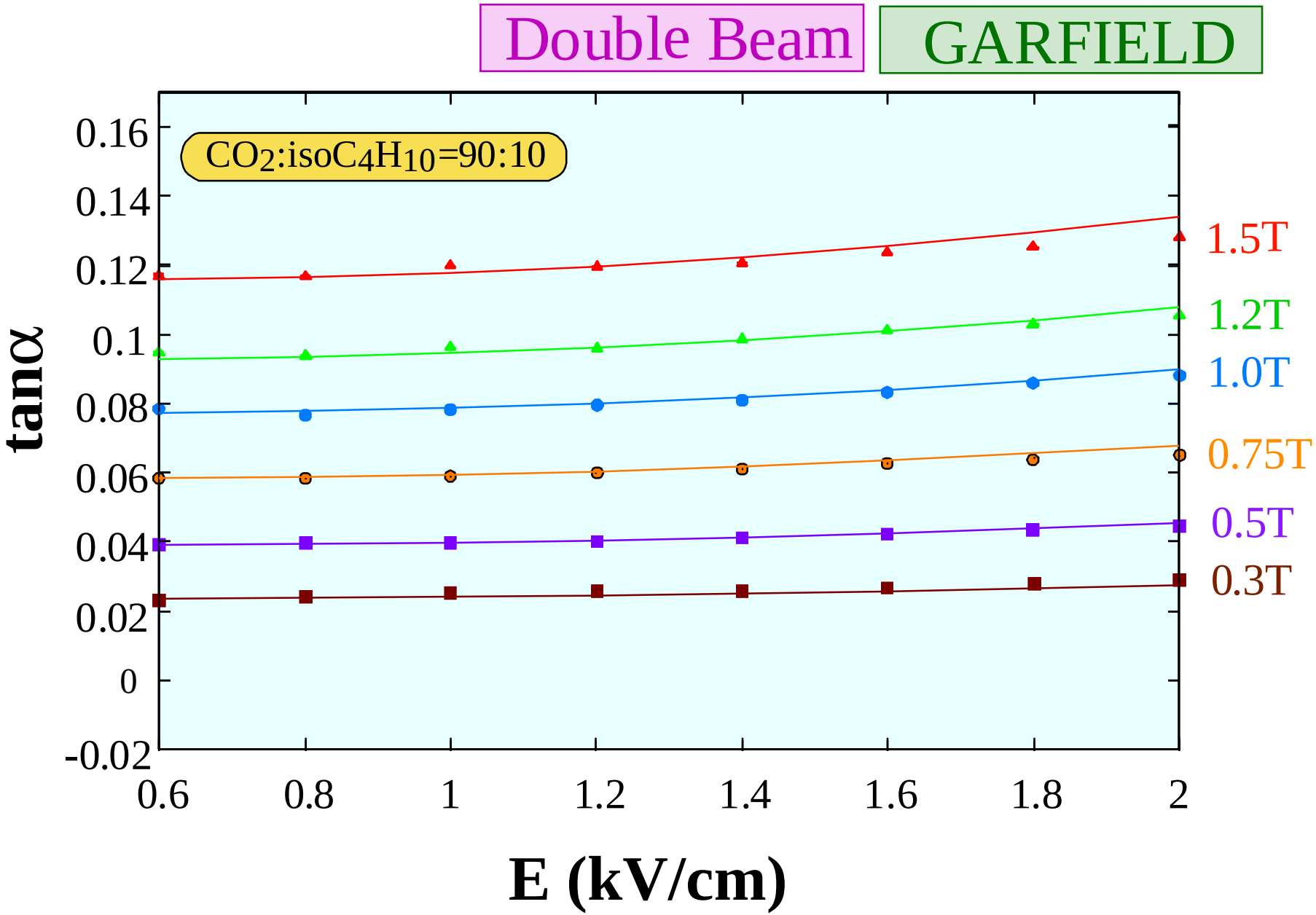

(G1-G2) is stable since G1 and G2 move coherently by the same amount

↓

tanα : stable


Single Beam
GARFIELD
$CO_2$:iso$C_4H_{10}$=90:10
1.5T
1.2T
1.0T
0.75T
0.5T
0.3T
tanα
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
0.6
0.8
1
1.2
1.4
1.6
1.8
2
E (kV/cm)

# Results (preliminary)



# Short Term Plan



| | R & D Item | Location | Means |
|---|---|---|---|
| ✔ | Improvement of DAQ system | Kogakuin Univ., Tokyo | Baby chamber |
| ★ | Two track separation re-measurement | KEK Tanashi, Tokyo | |
| | dE/dx - measurement | KEK Tanashi, Tokyo | |
| ✔ | 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 Tsukuba, Ibaraki | Lorentz - chamber |
| | Diffusion coefficient measurement | NoKoDai Univ., Tokyo | Diffusion - chamber |
| ★ | New material of potential wire | Kinki Univ., Osaka | Tension measurement |

# Future Direction (Personal View)



*Need to reconcile chamber parameters taking into account new external constraints*

**B=2T ⟶ 3T**

*For simplicity, scale all the quantities with the dimension of [L] by a factor of 2/3.*

⇢ *This preserves lepton ID momentum acceptance*

$$\begin{cases} B & = & 2T & \longrightarrow & 3T \\ l & = & 185cm & \longrightarrow & 123cm \\ \sigma_{xy} & = & 85\mu m & \longrightarrow & 60\mu m \\ L & = & 460cm & \longrightarrow & 307cm \\ n & = & 80 & \longrightarrow & 80 \end{cases}$$

*If this is possible* ⇢

$$\begin{cases} \sigma_{\kappa}^{meas} & : & \times 1 \\ \sigma_{\kappa}^{MS} & : & \times 2/3 \\ \sigma_{z} & : & \times 1 \\ \sigma_{T_0} & : & \times 1 \\ \text{2-track separation} & : & \times 2/3 \end{cases}$$

*Of course, this is not practicable!*

# Future Direction (Personal View)



## *Impossible/difficult to scale*

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

$$\begin{cases} B & = 2T & \longrightarrow & 3T & \\ l & = 185\ cm & \longrightarrow & 110\ cm & \text{same } R_{in} \\ \sigma_{xy} & = 85\ \mu m & \longrightarrow & 85\ \mu m & \text{same} \\ L & = 460\ cm & \longrightarrow & 307\ cm & \text{scaled by } 2/3 \\ n & = 80 & \longrightarrow & 50 & \text{same wire spacing} \end{cases}$$

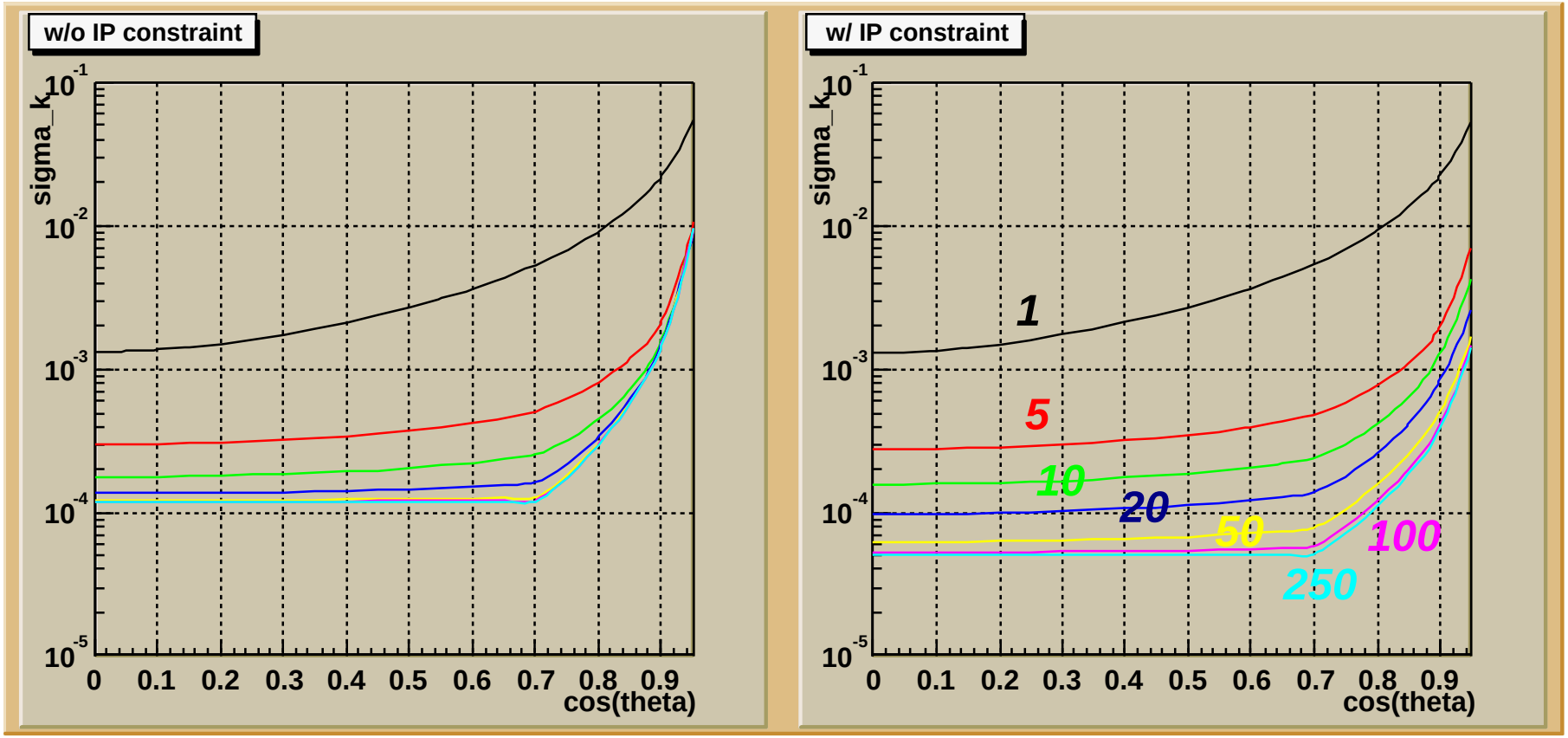
## *Then what happens to chamber performance?*

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

# Future Direction (Personal View)



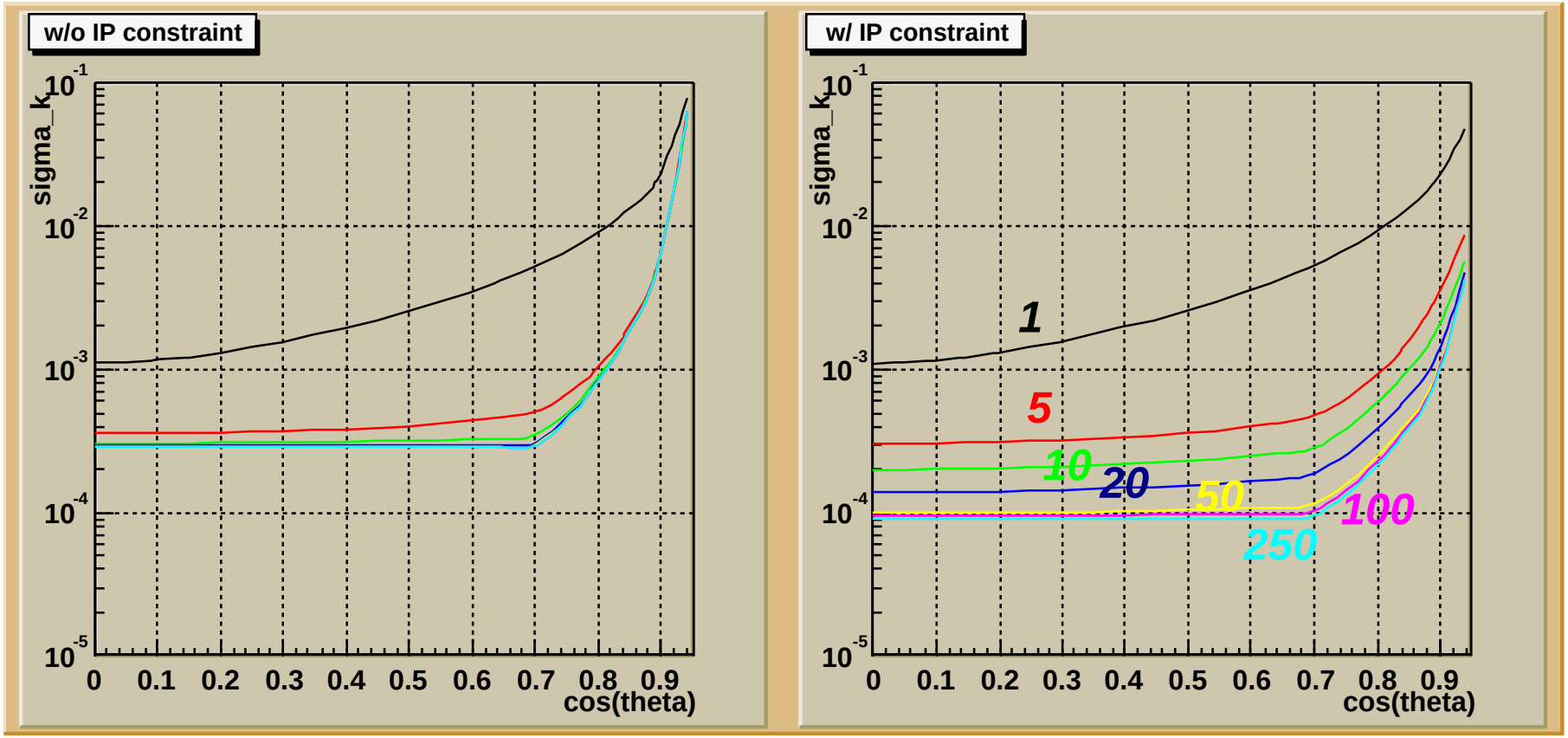
## CDC Momentum Resolution (2T Design)



# Future Direction (Personal View)



## CDC Momentum Resolution (3T Design)

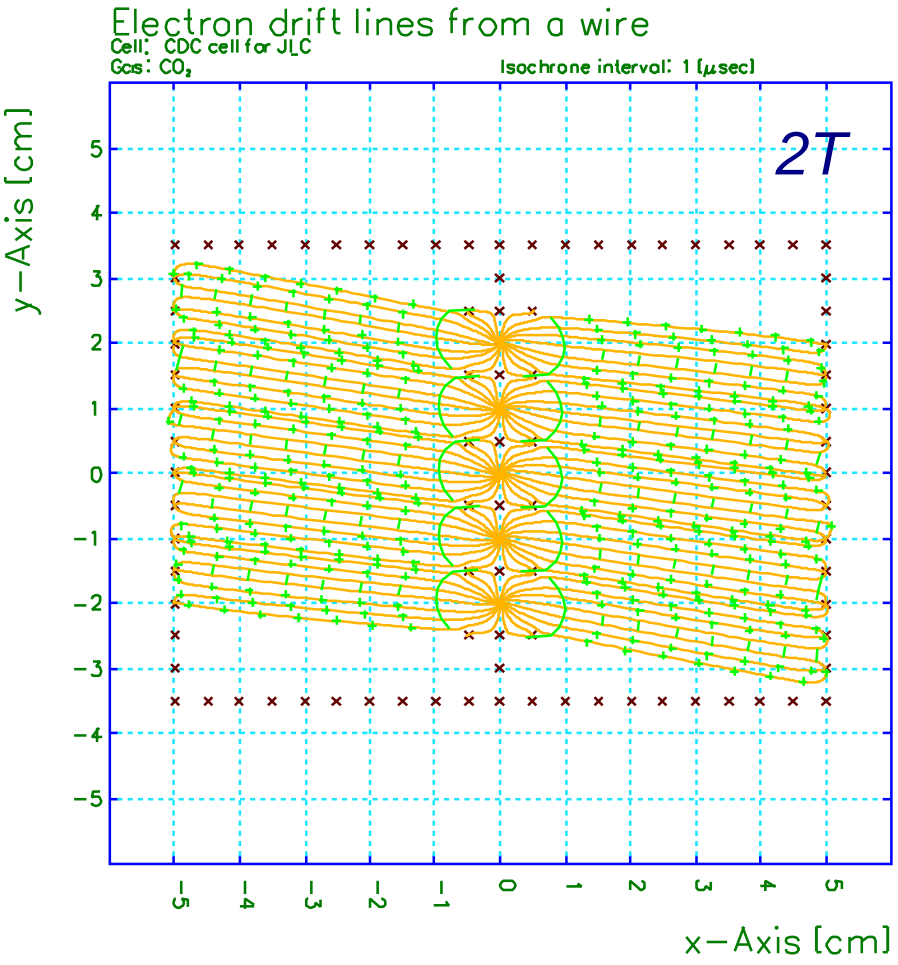


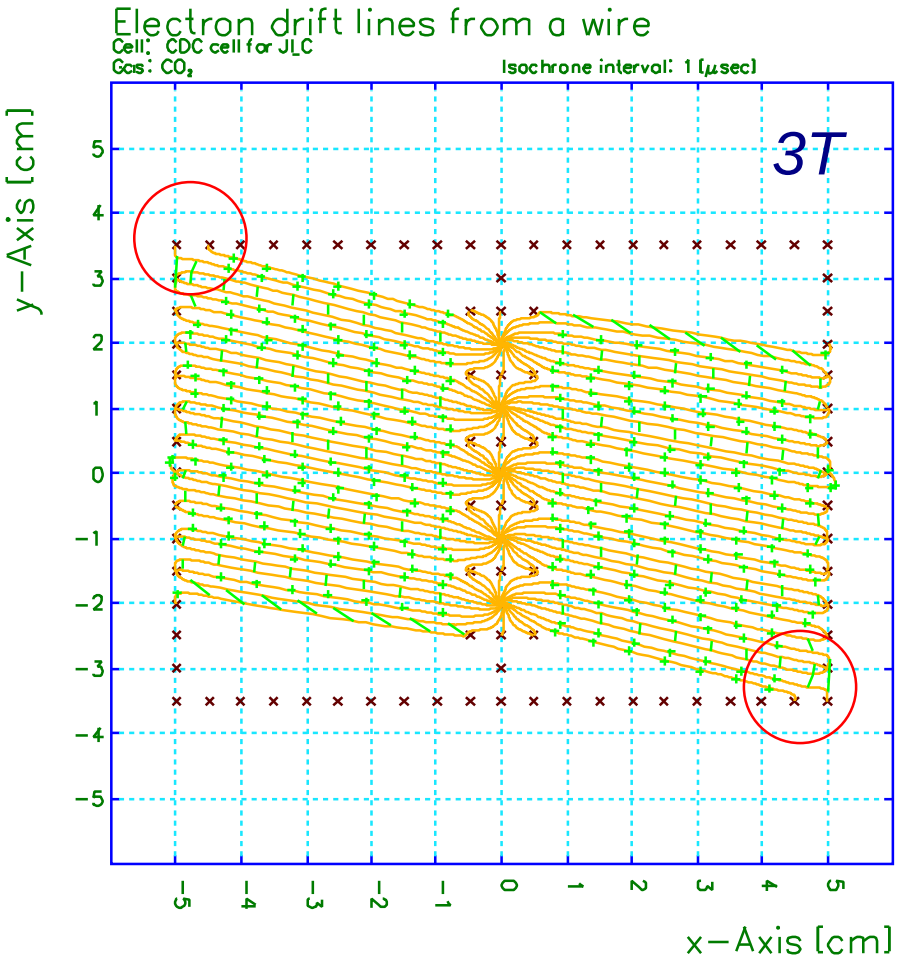

*Further improvement expected from combined fit with IMT and VTX*

# Future Direction (Personal View)



## Lorentz Angle




*Almost OK*

*We can make the drift length shorter if necessary.*

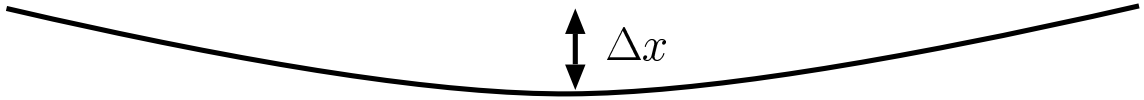
# Future Direction (Personal View)



## From Engineering Point of View

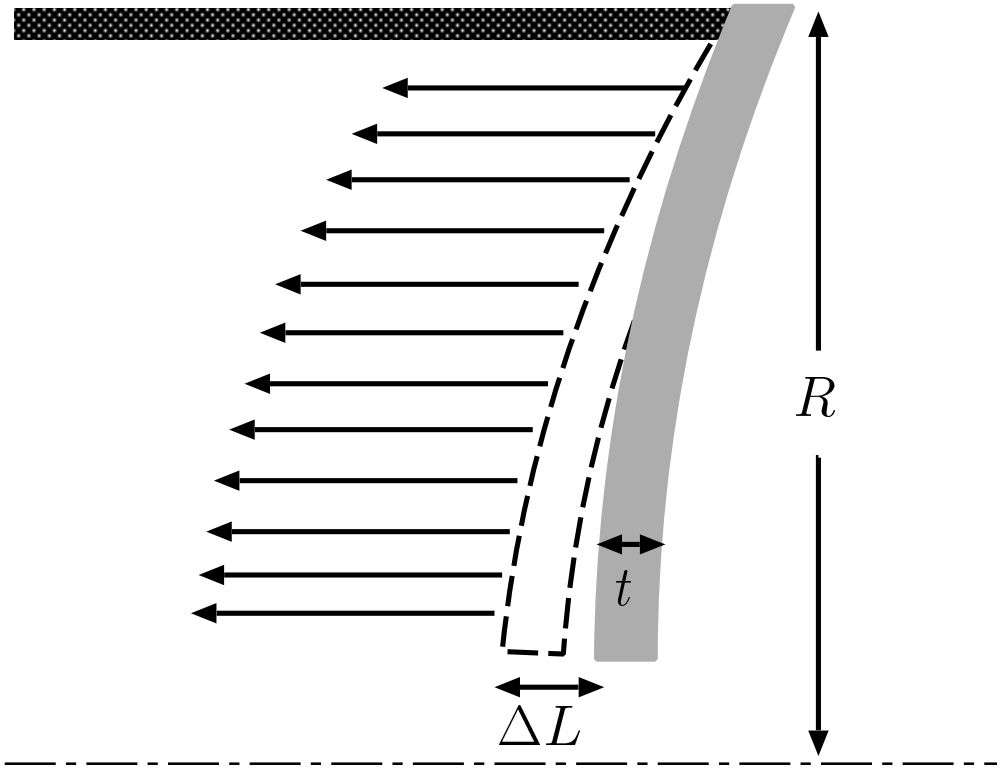
*The smaller the better!*

*Gravitational/Electrostatic Sag*




$$\Delta x \propto \frac{L^2}{T}$$

*Endplate Distortion*




$$\Delta L \propto \frac{R^4}{t^2} \cdot T$$

# Future Direction (Personal View)



## Neutron BG and Chamber Gas

*If we use pure CO2*

*Gas gain goes down* ⟶ *Higher H.V.*
- ⟶ *Saturation*
- ⟶ *Bigger E-sag* ☹

*Better electronics*
- ⟶ *Needs R&D*

*If we use, for instance, CO2 (90%) + Ar (10%)*

$$\sigma_{T_0} \simeq \frac{\sigma_{xy}}{v_{drift}\sqrt{n}} \lesssim 1.4\mathrm{nsec}$$ ⟶ *This might require faster gas anyway*

⟶ *Needs R&D*

*Can we reduce neutron Background further by putting more neutron absorber?*
- ⟶ *Some absorber outside the CDC?*
- ⟶ *Needs more studies*

*In any case, any design change should be justified by physics simulation studies!*

⟶ *Needs inputs from physics simulation studies w/ new CDC parameters!*