An ultra-low mass Tracking Chamber with Particle Identification capabilities for SCTF at BINP

F. Grancagnolo
INFN – Lecce

Joint Workshop on future tau-charm factory
December 4-7, 2018
Laboratoire de l’Accélérateur Linéaire, Orsay, France
I. **KLOE** ancestor chamber at INFN LNF Daφne φ factory (commissioned in 1998 and operating for the last 20 years)

II. **CluCou** Chamber proposed for the 4\textsuperscript{th}-**Concept** at ILC (2009)

III. **I-tracker** chamber proposed for the **Mu2e experiment** at Fermilab (2012)

IV. **DCH** for the **MEG upgrade** at PSI (designed in 2014, just completed at INFN and under commissioning)

V. **IDEA** drift chamber proposal for FCC-ee and CEPC (2016)

A unique volume, all stereo, cylindrical drift chamber, co-axial to B (0.6 T).

\[
\begin{align*}
\text{Rin} &= 25 \text{ cm}, \quad \text{Rout} = 200 \text{ cm}, \quad L = 2.8+3.3 \text{ m}, \\
12+46 \text{ co-axial layers,} \\
at \text{alternating sign stereo angles from 60 mrad to 150 mrad.} \\
\text{Square cell size } 2x2/3\pi \text{ (inner 12) and } 3x\pi \text{ (outer 46) cm}^2.
\end{align*}
\]

Total number of drift cells 12582. Total number of wires 52140

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A unique volume, high granularity, all stereo, low mass cylindrical drift chamber, co-axial to B (1.27+0.49 T).

\[
\begin{align*}
\text{Rin} &= 18 \text{ cm}, \quad \text{Rout} = 30 \text{ cm}, \quad L = 2 \text{ m}, \\
10 \text{ co-axial layers,} \\
at \text{alternating sign stereo angles from 100 mrad to 150 mrad,} \\
\text{Square cell size } \approx 7x7 \text{ mm}^2.
\end{align*}
\]

Total number of drift cells 1920. Total number of wires 12,678

Road to proposal
### The evolution from KLOE ... ... to SCTF

<table>
<thead>
<tr>
<th>I.</th>
<th>Wire configuration <strong>fully stereo</strong> (no axial layers)</th>
<th>I.</th>
<th><strong>Cluster timing</strong> for improved spatial resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>II.</td>
<td>new <strong>light Aluminum</strong> wires</td>
<td>II.</td>
<td><strong>Cluster counting</strong> for particle identification</td>
</tr>
<tr>
<td>III.</td>
<td>Very light gas mixture 90% He – 10% iC₄H₁₀</td>
<td>III.</td>
<td><strong>No feed-through</strong> wiring</td>
</tr>
<tr>
<td>IV.</td>
<td>Mechanical structure entirely in <strong>Carbon Fiber</strong></td>
<td>IV.</td>
<td>larger number of <strong>thinner</strong> (and <strong>lighter</strong> wires)</td>
</tr>
<tr>
<td>V.</td>
<td>Largest volume <strong>drift chamber</strong> ever built (45 m³)</td>
<td>V.</td>
<td><strong>Gas containment</strong> from <strong>wire support</strong> functions separation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VI.</td>
<td>New concepts for <strong>wire tension compensation</strong></td>
</tr>
</tbody>
</table>

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Cluster Timing

From the ordered sequence of the electrons arrival times, considering the average time separation between clusters and their time spread due to diffusion, reconstruct the most probable sequence of clusters drift times: \[ t_{cl}^i \] \[ i = 1, N_c \]

For any given first cluster (FC) drift time, the cluster timing technique exploits the drift time distribution of all successive clusters \( t_{cl}^i \) to determine the most probable impact parameter, thus reducing the bias and the average drift distance resolution with respect to those obtained from with the FC method alone.
Cluster Counting

\[
\frac{\sigma_{dE/dx}}{(dE / dx)} = 0.41 \cdot n^{-0.43} \cdot (L_{\text{track}} [m] \cdot P [\text{atm}])^{-0.32}
\]

from Walenta parameterization (1980)

\[
\frac{\sigma_{dN_{cl}/dx}}{(dN_{cl} / dx)} = (\delta_{cl} \cdot L_{\text{track}})^{-1/2}
\]

from Poisson distribution

\(dE/dx\)

- truncated mean cut (70-80%) reduces the amount of collected information

\(n = 64\) and \(0.6\) m track at 1 atm give

\(\sigma \approx 8.1\%\)

Increasing \(P\) to 2 atm improves resolution by 20% \((\sigma \approx 6.5\%)\) but at a considerable cost of multiple scattering contribution to momentum and angular resolutions.

\(dN_{cl}/dx\)

- \(\delta_{cl} = 12.5/\text{cm}\) for He/i\(C_4H_{10}\) = 90/10 and \(0.6\) m track give

\(\sigma \approx 3.6\%\)

A small increment of i\(C_4H_{10}\) from 10% to 20% \((\delta_{cl} = 20/\text{cm})\) improves resolution by 20% \((\sigma \approx 2.8\%)\) at only a reasonable cost of multiple scattering contribution to momentum and angular resolutions.
The data shown refer to a beam of \( \mu \) and \( \pi \) at 200 MeV/c, taken with a gas mixture He/iC\(_4\)H\(_{10}\)=95/5, \( \delta_{cl}=9/\text{cm} \), 100 samples, 2.6 cm each at 45\(^\circ\) (for a total track length of 3.7 m, corresponding to \( N_{cl}=3340 \), \( 1/\sqrt{N_{cl}}=1.7\% \)).

Setup:
- 25 \( \mu \)m sense wire (gas gain 2x10\(^5\)),
- through a high BW preamplifier (1.7 GHz, gain 10),
- digitized at 2 GSa/s, 1.1 GHz, 8 bits

\( dE/dx \):
- 100 samples 3.7 cm
  - theory: \( (\sigma=0.41 n^{-0.43}(L[m][P[\text{atm}])^{0.32}) \)
  - \( \sigma=3.7\% \)
  - \( \approx 2.0\sigma \) separation
  - experiment: 20% truncated mean
    - \( \sigma=4.5\% \)
    - \( \approx 1.4\sigma \) separation

\( dN_{cl}/dx \):
- theory
  - Poisson distribution
  - \( \sigma=1.7\% \)
  - \( \approx 5\sigma \) separation
  - experiment
  - \( \sigma=2.5\% \)
  - \( \approx 3.2\sigma \) separation

\( \text{(NIM A385 (1997) 458-469 and references therein)} \)
The MEG2 feed-through-less wiring
The MEG2 feed-through-less wiring
"Wire Cage" and "Gas Envelope"

**Wire support:**
*Wire cage* structure not subject to differential pressure can be light and feed-through-less.

**Gas containment:**
*Gas envelope* can freely deform without affecting the internal wire position and tension.

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Dec. 6, 2018
The Mu2e I-Tracker proposal

- Feed-through-less chamber allows for reducing wire spacing, thus increasing cell granularity:
  - Smaller cells
  - Larger ratios of field to sense wires
- Larger ratios of field to sense wires allows for thinner field wires, thus reducing:
  - Wire contribution to multiple scattering
  - Total wire tension

Instrumented end-plate:
- Wire PCB, spacers, HV distrib. and cables, limiting R, decoupling C and signal cables
- 0.28 g/cm²
- $1 \times 10^{-2} X_0$

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The Mu2e I-Tracker proposal

Gas envelope

- A structural multivariate analysis to find the optimal shape for the end plates profile by minimizing the total maximum stress and the stress on the inner cylinder.

use the 3-steps recipe to minimize materials

- A proper unidirectional pre-preg to form ply draping of the laminates and flat-wrap of the optimized model.

- Reduce inner cylinder buckling by increasing the moment of inertia with proper light core composite sandwich.

End plate:
- 4-ply × 38µm/ply orthotropic (0/90/90/0)
- 0.021 g/cm²
- 6×10⁻⁴ X₀

Inner cylinder:
- 2 C-fiber skins, 2-ply, + 5 mm C-foam core
- 0.036 g/cm²
- 8×10⁻⁴ X₀

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The IDEA Drift Chamber at CEPC and FCC-ee

The IDEA Detector at FCC-ee at CERN
CEPC at IHEP-China

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The IDEA Drift Chamber Performance

\[ \frac{\Delta p_t}{p_t} = (0.7p_t + 8.3) \times 10^{-4} \]
\[ \Delta \vartheta = (1.1 \oplus 9.4/p) \times 10^{-4} \text{ rad} \]
\[ \Delta \phi = (0.33 \oplus 9.4/p) \times 10^{-4} \text{ rad} \]

\[ dE/dx = 4.3 \% \]
\[ dN/dx = 2.2 \% \quad \text{(at } \varepsilon_N = 80 \%) \]

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TraPId: A proposal for SCTF

square cell vs. hex cell

- small deviation from perfect polygonal shape: 3.3% vs. 3.1% at innermost layer
- field to sense wire ratio: 5 to 1 vs. 2 to 1
  - more field wires implies better E-field isotropy and smaller E×B asymmetries
  - thinner field wires: 40 µm vs. 100-125 µm
    - less multiple scattering
    - less tension on end plates
- smaller gaps in B-field
- larger time-to-distance distortions
  - longer tails (> 500 ns for 1 cm cell) in signal pulse (hit pattern, dE/dx, pile up)
- easy implementation of a full stereo configuration

from: Mu2e I-tracker
B = 1 T - 75%He-25%iC4H10

from: https://ctd.inp.nsk.su/wiki/mages/e/e7/DCvariant.pdf
B = 1.5 T - 60%He-40%C3H8

CMD-3 at VEPP2000

He/iC4H10 = 80/20

hex cells 9 mm side

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# TraPId: A proposal for SCTF

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>R_{in} – R_{out} [mm]</strong></td>
<td><strong>200 – 800</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>active L – service area [mm]</strong></td>
<td><strong>1800 – 200</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## inner cylindrical wall

<table>
<thead>
<tr>
<th>Material</th>
<th>Description</th>
<th>Density $g/cm^2$</th>
<th>X/X$_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-fiber/C-foam sandwich</td>
<td>2×80 µm / 5 mm</td>
<td>0.036</td>
<td>8×10^{-4}</td>
</tr>
</tbody>
</table>

## outer cylindrical wall

<table>
<thead>
<tr>
<th>Material</th>
<th>Description</th>
<th>Density $g/cm^2$</th>
<th>X/X$_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-fiber/C-foam sandwich</td>
<td>2×5 mm / 10 mm</td>
<td>0.512</td>
<td>1.2×10^{-2}</td>
</tr>
</tbody>
</table>

## end plate

<table>
<thead>
<tr>
<th>Material</th>
<th>Description</th>
<th>Density $g/cm^2$</th>
<th>X/X$_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>gas envelope</td>
<td>160 µm C-fiber</td>
<td>0.021</td>
<td>6×10^{-4}</td>
</tr>
</tbody>
</table>

## Instrumented wire cage

<table>
<thead>
<tr>
<th>Material</th>
<th>Description</th>
<th>Density $g/cm^2$</th>
<th>X/X$_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>wire PCB, spacers, HV distr. and cables, limiting R, decoupling C and signal cables</td>
<td></td>
<td>0.833</td>
<td>3×10^{-2}</td>
</tr>
</tbody>
</table>

## Gas + wires [600 mm]

<table>
<thead>
<tr>
<th>Description</th>
<th>Density $g/cm^2$</th>
<th>X/X$_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>90%He – 10%CiC$<em>4$H$</em>{10}$</td>
<td>4.6×10^{-4}</td>
<td></td>
</tr>
<tr>
<td>wires (W=53%, Al=47%)</td>
<td>13.1×10^{-4}</td>
<td></td>
</tr>
</tbody>
</table>

## Cell

<table>
<thead>
<tr>
<th>Shape</th>
<th>square</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Size [mm]</th>
<th>7.265 – 9.135</th>
</tr>
</thead>
</table>

## Layer

<table>
<thead>
<tr>
<th>Description</th>
<th>8 super-layers</th>
<th>8 layer each</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Stereo angles</th>
<th>66 – 220 mrad</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>23,040</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>116,640</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>141,120</th>
</tr>
</thead>
</table>

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Dec. 6, 2018
KLOE spatial resolution (first cluster)

primary ionization only

cluster timing allows to reduce average spatial resolution from 100 µm down to ≤ 85 µm in a 8 mm cell

MEG2 spatial resolution averaged over all impact parameters (first cluster)


average resolution over 8 mm cell as a function of He content (first cluster)
Expected Performance: Track parameters resolutions

\( n = 64, B = 1.5 \text{ T}, R_{\text{out}} = 0.8 \text{ m}, L = 2.0 \text{ m}, (0.8+1.8) \times 10^{-3} \ X/X_0, \ \sigma_{xy} = 100 \ \mu\text{m}, \ \sigma_z = 0.8 \text{ mm} \)

measurement

\[
\frac{\Delta p_\perp}{p_\perp} = \frac{8\sqrt{5}\sigma}{3BR_{\text{out}}^2 \sqrt{n}} p_\perp = 7.8 \times 10^{-4} \ p_\perp \ [\text{GeV} / \text{c}]
\]

\[
\Delta \phi_0 = \frac{4\sqrt{3}\sigma}{R_{\text{out}} \sqrt{n}} = 1.1 \times 10^{-4}
\]

\[
\Delta \theta = \frac{\sqrt{12}\sigma_z}{R_{\text{out}} \sqrt{n}} \frac{1 + \tan^2 \theta}{\tan^2 \theta} = 3.8 \times 10^{-4} \text{ at } \theta = 90^\circ
\]

\[
\frac{\Delta p_\perp}{p_\perp} = 7.8 \times 10^{-4} \ p_\perp \oplus 1.8 \times 10^{-3}
\]

(7.8 \rightarrow 6.6 \text{ with cluster timing})

multiple scattering (gas + wires + inner wall)

\[
\frac{\Delta p_\perp}{p_\perp} = \frac{0.0523 [\text{GeV} / \text{c}]}{\beta B L} \left( \frac{L}{X_0} \right) = 1.8 \times 10^{-3} [\text{GeV} / \text{c}]
\]

\[
\Delta \phi_0 = \frac{13.6 \times 10^{-3} [\text{GeV} / \text{c}]}{\beta p} \left( \frac{L}{X_0} \right) = 6.9 \times 10^{-4} [\text{GeV} / \text{c}]
\]

\[
\Delta \theta = \frac{13.6 \times 10^{-3} [\text{GeV} / \text{c}]}{\beta p} \left( \frac{L}{X_0} \right) = 6.9 \times 10^{-4} [\text{GeV} / \text{c}]
\]

\[
\Delta p_\perp = \frac{6.9 \times 10^{-4}}{p}
\]

\[
\Delta \phi = 1.1 \times 10^{-4} \oplus \frac{6.9 \times 10^{-4}}{p}
\]

\[
\Delta \theta = 3.8 \times 10^{-4} \oplus \frac{6.9 \times 10^{-4}}{p}
\]
**TraPId: Tracking Performance**

**Expected Performance:** Track parameters resolutions

\[ n = 64, B = 1.5 \text{ T}, R_{\text{out}} = 0.8 \text{ m}, L = 2.0 \text{ m}, (0.8+1.8) \times 10^{-3} X/X_0, \sigma_{xy} = 100 \mu\text{m}, \sigma_z = 0.8 \text{ mm} \]

\[
\begin{align*}
\frac{\Delta p_{\perp}}{p_{\perp}} &= 2.0 \times 10^{-3}, \quad \Delta \phi = 0.70 \text{ mrad}, \quad \Delta \theta = 0.78 \text{ mrad} \\
&\text{at } p = 1 \text{ GeV} / c
\end{align*}
\]

\[
\begin{align*}
\frac{\Delta p_{\perp}}{p_{\perp}} &= 7.8 \times 10^{-4} p_{\perp} \oplus 1.8 \times 10^{-3} \\
&\text{(7.8 \rightarrow 6.6 with cluster timing)}
\end{align*}
\]

\[
\begin{align*}
\frac{\Delta \phi}{p} &= 1.1 \times 10^{-4} \oplus \frac{6.9 \times 10^{-4}}{p} \\
\frac{\Delta \theta}{p} &= 3.8 \times 10^{-4} \oplus \frac{6.9 \times 10^{-4}}{p}
\end{align*}
\]
## TraPlId: A proposal for SCTF

### Active L - Service Area [mm]

<table>
<thead>
<tr>
<th>Inner Cylindrical Wall</th>
<th>Outer Cylindrical Wall</th>
<th>End Plate</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-fiber/C-foam sandwich</td>
<td>2×80 μm / 5 mm</td>
<td>0.036 g/cm² – 8×10⁻⁴ X/X₀</td>
</tr>
<tr>
<td>C-fiber/C-foam sandwich</td>
<td>2×5 mm / 10 mm</td>
<td>0.512 g/cm² – 1.2×10⁻² X/X₀</td>
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<tr>
<td>Gas envelope</td>
<td>160 μm C-fiber</td>
<td>0.021 g/cm² – 6×10⁻⁴ X/X₀</td>
</tr>
<tr>
<td>Instrumented wire cage</td>
<td>wire PCB, spacers, HV distr. and cables, limiting R, decoupling C and signal cables</td>
<td>0.833 g/cm² – 3×10⁻² X/X₀</td>
</tr>
</tbody>
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### Gas + Wires [600 mm]

<table>
<thead>
<tr>
<th>90%He – 10%C₄H₁₀</th>
<th>4.6×10⁻⁴</th>
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### Cell

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<tr>
<th>Shape</th>
<th>Square</th>
</tr>
</thead>
</table>

| Size [mm] | 7.265 – 9.135 |

<table>
<thead>
<tr>
<th>Layer</th>
<th>64 layer total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stereo angles</td>
<td>66 – 220 mrad</td>
</tr>
<tr>
<td>n. sense wires [20μm W]</td>
<td>23,040</td>
</tr>
<tr>
<td>n. field wires [40/50μm Al]</td>
<td>116,640</td>
</tr>
<tr>
<td>n. total (incl. guard)</td>
<td>141,120</td>
</tr>
</tbody>
</table>
High-power impulse magnetron sputtering (HiPIMS) is a physical vapor deposition of thin films based on magnetron sputter deposition (extremely high power densities of the order of kW/cm² in short pulses of tens of µs at low duty cycle <10%) thanks to A. Popov - V. Logashenko, BINP.
## TraPIld: A proposal for SCTF

### Inner Cylindrical Wall
- **C-fiber/C-foam sandwich**
  - Size: 2×80 µm / 5 mm
  - Density: 0.036 g/cm² – 8×10⁻⁴ X/X₀

### Outer Cylindrical Wall
- **C-fiber/C-foam sandwich**
  - Size: 2×5 mm / 10 mm
  - Density: 0.512 g/cm² – 1.2×10⁻² X/X₀

### End Plate
- **Gas Envelope**
  - 160 µm C-fiber
  - Density: 0.021 g/cm² – 6×10⁻⁴ X/X₀

- **Instrumented Wire Cage**
  - Wire PCB, spacers, HV distr. and cables, limiting R, decoupling C and signal cables
  - Density: 0.833 g/cm² – 3×10⁻² X/X₀

### Cell
- **Shape**: Square
- **Size [mm]**: 7.265 – 9.135

### Layer
- **Number of Layers**: 64
- **Stereo Angles**: 66 – 220 mrad
- **Number of Sense Wires [20µm W]**: 23,040
- **Number of Field Wires [40/50µm Al]**: 116,640
- **Total Number (incl. guard)**: 141,120

### Gas + Wires [600 mm]
- **Helium-Propane**: 90%He – 10%C₄H₁₀
  - Density: 4.6×10⁻⁴
- **Alumina + Carbon**: W + 5Al → Ti + 5C
  - Density: (13.1 → 2.5)×10⁻⁴
Expected Performance: Track parameters resolutions

\( n = 64, B = 1.5 \, \text{T}, R_{\text{out}} = 0.8 \, \text{m}, L = 2.0 \, \text{m}, (0.8+0.7) \times 10^{-3} \, X/X_0, \sigma_{xy} = 100 \, \mu\text{m}, \sigma_z = 0.8 \, \text{mm} \)

\[
\begin{align*}
\Delta p_{\perp} &= 1.6 \times 10^{-3} \text{, } \Delta \phi = 0.54 \text{ mrad, } \Delta \theta = 0.65 \text{ mrad} \\
\text{at } p = 1 \text{ GeV} / c
\end{align*}
\]

\[
\begin{align*}
\Delta p_{\perp} &= 7.8 \times 10^{-4} \, p_{\perp} \oplus 1.4 \times 10^{-3} \\
&\quad \text{(7.8 \to 6.6 with cluster timing)}
\end{align*}
\]

\[
\begin{align*}
\Delta \phi &= 1.1 \times 10^{-4} \oplus \frac{5.3 \times 10^{-4}}{p} \\
\Delta \theta &= 3.8 \times 10^{-4} \oplus \frac{5.3 \times 10^{-4}}{p}
\end{align*}
\]
TraPId: Pld Performance

\[
\frac{\sigma_{dE/dx}}{(dE / dx)} = 0.41 \cdot n^{-0.43} \cdot (L_{\text{track}} \cdot P)^{-0.32}
\]

from Walenta parameterization (1980)

\[
\sigma_{dE/dx} = 8.1\% \quad \text{for} \quad L_{\text{track}} = 0.6 \text{ m}
\]

\[
\frac{n = 64}{P = 1 \text{ atm}}
\]

\[
\frac{\sigma_{dN_{cl}/dx}}{(dN_{cl} / dx)} = \left( \delta_{cl} \cdot L_{\text{track}} \right)^{-1/2}
\]

from Poisson distribution

\[
L_{\text{track}} = 0.6 \text{ m} \quad \delta_{cl} = 12.5/\text{cm}
\]

\[
\sigma_{dN_{cl}/dx} = 3.6\% \quad \text{for} \quad L_{\text{track}} = 1 \text{ m}
\]
## Summary of performance

<table>
<thead>
<tr>
<th>Experiment</th>
<th>$\frac{\Delta p_t}{p_t} \times 10^3$</th>
<th>at $p_t = 1\text{GeV}$</th>
<th>$\frac{dE}{dx} / \frac{dN}{dx}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>KLOE</td>
<td>$0.5 p_t \oplus 2.6$</td>
<td>$2.6 \times 10^{-3}$</td>
<td>5%</td>
</tr>
<tr>
<td>BaBar</td>
<td>$1.3 p_t \oplus 4.5$</td>
<td>$4.7 \times 10^{-3}$</td>
<td>7.5%</td>
</tr>
<tr>
<td>Belle</td>
<td>$2.8 p_t \oplus 3.5$</td>
<td>$4.5 \times 10^{-3}$</td>
<td>6.9%</td>
</tr>
<tr>
<td>Belle II</td>
<td>$1.9 p_t \oplus 2.9$</td>
<td>$3.5 \times 10^{-3}$</td>
<td>6.4%</td>
</tr>
<tr>
<td>BESIII</td>
<td>$2.7 p_t \oplus 4.7$</td>
<td>$5.1 \times 10^{-3}$</td>
<td>6 – 7%</td>
</tr>
<tr>
<td>Cleo3</td>
<td>$1.0 p_t \oplus 9.0$</td>
<td>$9.1 \times 10^{-3}$</td>
<td>5%</td>
</tr>
<tr>
<td>SCTF (Todyshev)</td>
<td>$2.6 p_t \oplus 5.1$</td>
<td>$5.7 \times 10^{-3}$</td>
<td>7%</td>
</tr>
<tr>
<td><strong>TraPId (this proposal)</strong></td>
<td>$0.78 p_t \oplus 1.8$</td>
<td>$2.0 \times 10^{-3}$</td>
<td>3.6% with cluster counting ($dE/dx = 8.1%$)</td>
</tr>
<tr>
<td><strong>TraPId (this proposal)</strong></td>
<td>$0.66 p_t \oplus 1.4$</td>
<td>$1.6 \times 10^{-3}$</td>
<td>2.8% with cluster timing and Ti + C wires 1 m track length - ($dE/dx = 6.9%$)</td>
</tr>
</tbody>
</table>
CONCLUSIONS

I. An ultra-low mass drift chamber for SCTF with a material budget $<1.5\times10^{-2} \ X/X_0$ in the radial direction and $<5\times10^{-2} \ X/X_0$ in the forward and backward directions (including HV and FEE services) can be built today with the novel technique adopted for the successful construction of the MEG2 drift chamber.

II. $\Delta p_t/p_t = 2.0 \times 10^{-3}$, $\Delta \theta = 0.70$ mrad, $\Delta \phi = 0.78$ mrad at $p = 1$ GeV/c.

III. Particle identification at the level of 3.6% with cluster counting allowing for $\pi/K$ separation $\geq 3\sigma$ over a wide range of momenta.

IV. Further gain (>25%) in momentum and angular resolutions can be obtained by
- applying cluster timing techniques,
- exploiting the possibilities of large scale production of metal coated C wires,
- operating the chamber at lower pressures, with moderate degradation of Pid performance.
Support slides

Orsay, Workshop on tau-charm factory

Drift chamber for the CMD-3 detector

F. Grancagnolo a, C. Fiore a, F.V. Ignatov b, A.V. Karavdina b, B.I. Khazin b, A. Miccoli a, V.S. Okhapkin b, S.G. Pivovarov b, A.S. Popov b, A.A. Taban b, A.L. Sibidanov b, L.G. Snopkov b

[Contents lists available at ScienceDirect](http://www.elsevier.com/locate/nima)

<table>
<thead>
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<th>Detector</th>
<th>$S/(1+bS)$</th>
<th>$10^{-3}$</th>
<th>10-13%</th>
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<tr>
<td>CMD-3</td>
<td>(4.3$p_t$+1.2)$\times10^{-2}$</td>
<td>$45\times10^{-3}$</td>
<td>10-13%</td>
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<td>CMD-3 TraPId proposal</td>
<td>(0.9$p_t$+0.33)$\times10^{-2}$</td>
<td>$9.6\times10^{-3}$</td>
<td>5.8%</td>
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