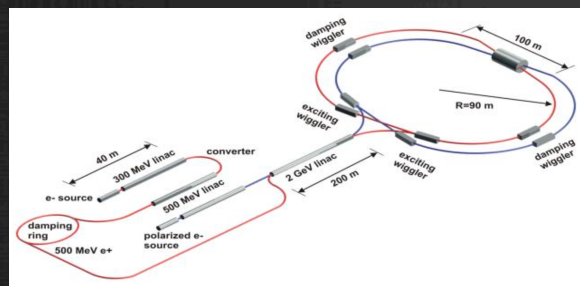


An ultra-low mass Tracking Chamber with Particle Identification capabilities for SCTF at BINP

F. Grancagnolo
INFN – Lecce

Joint Workshop on future tau-charm factory
Orsay Dec. 4-7, 2018



Istituto Nazionale di Fisica Nucleare

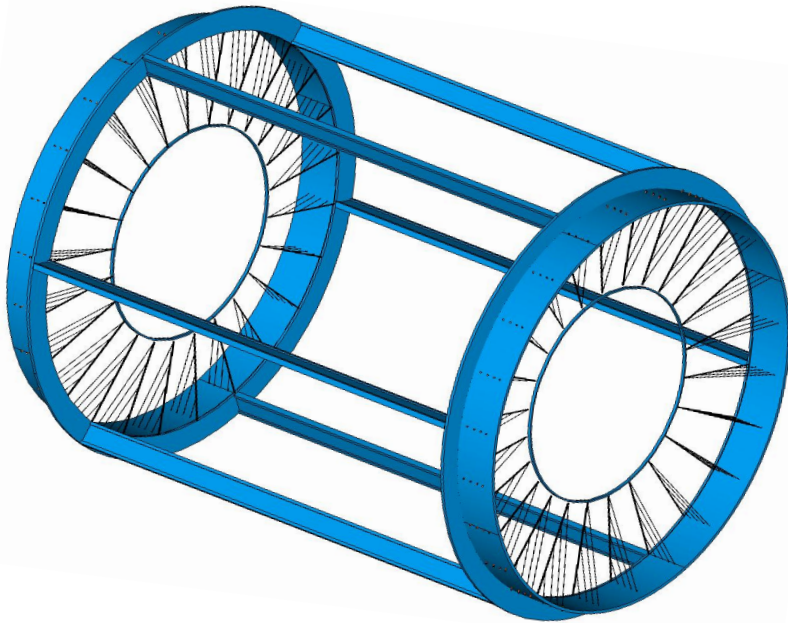
The evolution

from KLOE ...

... to SCTF

- | | | | |
|------|---|------|---|
| I. | Wire configuration fully stereo (no axial layers) | I. | Using cluster timing for improved spatial resolution |
| II. | new light Aluminum wires | II. | Using cluster counting for particle identification |
| III. | Very light gas mixture 90% He – 10% iC_4H_{10} | III. | Separating gas containment from wire support functions |
| IV. | Mechanical structure entirely in Carbon Fiber | IV. | New concepts for wire tension compensation |
| V. | Largest volume drift chamber ever built (45 m ³) | V. | Using a larger number of thinner (and lighter wires) |
| | | VI. | No feed-through wiring |

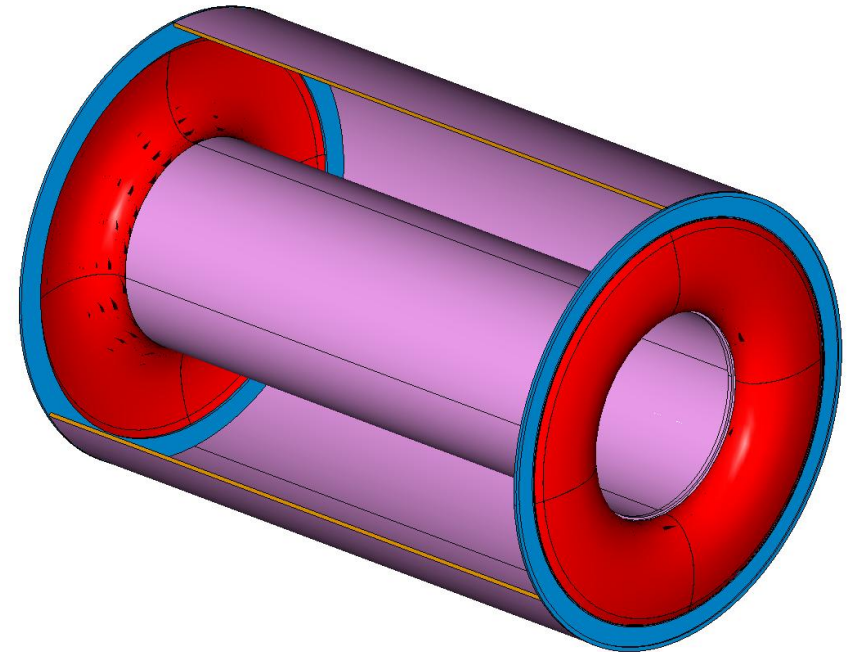
"Wire Cage" and "Gas Envelope"



Wire support:

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

Cremlin+: Super charm-tau factory



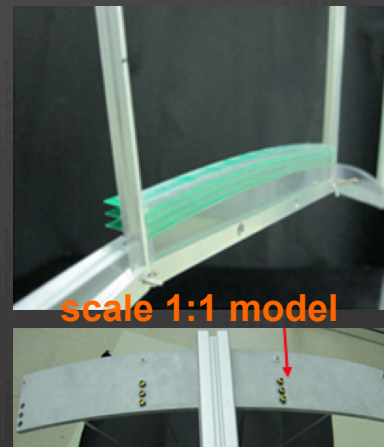
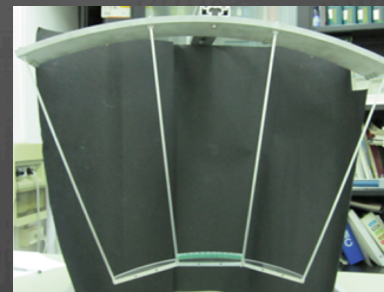
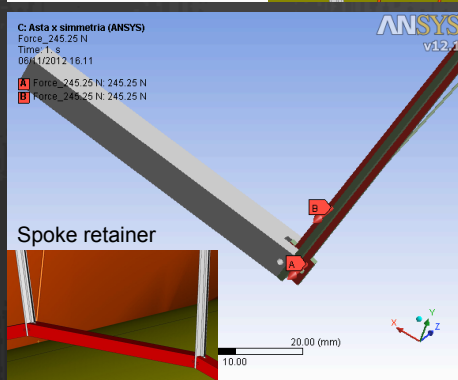
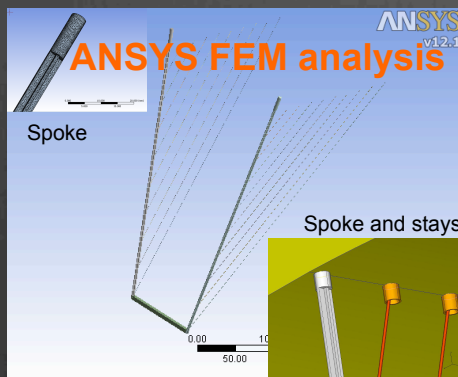
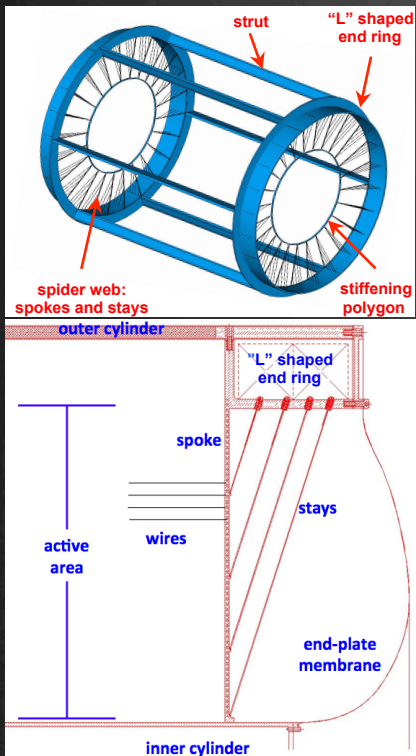
Gas containment:

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

The Mu2e I-Tracker proposal

Wire cage

turn all bending moments into traction or compression!



- **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

$$0.28 \text{ g/cm}^2$$

$$1 \times 10^{-2} X_0$$

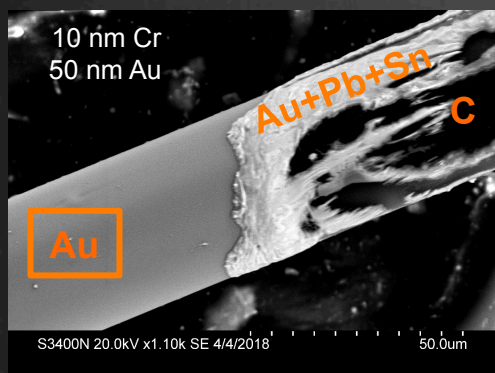
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C wire metal coating

HiPIMS: High-power impulse magnetron sputtering

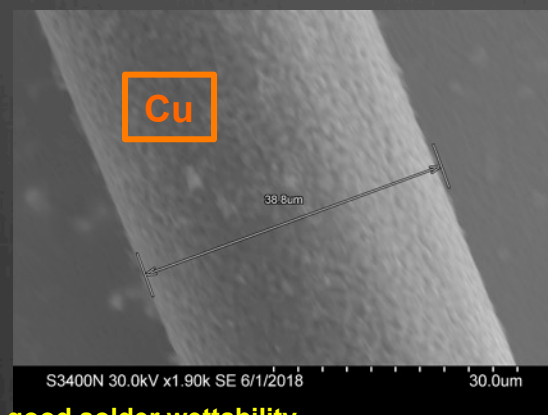
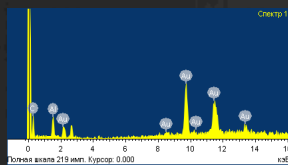
BINP
A. Popov
V. Logashenko

physical vapor deposition (PVD) of thin films based on magnetron sputter deposition (extremely high power densities of the order of kW/cm^2 in short pulses of tens of microseconds at low duty cycle $<10\%$)

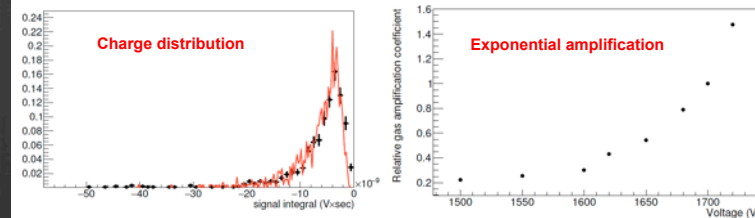
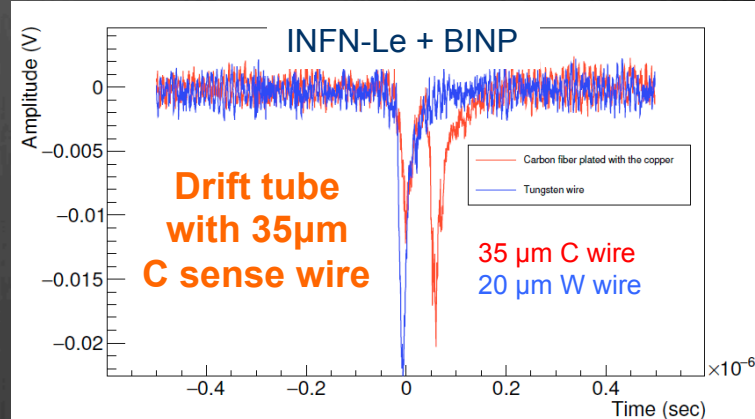
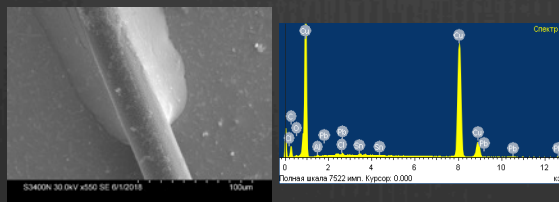


soldering attempt

Lead forms intermetallic compound with gold and completely dissolves the 50 nm Au layer.



good solder wettability on Cu



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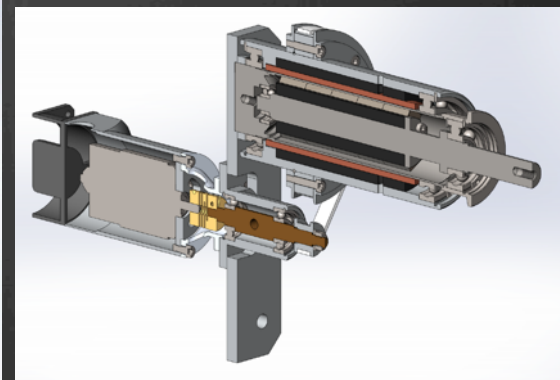
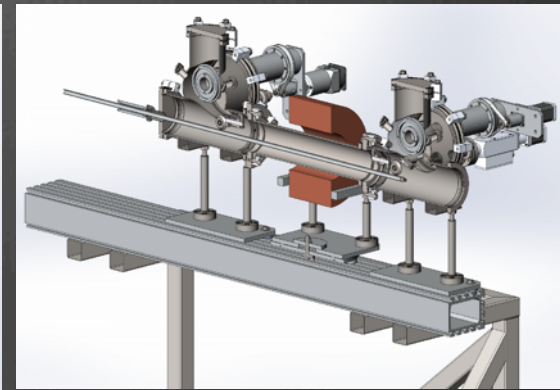
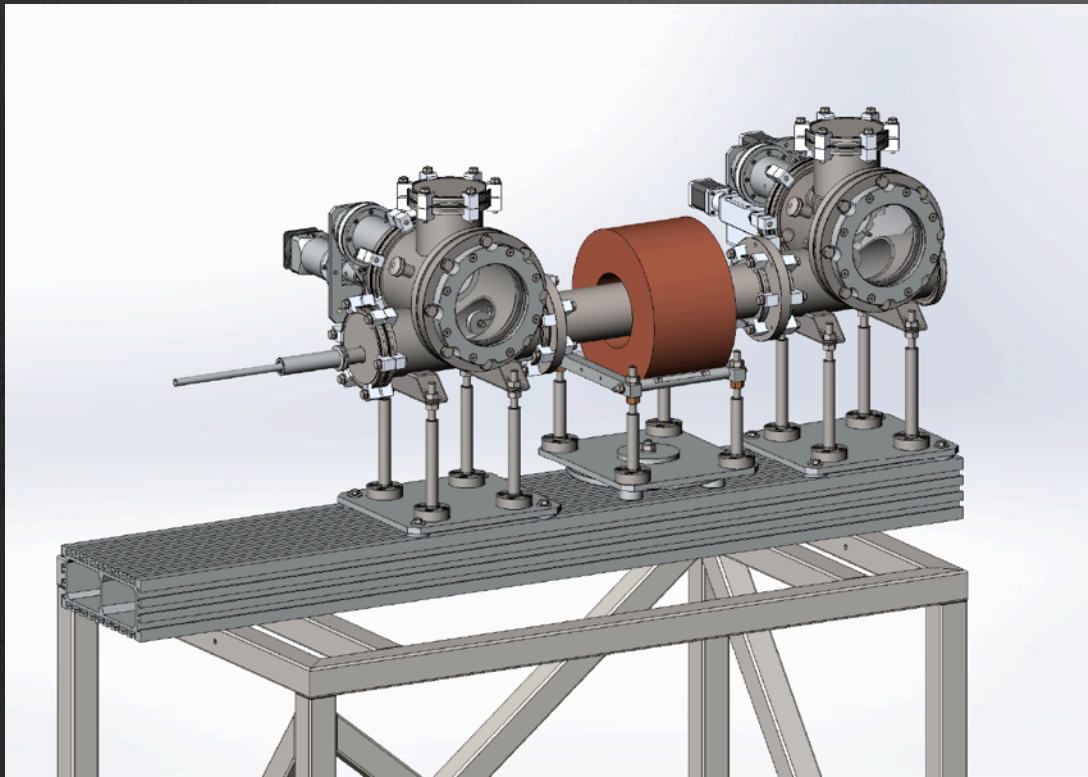
C wire metal coating

Considerations:

- Cu coating test of 35 μm carbon monofilament very successful on short samples with HiPIMS at BINP, Novosibirsk
- Investigation of magnetron sputtering facilities elsewhere (INFN LNL?)
- Industrialization of process for coating continuous spooled monofilament under study
- **Alternatives?**

C wire metal coating: BINP proposal

from
A. Popov
BINP



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C wire Ag gluing

EPOXY TECHNOLOGY

EPO-TEK® H20E
Technical Data Sheet
For Reference Only
Electrically Conductive, Silver Epoxy

Date: June 2018

Rev: 30

No. of Components: 2

Mix Ratio by Weight: 1:1

Specific Gravity: Part A: 2.03 Part B: 3.07 Syringe: 2.67

Part Life: 2.5 Days

Shelf Life - Bulk: One year at room temperature

Shelf Life - Syringe: One year at 40°C

NOTES:

1. Customers should be tested when not in use.

2. Final systems should be dried thoroughly before mixing and prior to use.

3. Performance properties (strength, conductivity, etc.) of the product may vary from those stated on the data sheet when in packaging or prior processing of any kind is performed. Epoxy's warranties shall not apply to any products that have been reprocessed or repackaged from Epoxy's original containers into any other containers of any kind, including but not limited to syringes, to bags, syringes, spindles, tubes, spacers, flow or other packages.

Product Description: EPO-TEK H20E is a two component, 100% solids silver-filled epoxy system designed specifically for chip bonding in microelectronics and optoelectronics. It has proven itself to be a high performance adhesive for a wide range of applications due to its high thermal conductivity. It has proven itself to be a high performance adhesive for a wide range of applications due to its high thermal conductivity. It has proven itself to be a high performance adhesive for a wide range of applications due to its high thermal conductivity.

Typical Properties: Cure condition: 150°C / 1 Hour. Different batches, conditions & applications yield differing results. Data below is not guaranteed. To be used as a guide only, not as a specification. * denotes test on lot acceptance basis.

PHYSICAL PROPERTIES:

	Part A: Silver	Part B: Silver
Color (before cure)	109	109
Consistency	Smooth rheological paste	Smooth rheological paste
Viscosity (23°C) @ 100 rpm	2,200 - 3,200 cP	2,200 - 3,200 cP
Thixotropic Index	4.0	4.0
Glass Transition Temp.	8.60 °C (dynamic Cure 20-300°C/30 Min. Remo -10-20°C @ 2°C/MIN)	8.60 °C (dynamic Cure 20-300°C/30 Min. Remo -10-20°C @ 2°C/MIN)
Coefficient of Thermal Expansion (CTE)	31 x 10 ⁻⁶ /in/°C	31 x 10 ⁻⁶ /in/°C
Shrinkage	Above Tg	Above Tg
Shore D Hardness:	109	109
Modulus @ 23°C:	4.47E	4.47E
Die Shear @ 23°C:	1.10 Kg	3,056 psi
Die Shear @ 125°C:	425	425
Weight Loss:	@ 200°C: 0.26 %	@ 200°C: 0.26 %
	@ 250°C: 1.09 %	@ 250°C: 1.09 %
	@ 300°C: 1.67 %	@ 300°C: 1.67 %
Suggested Operating Temperature	< 300 °C (Intermittent)	< 300 °C (Intermittent)
Storage Modulus	858,700 psi	858,700 psi
Ion Content:	Cl ⁻ : 73 ppm Na ⁺ : 2 ppm	Cl ⁻ : 73 ppm Na ⁺ : 2 ppm
	NH ₄ ⁺ : 98 ppm K ⁺ : 3 ppm	NH ₄ ⁺ : 98 ppm K ⁺ : 3 ppm
Particle Size:	< 4.45 μm	< 4.45 μm

ELECTRICAL AND THERMAL PROPERTIES:

Thermal Conductivity: 2.8 W/mK (based on standard method) Laser Flux

Thermal Conductivity: 29 W/mK (based on Thermal Resistance Duty: 40 x L x K² x A²)

Thermal Resistance (Junction to Case): TC-18 package with metal-grid metallized 20 x 20 mil chips and bonded with H20E (5 mils thick)

Volume Resistivity @ 23°C: 1.1E+004 ohm-cm

LOCTITE

Technical Data Sheet

LOCTITE ABLESTIK 84-1LMI

October 2014

PRODUCT DESCRIPTION:

LOCTITE ABLESTIK 84-1LMI provides the following product characteristics:

Electrical Loss Content (ppm)	100
Chloride (Cl ⁻)	100
Sulfur (S)	100
Phosphorus	100
Fluoride (F)	100
Water Extract Conductivity (μmhos/cm)	10
Moisture Uptake @ 23°C, 50% RH	0.16
Volume Resistivity (ohm-cm)	> 10 ¹⁰

Application: Die attach

Typical Properties of Cured Material:

Die Shear Strength @ 23°C: 18 N/mm² (2.6 ksi)

Die Shear Strength @ 150°C: 12 N/mm² (1.7 ksi)

GENERAL INFORMATION:

For safe handling information on this product, consult the Material Safety Data Sheet (MSDS).

WARNING:

- Always refer to the MSDS for safety information before use.
- After removing from the dispenser, set the syringe to stand upright with the plunger facing down for 10 minutes before use.
- DO NOT open the container before contents reach 25°C temperature. Any moisture that collects on the plunger should be removed prior to opening the container.
- DO NOT breathe. Once placed in 40°C, the adhesive should not be reused.

Typical Properties of Uncured Material:

Viscosity (uncured @ 23°C)	4.0 cP
Viscosity (uncured @ 150°C)	100 cP
Modulus @ 23°C (kPa)	14
Modulus @ 150°C (kPa)	91
Die Shear (on case of manufacturer)	163
Die Shear @ 23°C (kPa)	365

Typical Properties of Cured Material:

Die Shear @ 23°C (kPa)	163
Die Shear @ 150°C (kPa)	103
Thermal Conductivity (W/mK)	2.4

Henkel

drawbacks

- curing time 1 hr at 150°C
- dispensing expensive dispensers
- cost Epo-TEK H20E 12.5 €/g
- ABLEBOND 84-1LMI 54.0 €/cc

solution (?)

- curing time pulsed infrared laser (from MEG2 wiring robot)?

EPO-TEK Adhesive, for

agar

Price: \$277.00 - \$310.00

1 kg (35.27 oz)

1 kg (35.27 oz)

87-77640 FREE

87-77640 FREE

87-77640 FREE

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C wire soldering without metal coating

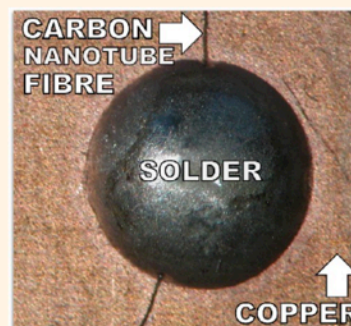
Soldering of Carbon Materials Using Transition Metal Rich Alloys

Published online August 09, 2015
10.1021/acsnano.5b02176

Marek Burda,^{*,†} Agnieszka Lekawa-Raus,[†] Andrzej Gruszczczyk,[‡] and Krzysztof K. K. Koziol^{*,†}

[†]Department of Materials Science and Metallurgy, University of Cambridge, 27 Charles Babbage Road, CB3 0FS, Cambridge, U.K. and [‡]Welding Department, Silesian University of Technology, Konarskiego 18a, 44-100 Gliwice, Poland

ABSTRACT Joining of carbon materials *via* soldering has not been possible up to now due to lack of wetting of carbons by metals at standard soldering temperatures. This issue has been a severely restricting factor for many potential electrical/electronic and mechanical applications of nanostructured and conventional carbon materials. Here we demonstrate the formation of alloys that enable soldering of these structures. By addition of several percent (2.5–5%) of transition metal such as chromium or nickel to a standard lead-free soldering tin based alloy we obtained a solder that can be applied using a commercial soldering iron at typical soldering temperatures of approximately 350 °C and at ambient conditions. The use of this solder enables the formation of mechanically strong and electrically conductive joints between carbon materials and, when supported by a simple two-step technique, can successfully bond carbon structures to any metal terminal. It has been shown using optical and scanning electron microscope images as well as X-ray diffraction patterns and energy dispersive X-ray mapping that the successful formation of carbon–solder bonds is possible, first, thanks to the uniform nonreactive dispersion of transition metals in the tin-based matrix. Further, during the soldering process, these free elements diffuse into the carbon–alloy border with no formation of brazing-like carbides, which would damage the surface of the carbon materials.



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C wire soldering without metal coating

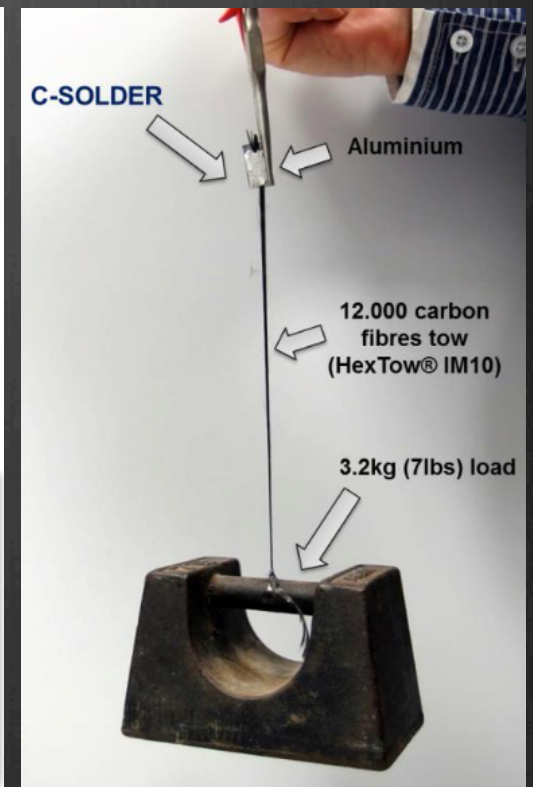
Up to now it has not been possible to apply soldering to graphitic materials as they are not wetted by the commercially available alloys.

C-SOLDER is a trade name for a group of new tin-based lead-free low-temperature soldering alloys which enable joining of various carbon materials including carbon fibres or carbon nanotube fibres in both carbon-carbon and carbon-metal arrangements.

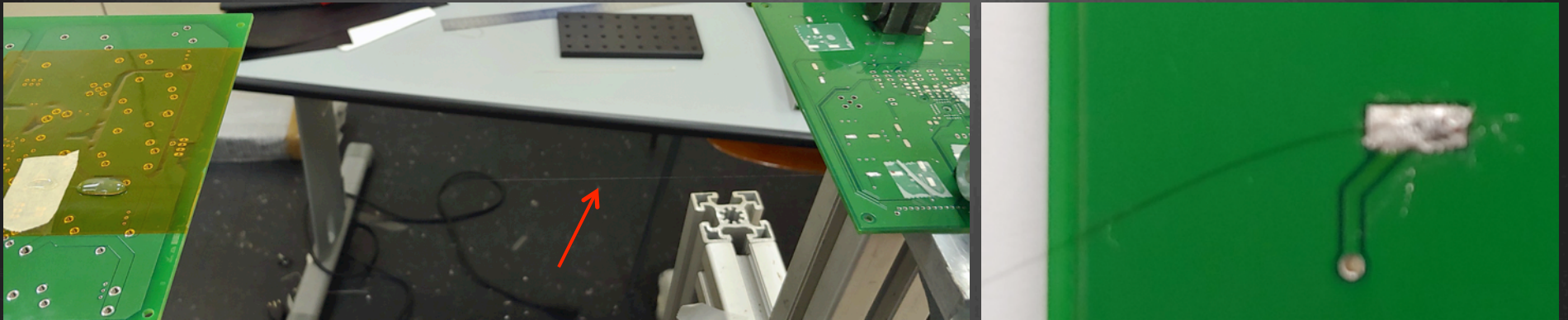
The use of these alloys allows fast formation of mechanically strong bonds which are electrically conductive simultaneously.

C-SOLDER Type: SAC-1B:

- Excellent wetting of carbon materials: graphite, carbon fibres, carbon nanotube fibres, graphene, etc.
- Suitability for bonding in carbon-carbon and carbon-metal systems.
- Soldering temperatures below 450°C.
- Good mechanical and electrical properties.
- Lead free.
- Flux free.



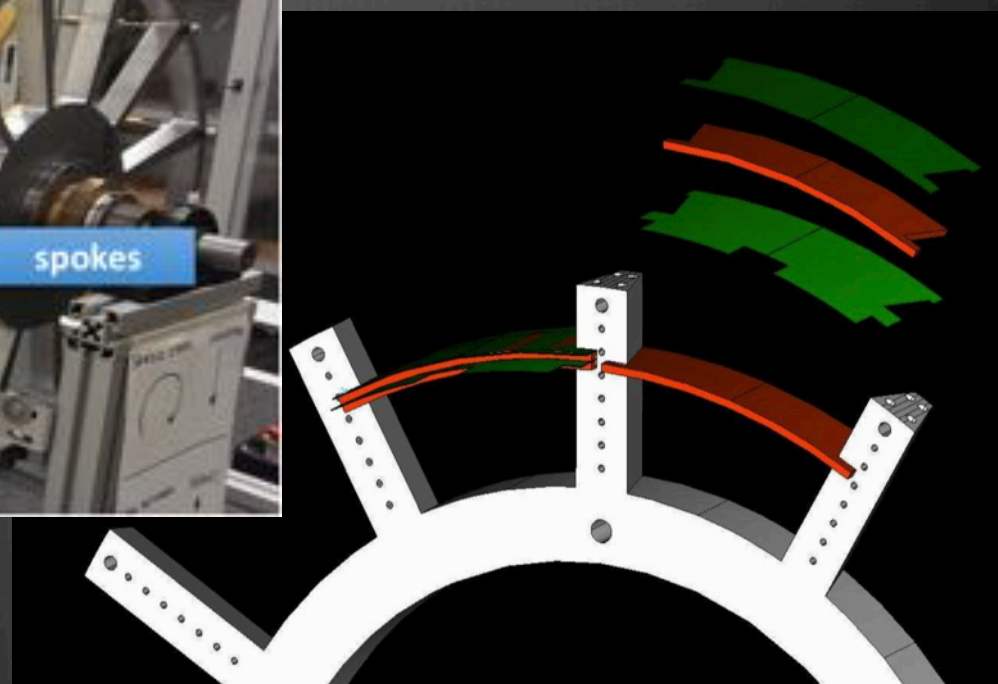
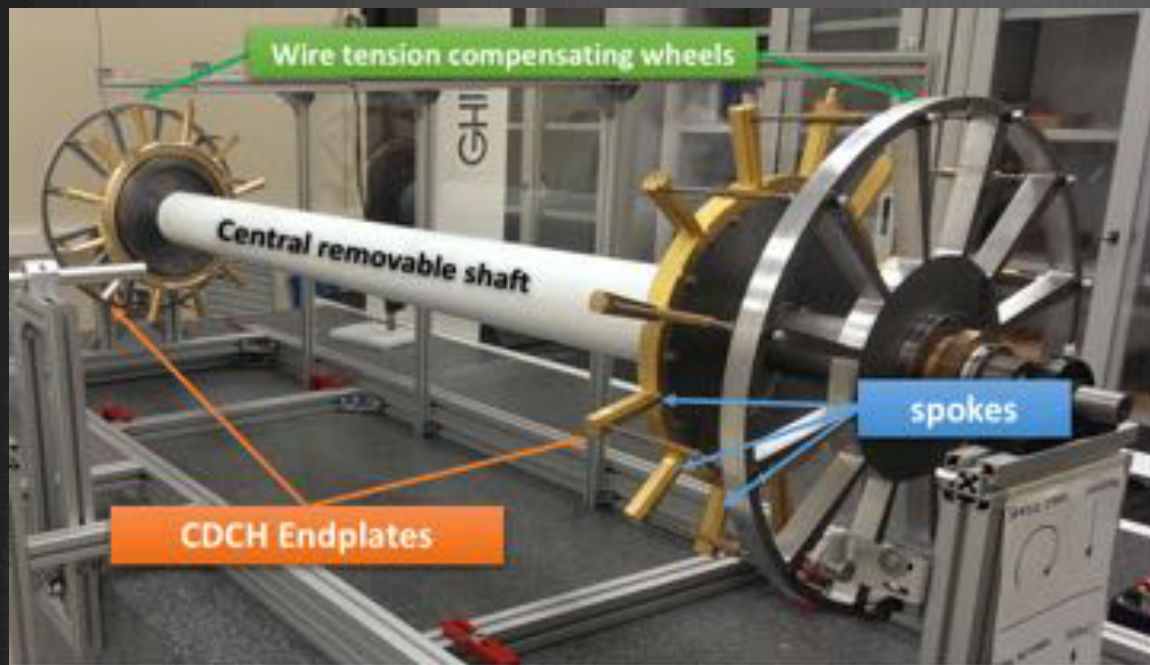
C wire without metal coating: hand soldering



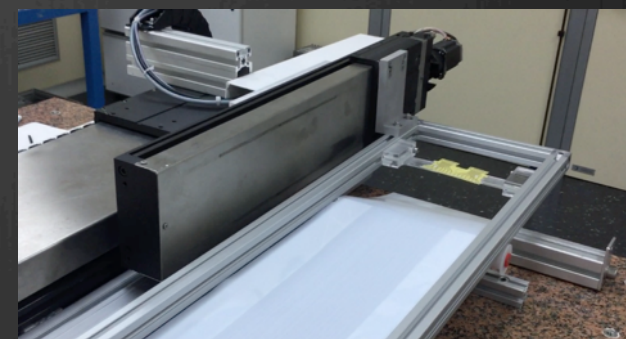
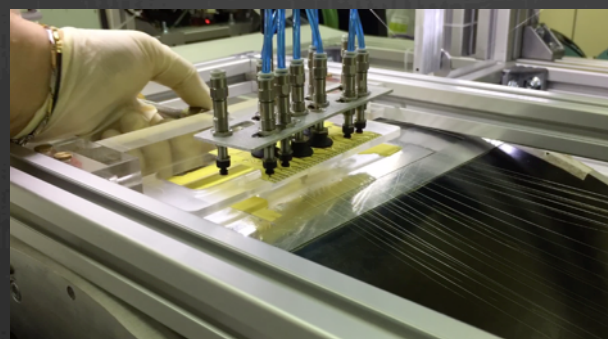
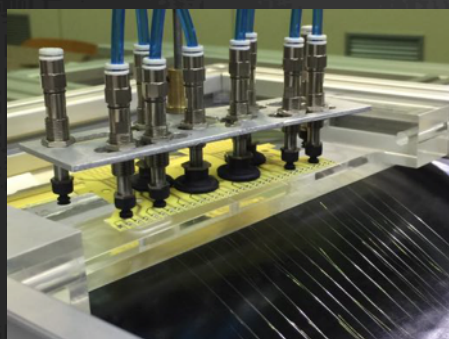
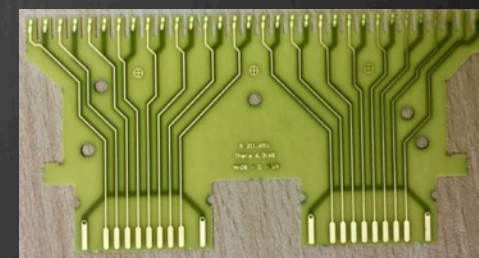
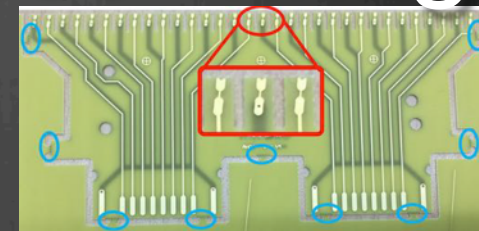
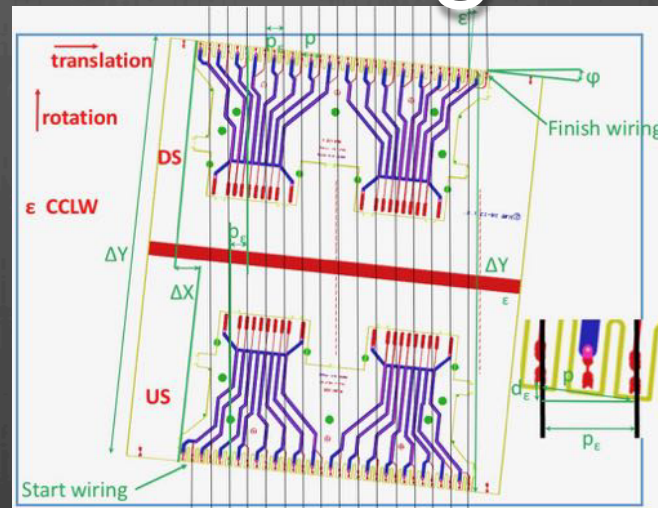
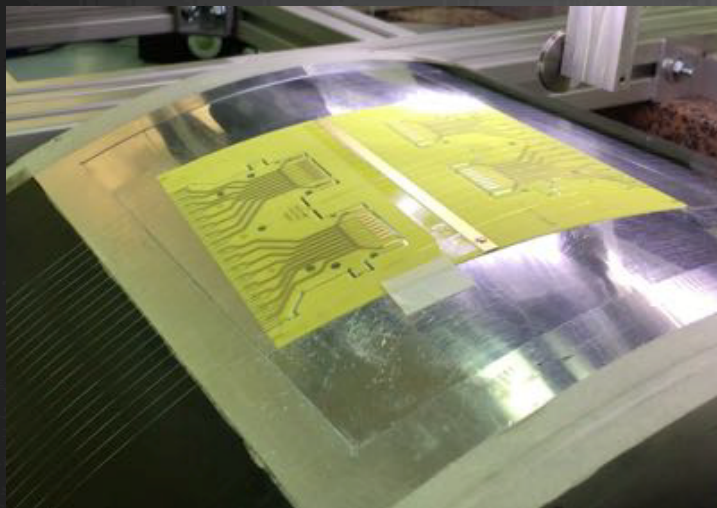
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The MEG2 feed-through-less wiring



The MEG2 feed-through-less wiring



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The IDEA Drift Chamber at CEPC and FCC-ee

The IDEA Detector at

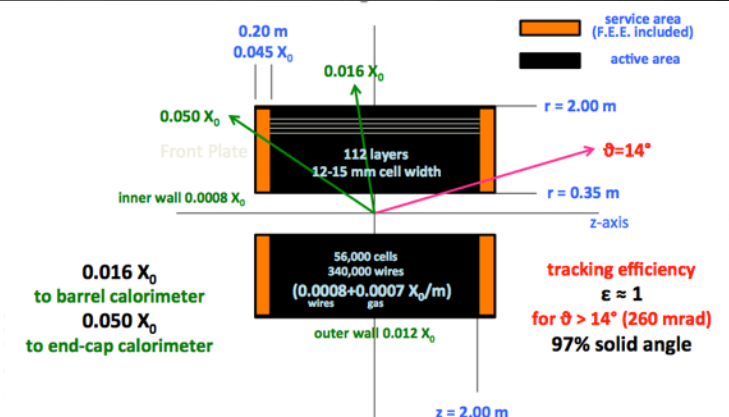
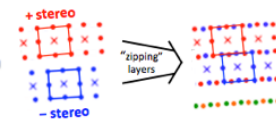
FCC-ee at CERN



CEPC at IHEP-China

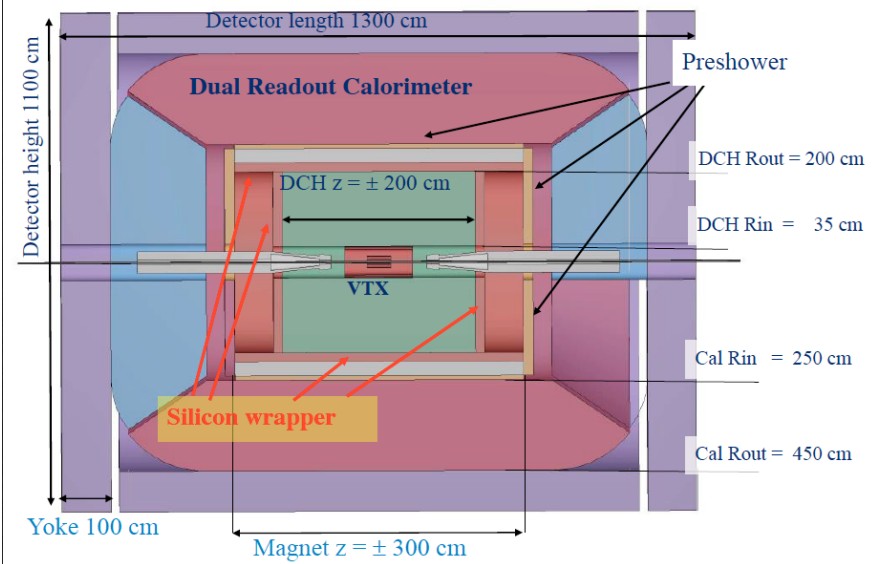


The IDEA Drift Chamber



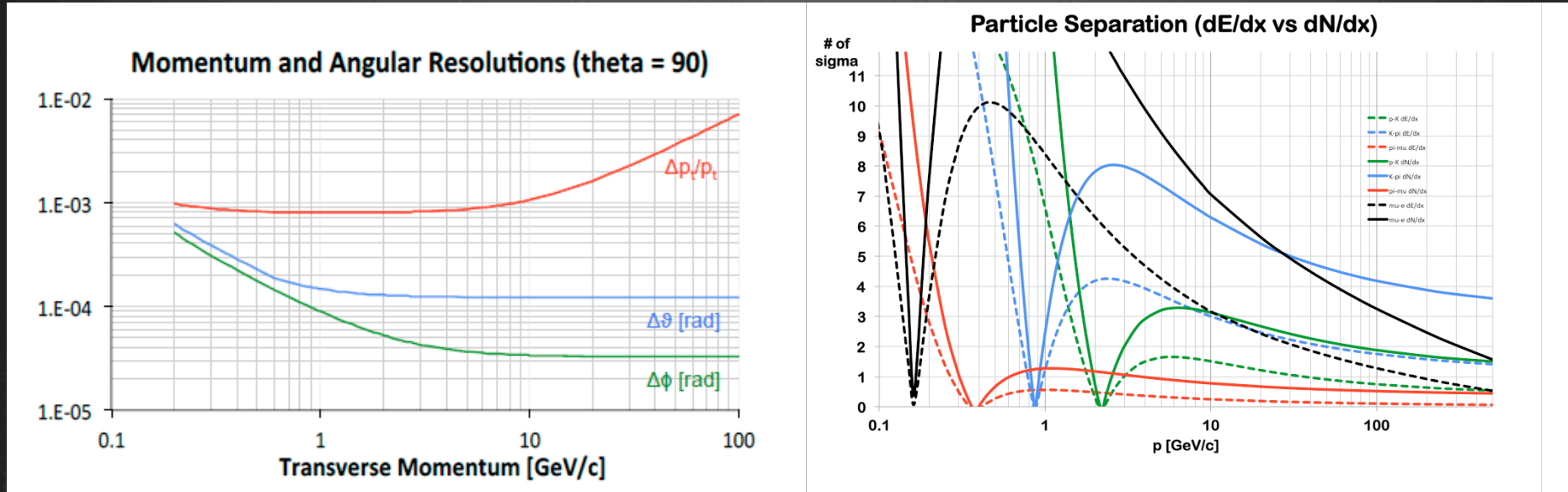
	R_{in} [mm]	R_{out} [mm]	z [mm]		inner wall	gas	wires	outer wall	service area
drift chamber	350	2000	± 2000	thickness [mm]	0.2	1000	1000	20	250
service area	350	2000	$\pm(2000+2250)$	X_0 [%]	0.08	0.07	0.13	1.2	4.5

# of layers	112	min 11.8 mm – max 14.9 mm	active volume	50 m ³	0.9 He-0.1 iC ₄ H ₁₀
# of cells	56448	192 at first layer – 816 at last layer	readout channel	112,896	r.o. from both ends
average cell size	13.9 mm	min 11.8 mm – max 14.9 mm	max drift time	400 ns	800 × 8 bit at 2 GHz
average stereo angle	134 mrad	min 43 mrad – max 223 mrad			
transverse resolution	100 μ m	80 μ m with cluster timing			
longitudinal resolution	750 μ m	600 μ m with cluster timing			



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The IDEA Drift Chamber Performance



$$\Delta p_t/p_t = (0.7p_t \oplus 8.3) \times 10^{-4}$$

$$\Delta\vartheta = (1.1 \oplus 9.4/p) \times 10^{-4} \text{ rad}$$

$$\Delta\phi = (0.33 \oplus 9.4/p) \times 10^{-4} \text{ rad}$$

$$dE/dx = 4.3 \%$$

$$dN/dx = 2.2 \% \quad (\text{at } \epsilon_N = 80 \%)$$

TraPId: A proposal for SCTF

$R_{in} - R_{out}$ [mm]		200 – 800
active L – service area [mm]		1800 – 200
inner cylindrical wall		
C-fiber/C-foam sandwich	2×80 μm / 5 mm	0.036 g/cm ² – 8×10 ⁻⁴ X/X ₀
outer cylindrical wall		
C-fiber/C-foam sandwich	2×5 mm / 10 mm	0.512 g/cm ² – 1.2×10 ⁻² X/X ₀
end plate		
gas envelope	160 μm C-fiber	0.021 g/cm ² – 6×10 ⁻⁴ X/X ₀
instrumented wire cage	wire PCB, spacers, HV distr. and cables, limiting R, decoupling C and signal cables	0.833 g/cm ² – 3.0×10 ⁻² X/X ₀

cell	
shape	square
size [mm]	7.265 – 9.135
layer	
8 super-layers	8 layer each
64 layer total	
stereo angles	66 – 220 mrad
n. sense wires [20μm W]	23,040
n. field wires [40/50μm Al]	116,640
n. total (incl. guard)	141,120
gas + wires [600 mm]	
90%He – 10%iC ₄ H ₁₀	4.6×10 ⁻⁴
W + 5 Al → Ti + 5 C	(13.1 → 2.5)×10⁻⁴

TraPId: Tracking Performance

Expected Performance: Track parameters resolutions

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

measurement

multiple scattering (gas + wires + inner wall)

$$\frac{\Delta p_{\perp}}{p_{\perp}} = 2.0 \times 10^{-3}, \quad \Delta\phi = 0.70 \text{ mrad}, \quad \Delta\theta = 0.78 \text{ mrad}$$

at $p = 1 \text{ GeV} / c$

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

(7.8 \rightarrow 6.6 with cluster timing)

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

$$\Delta\theta = 3.8 \times 10^{-4} \oplus \frac{6.9 \times 10^{-4}}{p}$$

TraPId: PId Performance

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

from *Walenta parameterization (1980)*

$$\begin{aligned} L_{track} &= 0.6 \text{ m} \\ P &= 1 \text{ atm} \\ n &= 64 \end{aligned}$$

$$\frac{\sigma_{dE/dx}}{(dE/dx)} = 8.1\%$$

6.9% for $L_{track} = 1 \text{ m}$

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

from *Poisson distribution*

$$\begin{aligned} L_{track} &= 0.6 \text{ m} \\ \delta_{cl} &= 12.5/\text{cm} \end{aligned}$$

$$\frac{\sigma_{dN_{cl}/dx}}{(dN_{cl}/dx)} = 3.6\%$$

2.8% for $L_{track} = 1 \text{ m}$

Summary of performance

	$\frac{\Delta p_t}{p_t} \times 10^3$	at $p_t = 1\text{GeV}$	$\frac{dE}{dx} / \frac{dN}{dx}$	
KLOE	$0.5 p_t \oplus 2.6$	2.6×10^{-3}	5%	still best world performance
BaBar	$1.3 p_t \oplus 4.5$	4.7×10^{-3}	7.5%	
Belle	$2.8 p_t \oplus 3.5$	4.5×10^{-3}	6.9%	
BelleII	$1.9 p_t \oplus 2.9$	3.5×10^{-3}	6.4%	
BESIII	$2.7 p_t \oplus 4.7$	5.1×10^{-3}	6–7%	
Cleo3	$1.0 p_t \oplus 9.0$	9.1×10^{-3}	5%	
SCTF (Todyshev)	$2.6 p_t \oplus 5.1$	5.7×10^{-3}	7%	
TraPID (this proposal)	$0.78 p_t \oplus 1.8$	2.0×10^{-3}	8.1/3.6%	
TraPID (this proposal)	$0.66 p_t \oplus 1.4$	1.6×10^{-3}	6.9/2.8%	C wires + cluster timing 1 m track length

CONCLUSIONS

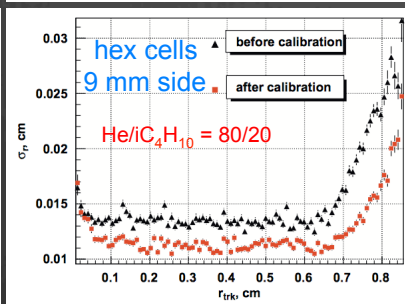
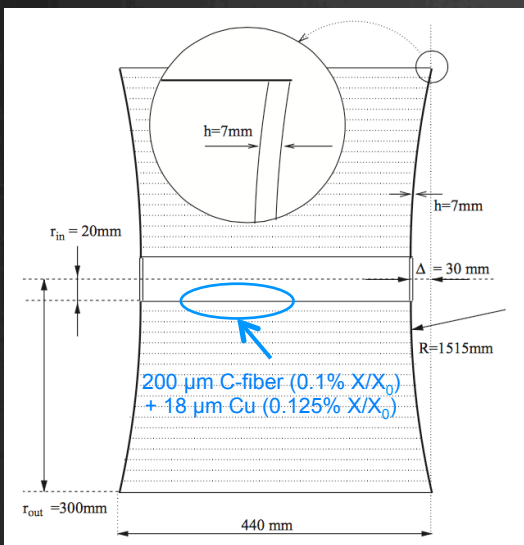
- I. **An ultra-low mass drift chamber for SCTF** with a material budget $<1.5 \times 10^{-2} X/X_0$ in the radial direction and $<5 \times 10^{-2} X/X_0$ in the forward and backward directions (including HV and FEE services) **can be built** with the novel technique adopted for the successful construction 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 **π/K separation $\geq 3\sigma$** over a wide range of momenta.
- IV. Further gain in momentum and angular resolutions and in particle identification, will be obtained by
 - applying **cluster timing** techniques,
 - exploiting the possibilities of large scale implementation of **C wires**
 - **operating the chamber at lower than atmospheric pressures**, with moderate degradation of particle identification performance

Cremlin+: **CMD-3** drift chamber as a prototype for **TraPId**

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**Nuclear Instruments and Methods in
 Physics Research A**
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Drift chamber for the CMD-3 detector
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$\Delta\rho_t/\rho_t = (1.5 \div 4.5) \%$
 $\rho = 100\text{-}1000 \text{ MeV}/C$
 $\Delta\vartheta = 20 \text{ mrad}$
 $\Delta\phi = 3.5\text{-}8 \text{ mrad}$
 $\Delta(dE/dx)/(dE/dx) = (10\text{-}13)\%$

CMD-3	$43 p_t \oplus 12$	45×10^{-3}	10–13%
CMD-3 TraPId proposal	$9.0 p_t \oplus 3.3$	9.6×10^{-3}	5.8%