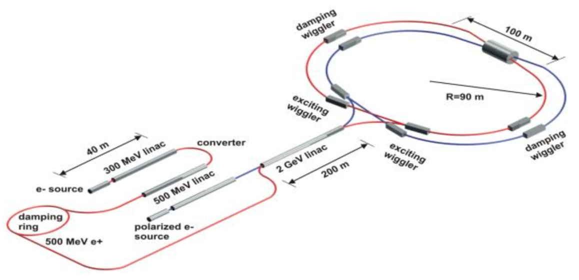
An ultra-low mass Tracking Chamber with Particle Identification capabilities for SCTF at BINP

F. Grancagnolo
INFN – Lecce

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



The evolution

from KLOE ...

I. Wire configuration **fully stereo** (no axial layers)

II. new **light Aluminum** wires

III. Very light gas mixture **90% He – 10% iC_4H_{10}**

IV. Mechanical structure entirely in **Carbon Fiber**

V. Largest volume **drift chamber** ever built (45 m^3)

... to SCTF

I. Using **cluster timing** for improved spatial resolution

II. Using **cluster counting** for particle identification

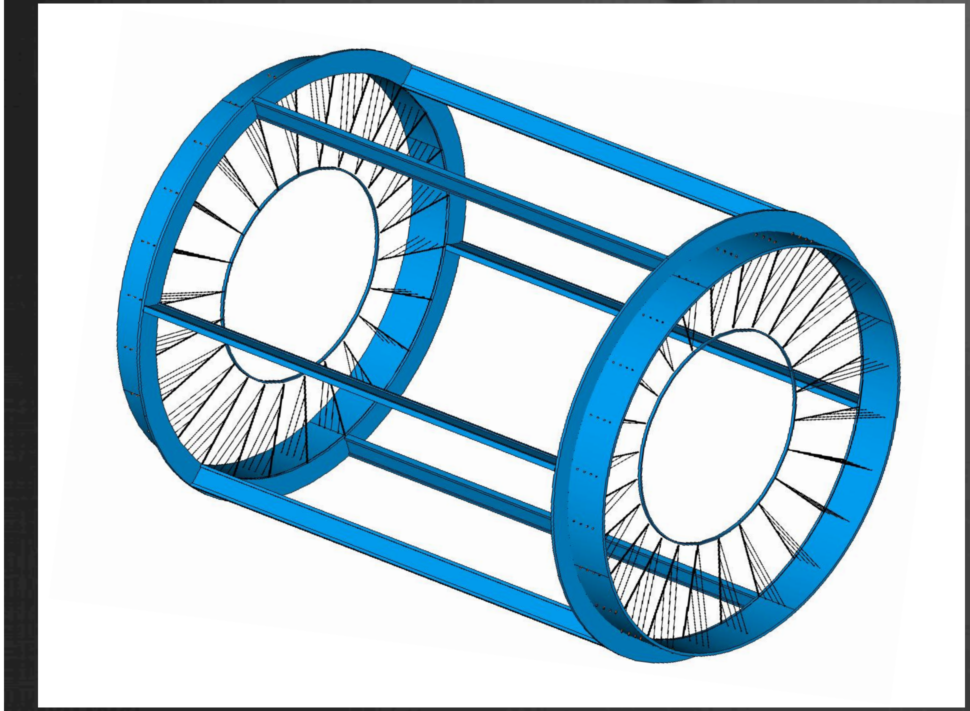
III. Separating **gas containment** from **wire support** functions

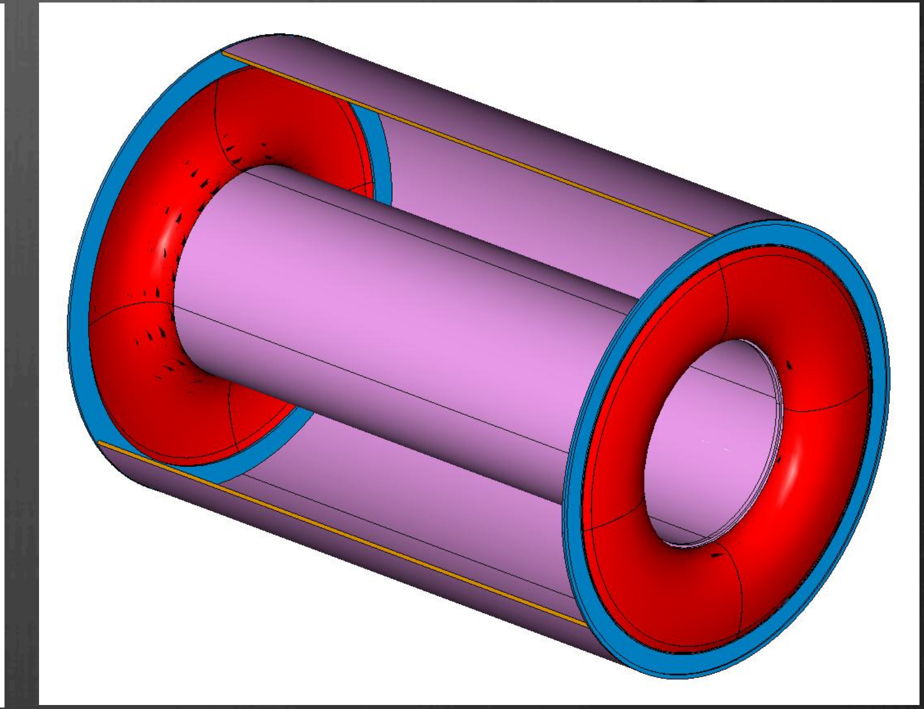
IV. New concepts for **wire tension compensation**

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.

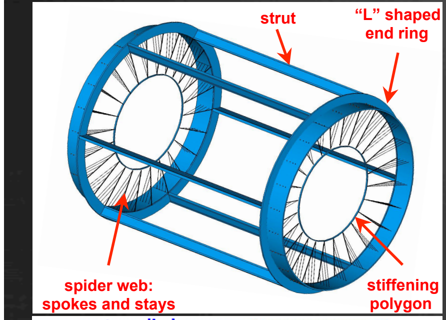
Gas containment:

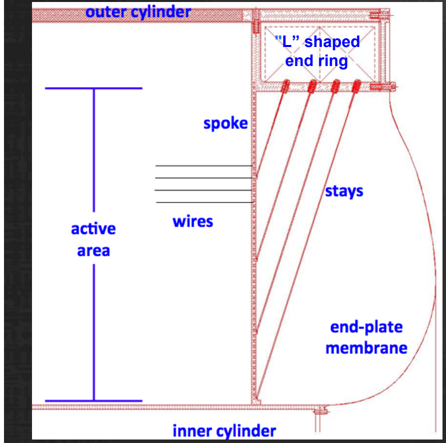
Gas envelope can freely deform without affecting the internal wire position and tension.

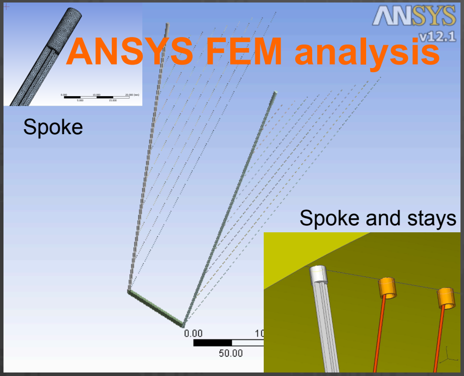
The Mu2e I-Tracker proposal

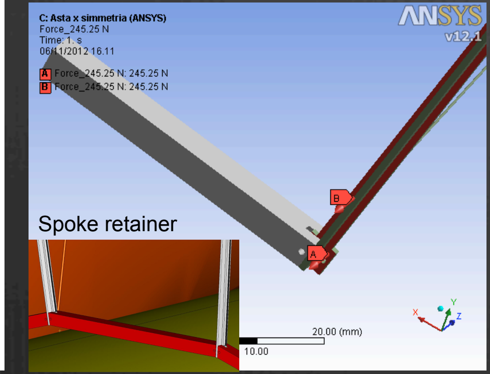
Wire cage

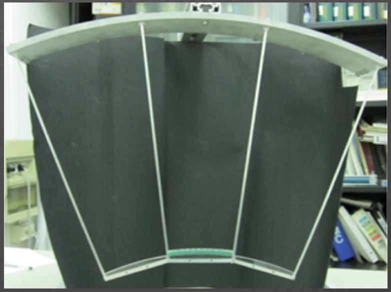
turn all bending moments into traction or compression!

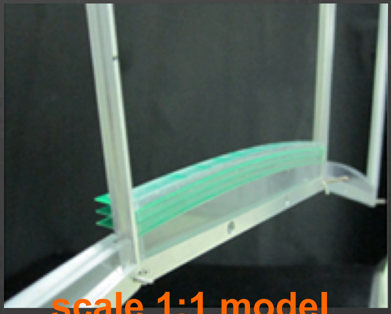


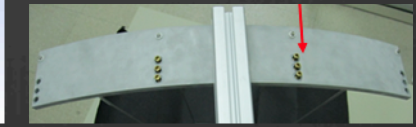












- ➢ **feed-through-less chamber** allows for reducing wire spacing, thus increasing cell granularity:
  - ○ **smaller cells**
  - ○ **larger ratios of field to sense wires**
- ➢ **larger ratios of field to sense wires** allows for thinner field wires, thus reducing
  - ○ **wire contribution to multiple scattering**
  - ○ **total wire tension**

Instrumented end-plate:

wire PCB, spacers, HV distrib. and cables, limiting R, decoupling C and signal cables

0.28 g/cm^2

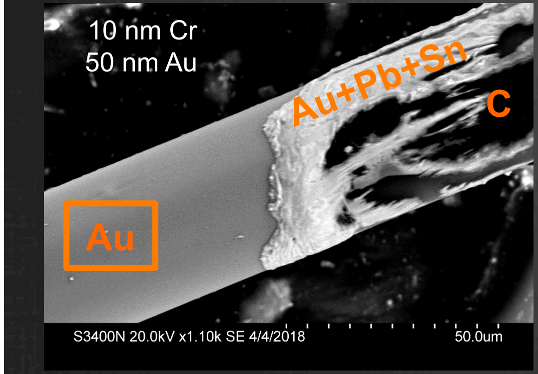
$1\times10^{-2}\ X_0$

C wire metal coating

HiPIMS: High-power impulse magnetron sputtering

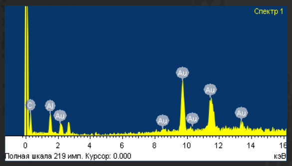
BINP
A. Popov
V. Logashenko

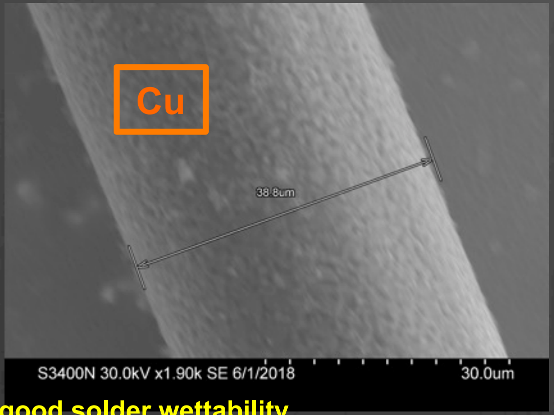
physical vapor deposition (PVD) of thin films based on magnetron sputter deposition (extremely high power densities of the order of kW/cm^2 in short pulses of tens of microseconds at low duty cycle <10%)



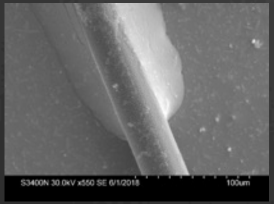
soldering attempt

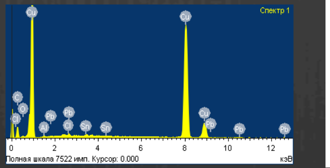
Lead forms intermetallic compound with gold and completely dissolves the 50 nm Au layer.

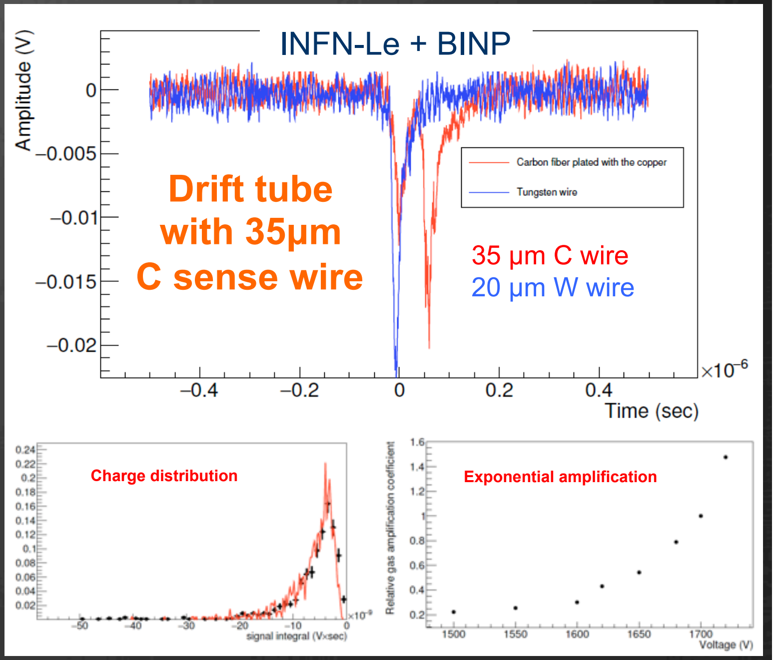




good solder wettability on Cu







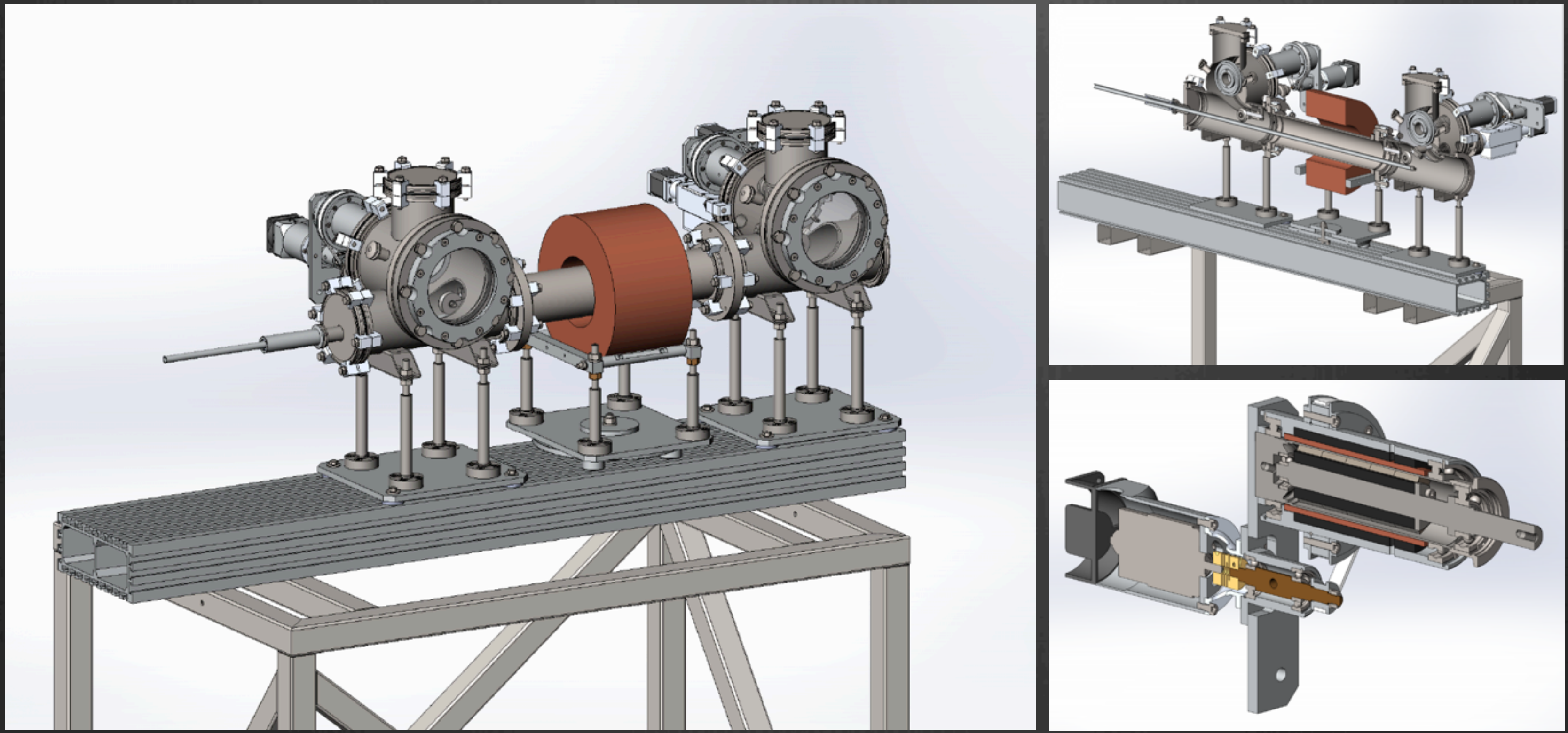
C wire metal coating

Considerations:

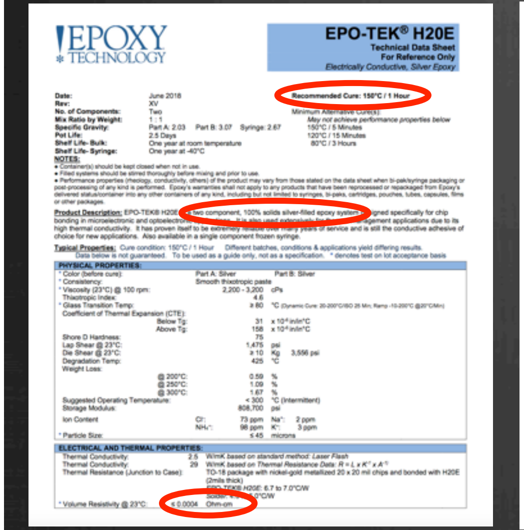
- Cu coating test of 35 μm carbon monofilament very successful on short samples with HiPIMS at BINP, Novosibirsk
- Investigation of magnetron sputtering facilities elsewhere (INFN LNL?)
- Industrialization of process for coating continuous spooled monofilament under study
- **Alternatives?**

C wire metal coating: BINP proposal

from
A. Popov
BINP

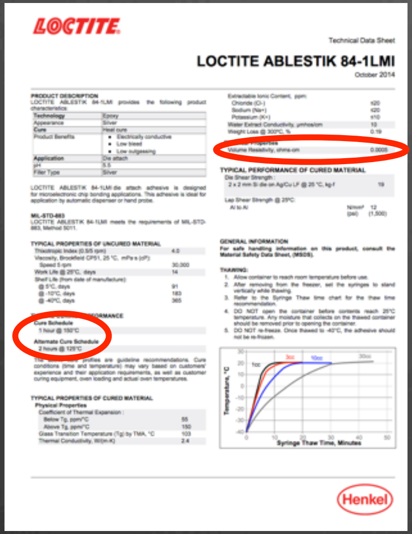


C wire Ag gluing



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

Recommended Cure: 150°C / 1 Hour



Technical Data Sheet
LOCTITE ABLESTIK 84-1LMI
October 2014

EPO-Tek H20E Adhesive, 1oz

Henkel Loctite Conductive Adhesive ablestik 84-1LMI conductive silver adhesive ABLEBOND 84-1LMI 3cc

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)?

C wire soldering **without** metal coating

Soldering of Carbon Materials Using Transition Metal Rich Alloys

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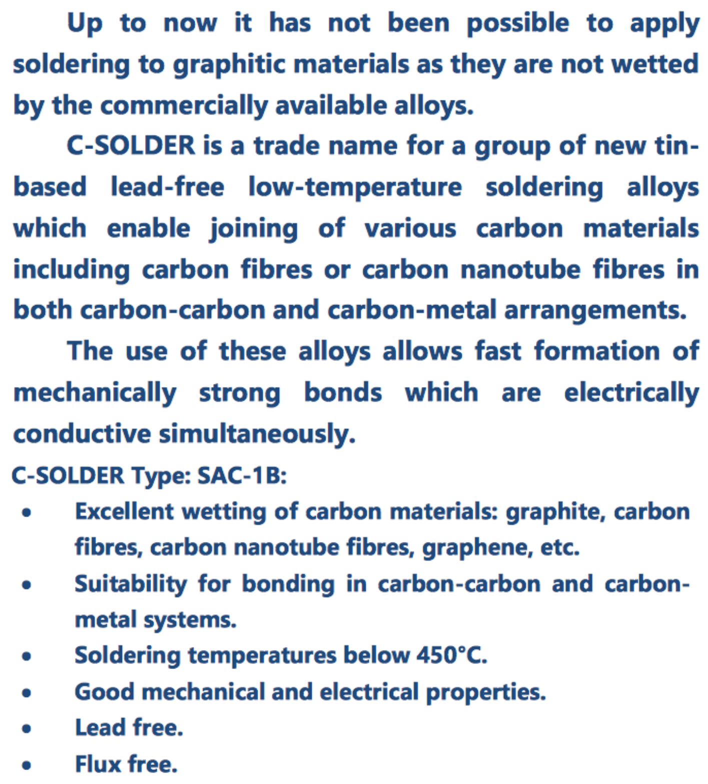
ABSTRACT Joining of carbon materials *via* soldering has not been possible up to now due to lack of wetting of carbons by metals at standard soldering temperatures. This issue has been a severely restricting factor for many potential electrical/electronic and mechanical applications of nanostructured 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.

C wire soldering **without** metal coating



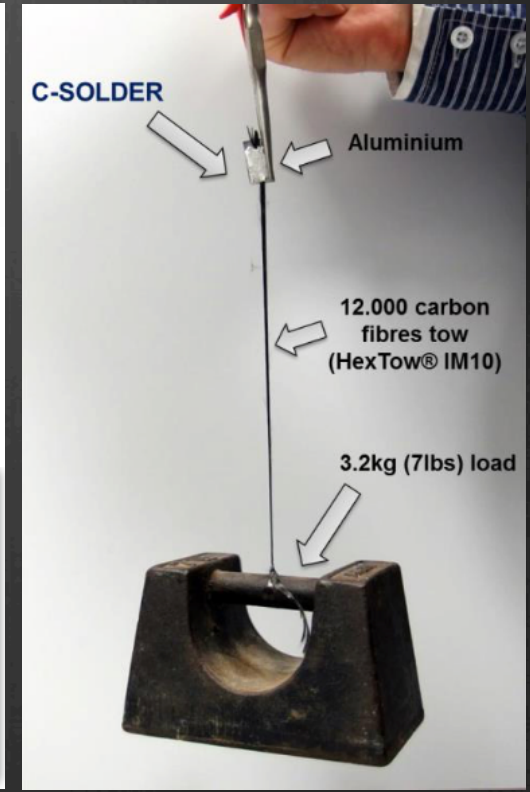
Up to now it has not been possible to apply soldering to graphitic materials as they are not wetted by the commercially available alloys.

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.

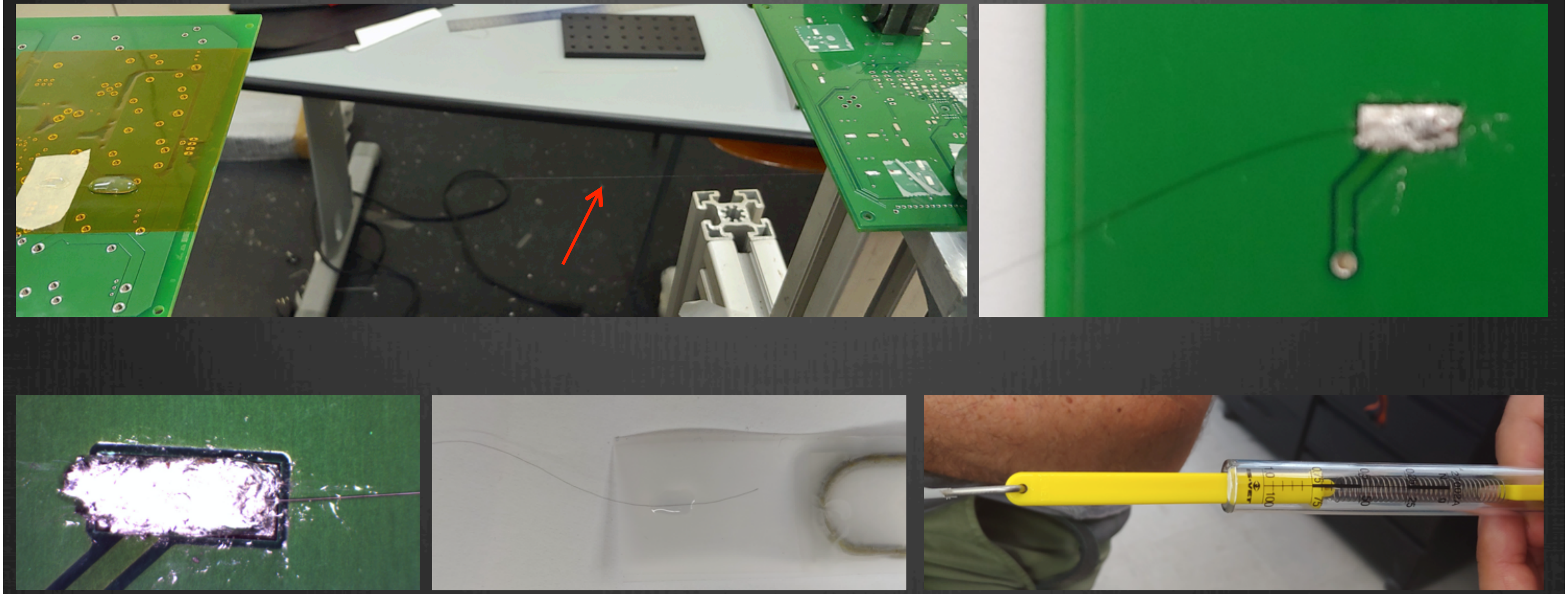
The use of these alloys allows fast formation of mechanically strong bonds which are electrically conductive simultaneously.

C-SOLDER Type: SAC-1B:

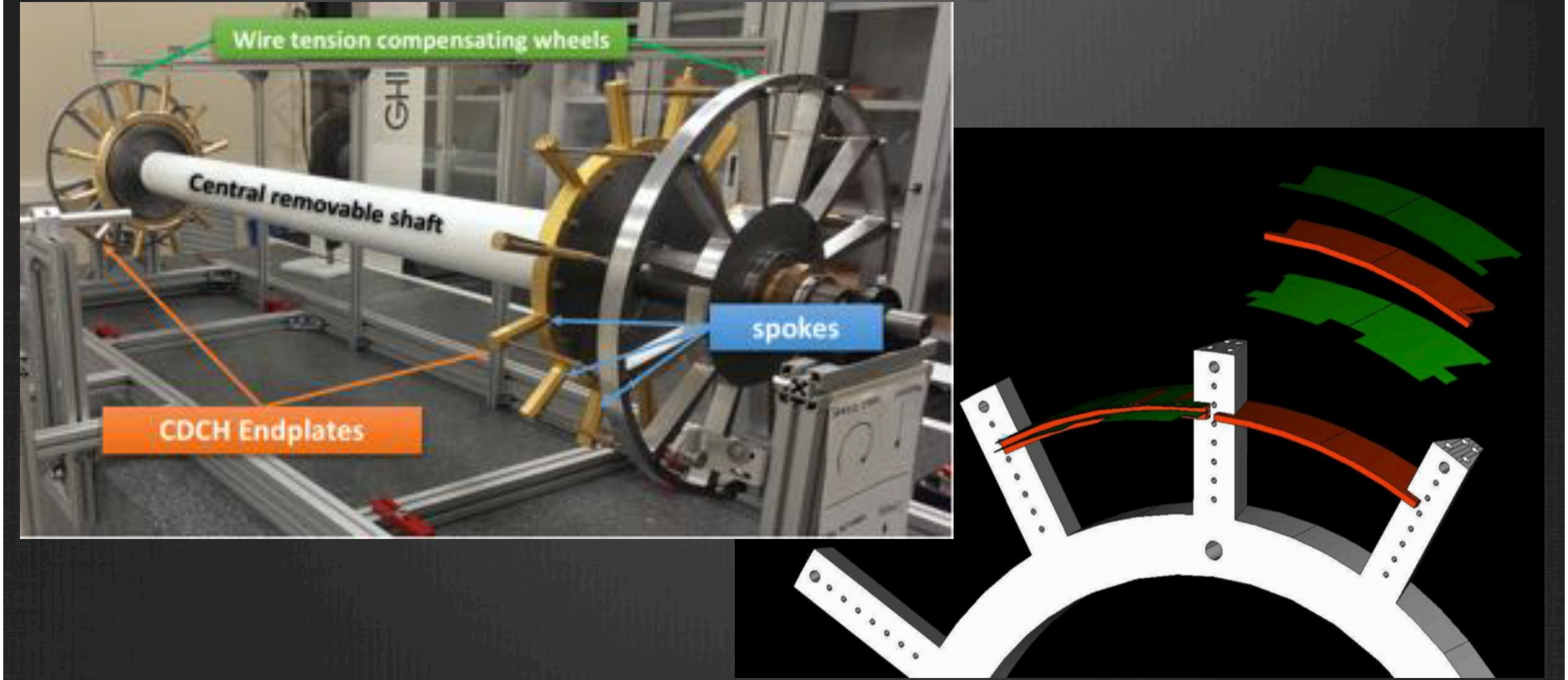
- Excellent wetting of carbon materials: graphite, carbon fibres, carbon nanotube fibres, graphene, etc.
- Suitability for bonding in carbon-carbon and carbon-metal systems.
- Soldering temperatures below 450°C.
- Good mechanical and electrical properties.
- Lead free.
- Flux free.



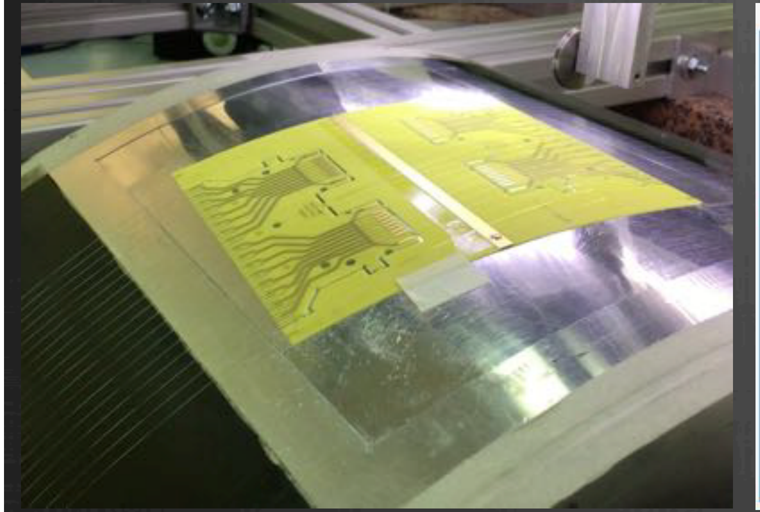
C wire **without** metal coating: **hand** soldering

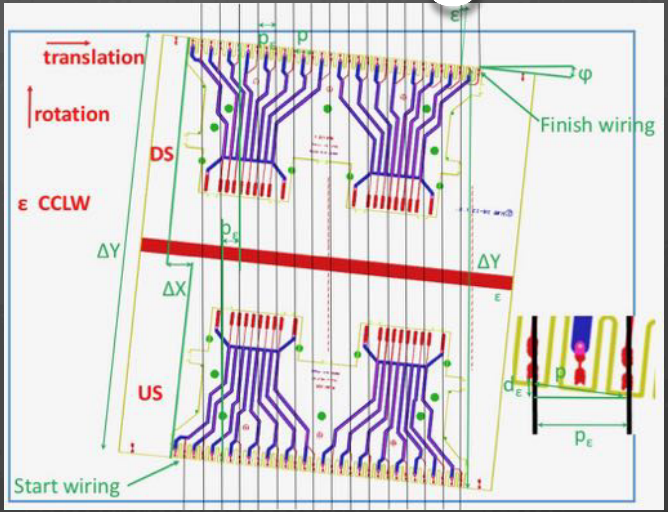


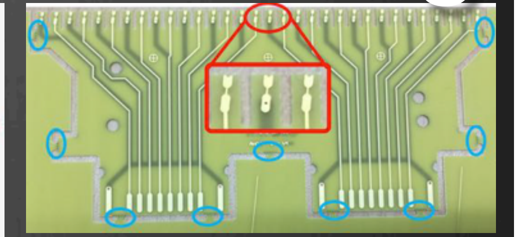
The MEG2 feed-through-less wiring

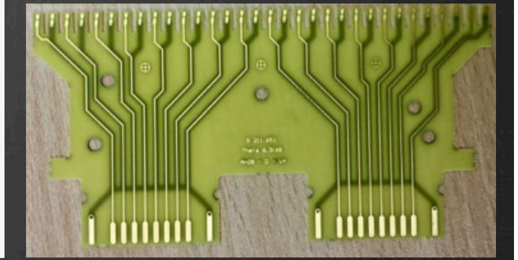


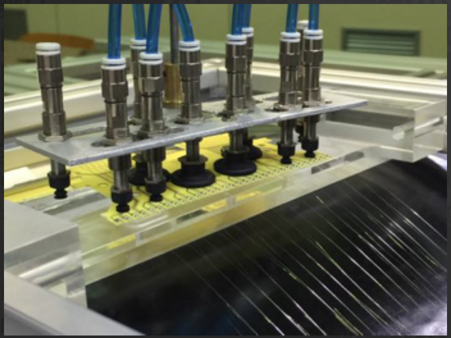
The MEG2 feed-through-less wiring

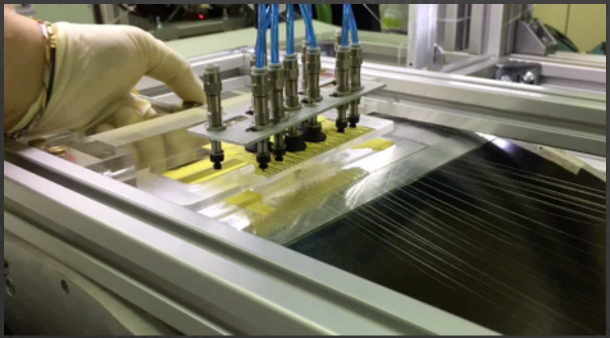


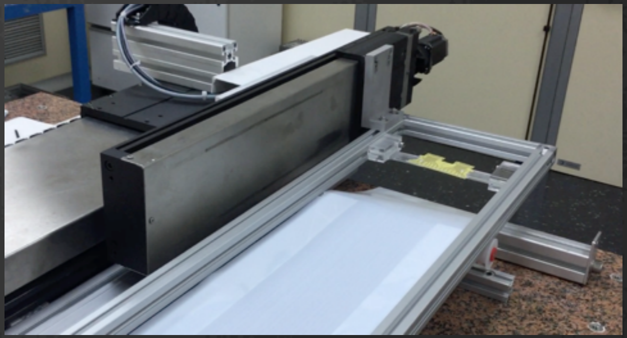










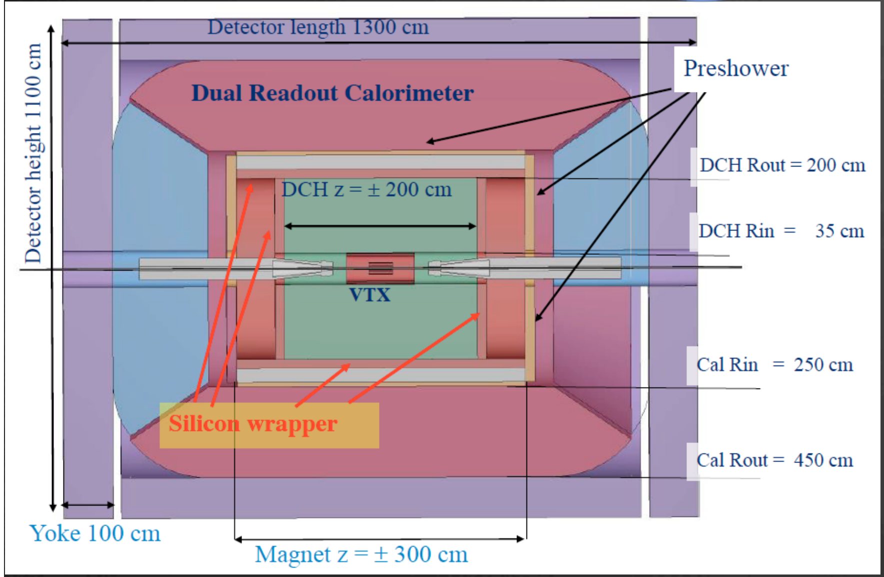


The IDEA Drift Chamber at CEPC and FCC-ee

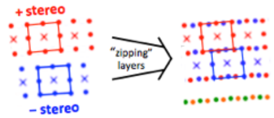
The **IDEA** Detector at

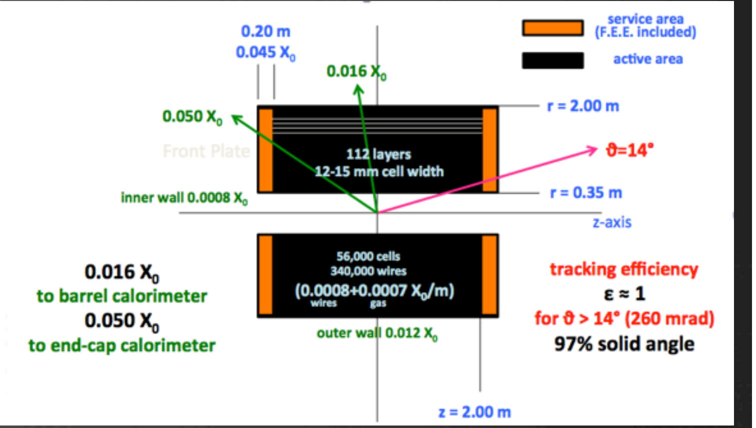
FCC-ee at CERN

CEPC at IHEP-China



The IDEA Drift Chamber





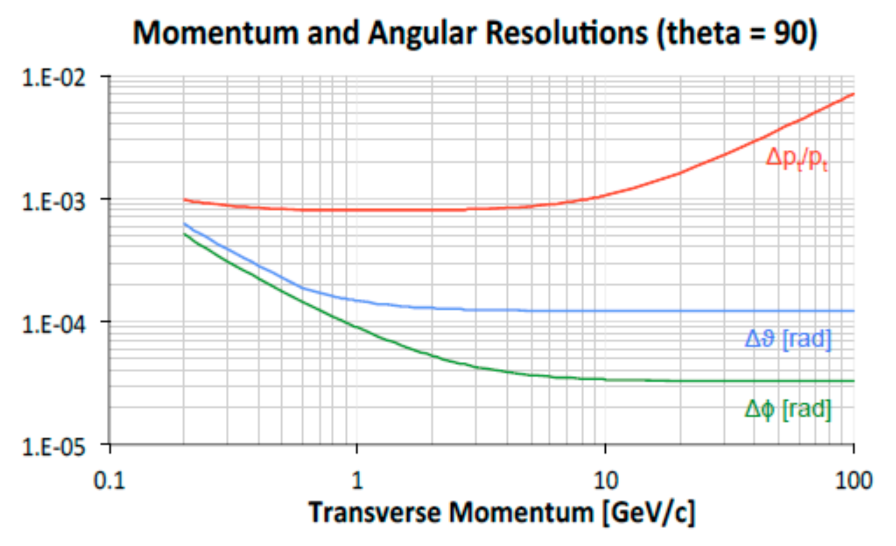
	R_{in} [mm]	R_{out} [mm]	z [mm]
drift chamber	350	2000	±2000
service area	350	2000	±(2000÷2250)

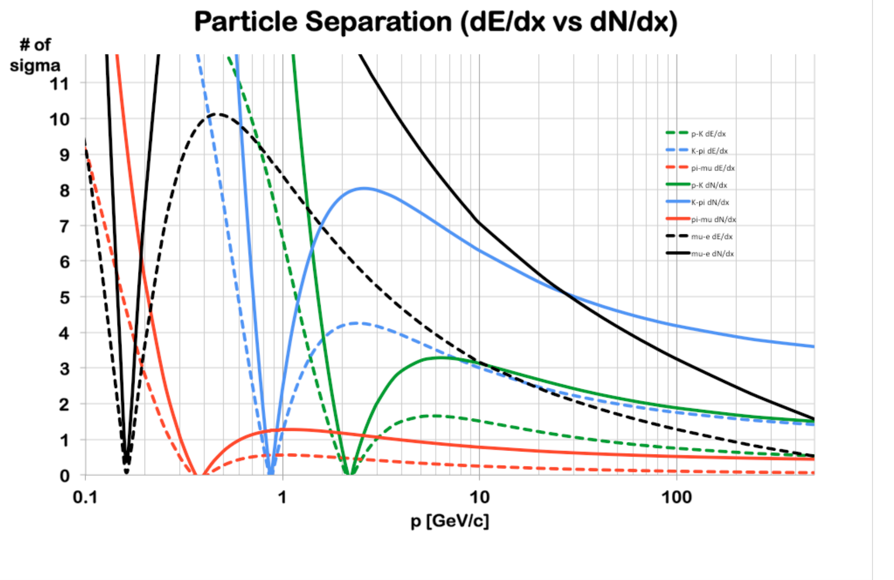
	inner wall	gas	wires	outer wall	service area
thickness [mm]	0.2	1000	1000	20	250
X_0 [%]	0.08	0.07	0.13	1.2	4.5

# of layers	112	min 11.8 mm – max 14.9 mm
# of cells	56448	192 at first layer – 816 at last layer
average cell size	13.9 mm	min 11.8 mm – max 14.9 mm
average stereo angle	134 mrad	min 43 mrad – max 223 mrad
transverse resolution	100 µm	80 µm with cluster timing
longitudinal resolution	750 µm	600 µm with cluster timing

active volume	50 m^3	0.9 He-0.1 iC_4H_{10}
readout channel	112,896	r.o. from both ends
max drift time	400 ns	800 × 8 bit at 2 GHz

The IDEA Drift Chamber Performance


Momentum and Angular Resolutions (theta = 90)


Particle Separation (dE/dx vs dN/dx)

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

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

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

$dE/dx = 4.3\ \%$

$dN/dx = 2.2\ \%$ (at $\varepsilon_N = 80\ \%$)

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_4H_{10}	4.6×10^{-4}
W + 5 Al ➔ Ti + 5 C	**$(13.1 \rightarrow 2.5)\times10^{-4}$**

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)x10^{-3} X/X_0, σ_{xy} = 100 μm, σ_z = 0.8 mm

measurement	multiple scattering (gas + wires + inner wall)

$$\frac{\Delta p_\perp}{p_\perp} = 2.0\times10^{-3},\ \Delta\phi = 0.70\ mrad,\ \Delta\theta = 0.78\ mrad$$

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

$$\frac{\Delta p_\perp}{p_\perp} = 7.8\times10^{-4}\,p_\perp \oplus 1.8\times10^{-3}$$

(7.8 → 6.6 with cluster timing)

$$\Delta\phi = 1.1\times10^{-4} \oplus \frac{6.9\times10^{-4}}{p}$$

$$\Delta\theta = 3.8\times10^{-4} \oplus \frac{6.9\times10^{-4}}{p}$$

TraPId: PId Performance

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

from *Walenta parameterization (1980)*

$L_{track} = 0.6\ m$
$P = 1\ atm$
$n = 64$

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

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

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

from *Poisson distribution*

$L_{track} = 0.6\ m$
$\delta_{cl} = 12.5/cm$

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

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

Summary of performance

	$\frac{\Delta p_t}{p_t}\times 10^3$	at $p_t = 1GeV$	$\frac{dE}{dx}\Big/\frac{dN}{dx}$	
KLOE	$0.5p_t \oplus 2.6$	2.6×10^{-3}	5%	still best world performance
BaBar	$1.3p_t \oplus 4.5$	4.7×10^{-3}	7.5%	
Belle	$2.8p_t \oplus 3.5$	4.5×10^{-3}	6.9%	
BelleII	$1.9p_t \oplus 2.9$	3.5×10^{-3}	6.4%	
BESIII	$2.7p_t \oplus 4.7$	5.1×10^{-3}	$6-7\%$	
Cleo3	$1.0p_t \oplus 9.0$	9.1×10^{-3}	5%	
SCTF (Todyshev)	$2.6p_t \oplus 5.1$	5.7×10^{-3}	7%	
TraPId (this proposal)	$0.78p_t \oplus 1.8$	2.0×10^{-3}	$8.1/3.6\%$	
TraPId (this proposal)	$0.66p_t \oplus 1.4$	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 **$<1.5\times10^{-2}$ 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** with the novel technique adopted for the successful construction of the MEG2 drift chamber

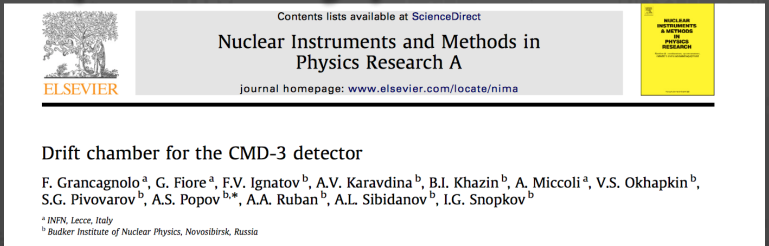
II. **$\Delta p_t/p_t = 2.0\times10^{-3}$, $\Delta\theta = 0.70$ mrad, $\Delta\phi = 0.78$ mrad at $p = 1$ GeV/c.**

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**



Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

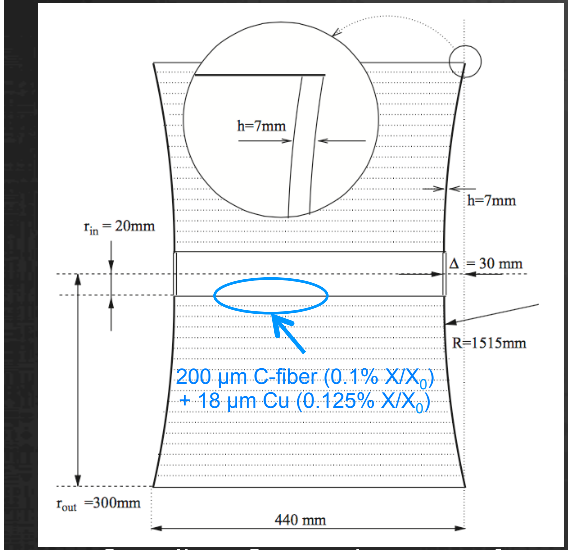
journal homepage: www.elsevier.com/locate/nima

Drift chamber for the CMD-3 detector

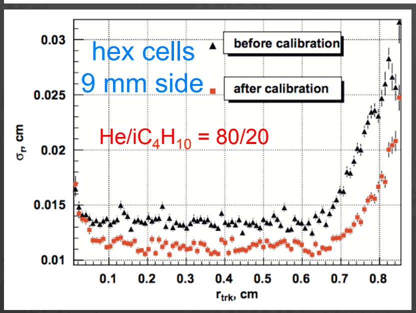
F. Grancagnolo [a], G. Fiore [a], F.V. Ignatov [b], A.V. Karavdina [b], B.I. Khazin [b], A. Miccoli [a], V.S. Okhapkin [b], S.G. Pivovarov [b], A.S. Popov [b,*], A.A. Ruban [b], A.L. Sibidanov [b], I.G. Snopkov [b]

[a] INFN, Lecce, Italy

[b] Budker Institute of Nuclear Physics, Novosibirsk, Russia



200 µm C-fiber (0.1% X/X_0)
+ 18 µm Cu (0.125% X/X_0)



hex cells
9 mm side

He/iC_4H_{10} = 80/20

$\Delta p_t/p_t$ = (1.5 ÷ 4.5) %
p = 100-1000 MeV/C

$\Delta\vartheta$ = 20 mrad

$\Delta\varphi$ = 3.5-8 mrad

$\Delta(dE/dx)/(dE/dx)$ = (10-13)%

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%