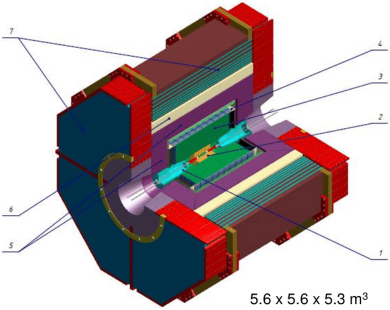
BINP R&D on DC with hexagonal cell

DC group of BINP

BINP

The outline

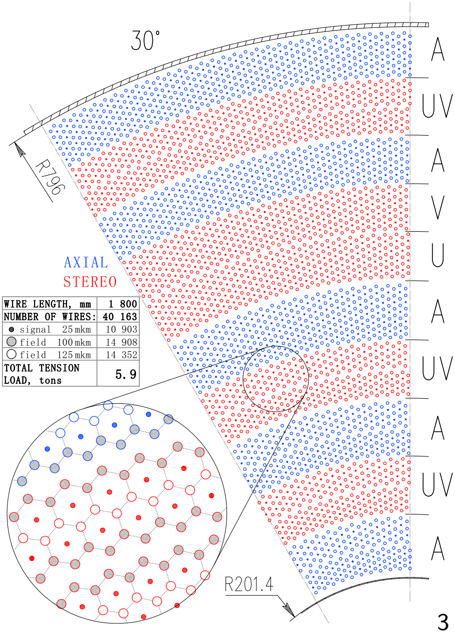
- The Drift Chamber
- The wires
- Geometry optimization
- Momentum resolution
- The small prototype of DC
- Summary



1. Vacuum pipe
2. Inner tracker
3. Drift chamber
4. PID
5. Calorimeter
6. SC magnet
7. Muon system

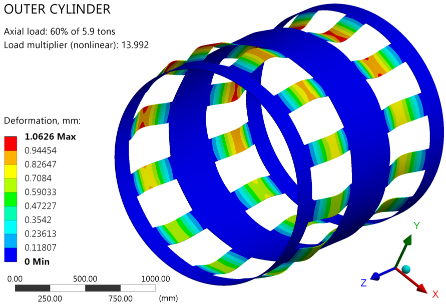
The Drift Chamber

- Shape - hexagonal
- 41 layer are divided into 10 superlayers
- Average radius $\sim$ 7 mm
- Gas mixture - $He/C_3H_8 - 60/40$
- Gas gain $\sim 4 * 10^4$
- Voltage $\sim$ 2200 V
- Drift time $\sim$ 350 - 400 ns
- $\sigma \sim$ 90 μm
- $\frac{\sigma_{dE/dx}}{dE/dx} \sim$ 7 %



The outer tube

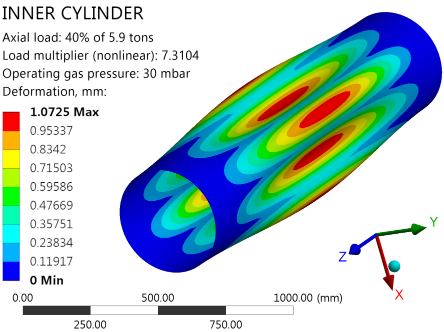
- To facilitate the wiring the outer tube is provided with 24 windows
- The outer tube has a cylindrical shape (CFRP material)
- The wall thickness is 4.5 mm ($X/X_0 = 2.1\%$)
- The load of wire tension 3.54 tons (maximum deformation is about 80 μm)
- Stability safety factor is about 14



The outer tube simulated in ANSYS

The inner tube

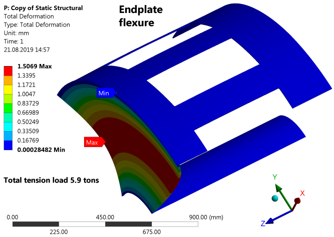
- The inner tube of CFRP has a cylindrical shape
- The wall thickness is 0.9 mm ($X/X_0 = 0.46\%$)
- The load of wire tension is about 2.36 tons (maximum deformation is about 20 μm)
- Stability safety factor is 7.3



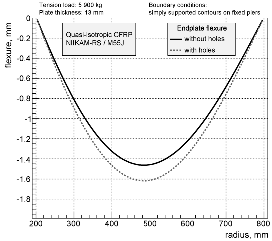
The inner tube simulated in ANSYS

The endplate

- Holes drilled in the endplate result in an increase in flexure of about 10 %
- Endplate is flat
- The thickness is 13 mm (material CFRP, $X/X_0 = 5.9\%$)
- The full load is about 5.9 tons (maximum deformation is about 1.6 mm)

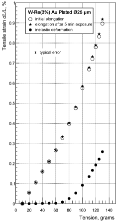


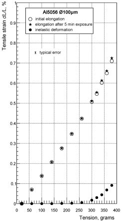
The endplate simulated in ANSYS

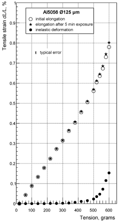


Endplate deformation as a function of radius

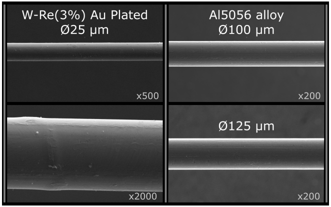
- Anode wire - 25 μm in diameter W-Re(3%) Au Plated (tension $\sim$ 60 g)
- Two type of cathode wires - 125 (tension $\sim$ 220 g) and 100 μm Al (tension $\sim$ 140 g)
- Anode wire has been made in LUMA (Sweden)
- Cathode wires have been made in Danyang Litong Cable Technology Co.,Ltd (LT Cable Technology, China)
- Mechanical tests have been made



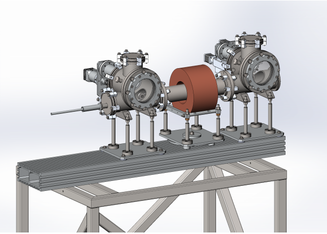




Mechanical tensile testing of wire



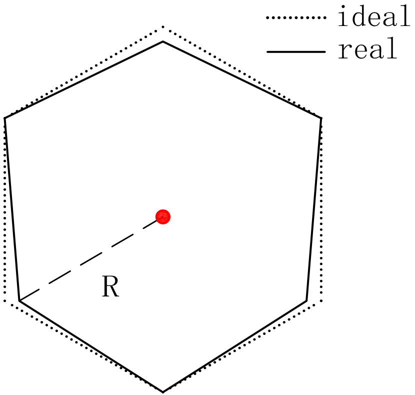
Wires



Project of cylindrical magnetron sputtering apparatus

Optimization of cell structure

- Due to imperfections of hexagonal shape ⇒ deviation of the electric field from cylindrical symmetry at the wire
- Solution ⇒ cells structure optimization

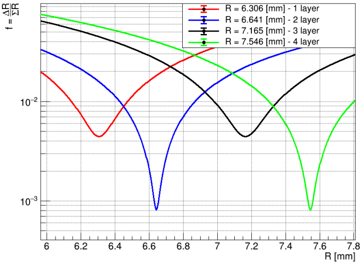


Distortion of cells from hexagonal shape

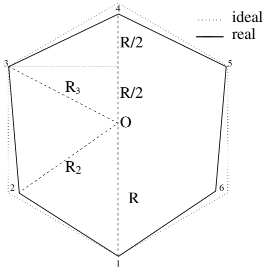
Wire structure optimization

- The development of cell structure was carried out sequentially layer by layer. The wire positions in the cell were optimized for each layer:

$$f = \frac{\sqrt{(R-R_2)^2+(R-R_3)^2+(R_2-R_3)^2}}{R+R_2+R_3}$$



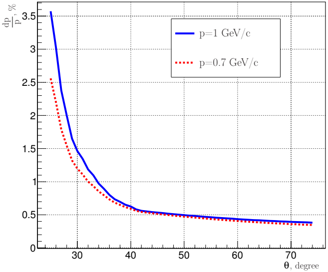
Dependence of f as a function of R for the first superlayer



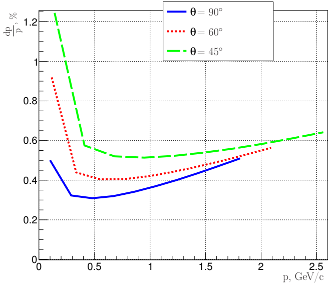
Definition R, R_2, R_3

Momentum resolution

The toy simulation of pions flight through DC was performed;



Momentum resolution as a function of polar angle



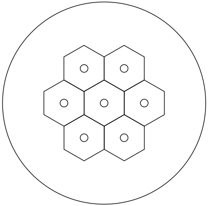
Momentum resolution as a function of full momentum

dE/dx resolution $\sigma_{dE/dx} \sim 7\%$ was estimated from CLEO dE/dx resolution and comparable with Belle(6.9%) and BaBar(7.5%)

The article has been published:
https://doi.org/10.1016/j.nima.2021.165490

The small prototype of DC

- Diameter - 70 mm
- Length - 300 mm
- 7 hexagonal cells
- Measurements of spatial resolution and aging tests are planned there
- The trigger consists of two aerogel scintillation counters
- Has been tested on cosmic rays



Layout of cells in the prototype

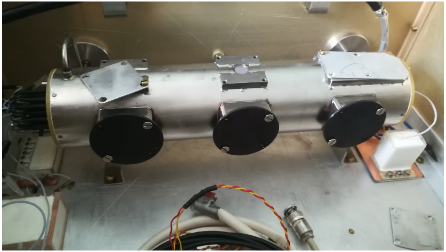


Photo of the Prototype

Photo of the scintillation counters

Summary

- The MC simulation has been done
- The preliminary calculation of the DC construction has been completed in ANSYS
- Mechanical tests have been carried out
- The article about the DC has been published in NIM

In the near future we plan:

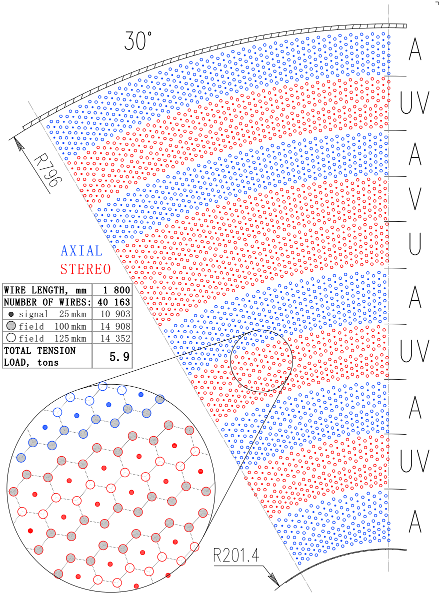
- To perform aging tests on wire samples on the small prototype
- To perform spatial resolution measurements on the small prototype
- The full size drift chamber prototype creation ($\sim$ 150 cells, 3 superlayers)

THANK YOU FOR YOUR ATTENTION!

BACKUP

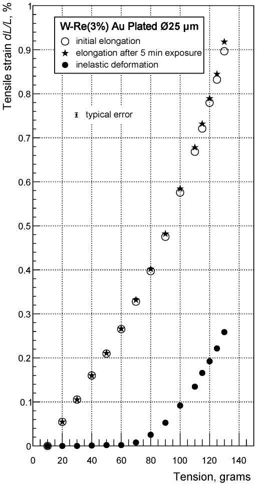
Drift Chamber

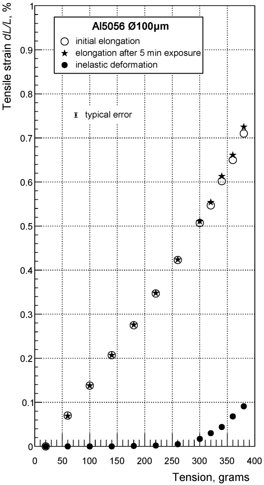
SUPER LAYER NUMBER	NUMBER OF MONO-LAYERS	NUMBER OF CELLS IN MONOLAYER	NUMBER OF CELLS	STEREO ANGLE, mrad	CELL SIZE r	± Δr, mm	RADIUS OF ANODE WIRE LAYER, mm
1	4	125	500	0	6.306	0.034	217.306
					6.644	0.007	227.100
					7.165	0.039	246.906
					7.549	0.009	258.035
2	4	157	628	+ 33.8	6.473	0.028	280.154
					6.747	0.006	290.136
				− 34.2	7.182	0.031	310.863
					7.486	0.007	321.938
3	4	189	756	0	6.564	0.024	341.986
					6.794	0.005	352.060
					7.140	0.026	371.992
					7.388	0.005	382.950
4	4	223	892	+ 48.9	6.603	0.020	405.941
					6.799	0.004	416.040
				− 49.3	7.104	0.021	436.741
					7.314	0.005	447.606
5	5	255	1275	0	6.651	0.018	467.570
					6.823	0.003	477.718
					6.968	0.001	488.097
					7.120	0.001	498.701
					7.274	0.001	509.535
6	4	287	1148	+ 63.1	6.741	0.016	533.350
					6.895	0.004	543.615
					7.026	0.001	554.088
					7.161	0.001	564.762
7	4	313	1252	− 63.4	6.778	0.015	584.801
					6.919	0.003	595.108
					7.039	0.001	605.606
					7.163	0.001	616.289
8	4	341	1364	0	6.768	0.014	636.220
					6.898	0.003	646.501
					7.007	0.001	656.957
					7.121	0.001	667.581
9	4	371	1484	+ 64.7	6.746	0.013	689.948
					6.865	0.003	700.185
				− 65.0	7.041	0.013	720.090
					7.165	0.002	730.775
10	4	401	1604	0	6.791	0.012	750.730
					6.902	0.003	761.027
					6.995	0.001	771.472
					7.091	0.001	782.061
TOTAL	41		10903				

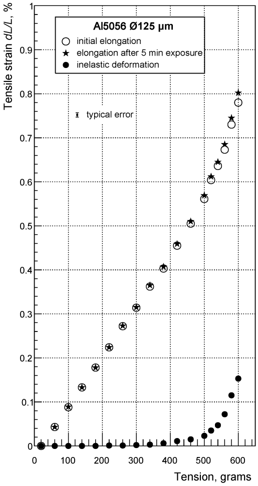


WIRE LENGTH, mm	1 800
NUMBER OF WIRES:	40 163
● signal 25 mkm	10 903
field 100 mkm	14 908
○ field 125 mkm	14 352
TOTAL TENSION LOAD, tons	5.9

Wires tests







Mechanical tensile testing of wire

Wires properties

	W-Re(3%) Au Plated 25 µm in dia.	**Al5056 alloy 100 µm in dia.**	**Al5056 alloy 125 µm in dia.**
Manufacture Date	2019-04-03	2019-06	2019-06
Wire Type	861/67	-	-
Diameter (rating)	25 microns	100 microns	125 microns
Diameter Tolerance (±)	2%	2 microns	2 microns
Straightness grade	1	-	-
Ovality	2%	-	-
Measured Properties*:			
Diameter, microns	25.0 ± 0.2	102 ± 1	126 ± 1
Linear Density**, mg/m	9.4	21.6	32.9
Yield Strength, g	65 ± 5	240 ± 20	360 ± 20
Young's Modulus, GPa	381 ± 1	70 ± 2	70 ± 2
Tensile Strength, g	140 ± 5	400 ± 20	600 ± 20
Elongation (before breaking), %	> 0.92	> 0.72	> 0.8
*Based on samples taken from the first 10 meters of wire length on the spool.			
**Calculated mean value using the material density from the specification.			

Similar experiments

Characteristics	Detector				
	CLEOIII	BaBar	BESIII	BelleII	SCTF
B,T	1.5	1.5	1.0	1.5	1.5
N_{cells}	9796	7104	6796	14336	10903
Shape	Square	Hex.	Square	Square	Hex.
Anode wire d, mkm	W 20	W 20	W 25	W 30	W-Re(3 %) 25
Field wire d, mkm	Al 110	Al 120	Al 110	Al 126	Al 100, 125
Size mm × mm	14×14	18×12	12×12 16×16	7×7 10×10	$\sim 14 \times 14$
Gas mixture	He/C_3H_8 60/40	He/iC_4H_{10} 80/20	He/C_3H_8 60/40	He/C_2H_6 50/50	He/C_3H_8 60/40
V_{anode}, B	1900	1930	2200	2300	2200
T/D, ns/mm	$\sim 300/7$	$\sim 500/9$	$\sim 350/8$	$\sim 350/8$	$\sim 350/7$
σ, μm	110	120	120	~ 120	~ 90

Gas mixtures

Gas mixture	Ratio	X_0, m	N_p, $\frac{1}{\text{cm}}$	V_{dr}, $\frac{\text{cm}}{\mu\text{s}}$	D_l, $\frac{\mu\text{m}}{\sqrt{\text{cm}}}$	Experiment
He/iC_4H_{10}	80/20	807	21.2	2.79	141	BaBar
He/iC_4H_{10}	90/10	1313	12.7	2.31	162	Kloe
He/C_3H_8	60/40	569	31	3.06	133	CLEOIII BESIII
He/C_2H_6	50/50	686	22.9	3.52	142	Belle BelleII
He/CH_4	80/20	3087	7	2.54	172	Kloe
Ar/C_2H_6	50/50	178	34	5.27	143	CLEOII
He/DME	70/30	678	21	1.12	123	-

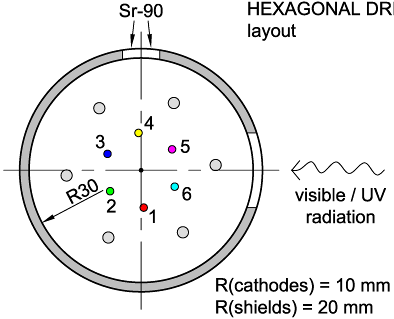
Characteristics of different gas mixtures at B = 0 T, E = 1 kV/cm

Stereo layers

SCTF		BELLE II		BaBar		BES III	
R mm	α_{stereo} mrad	R mm	α_{stereo} mrad	R m	α_{stereo} mrad	R mm	α_{stereo} mrad
280.154	$+33.8$	257.0	$+45.4$	–	–	327.5	-30.68
290.136	-34.2	348.0	$+45.8$	318.5	$+44.9$	334.1	-31.31
405.941	$+48.9$	–	–	370.5	-52.3	402.1	$+31.41$
416.040	-49.3	476.9	-55.3	480.8	$+55.6$	415.5	$+32.46$
533.350	$+63.1$	566.9	-64.3	533.2	-62.8	531.7	-42.06
584.801	-63.4	–	–	–	–	583.0	$+40.37$
689.948	$+64.7$	695.3	$+63.1$	643.0	$+65.0$	676.3	-41.62
730.775	-65.0	785.3	$+70.0$	695.2	-72.1	–	–

Aging tests. Wire arrangement

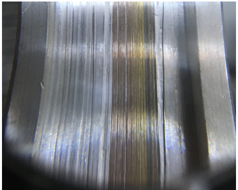
HEXAGONAL DRIFT CELL
layout



R(cathodes) = 10 mm
R(shields) = 20 mm

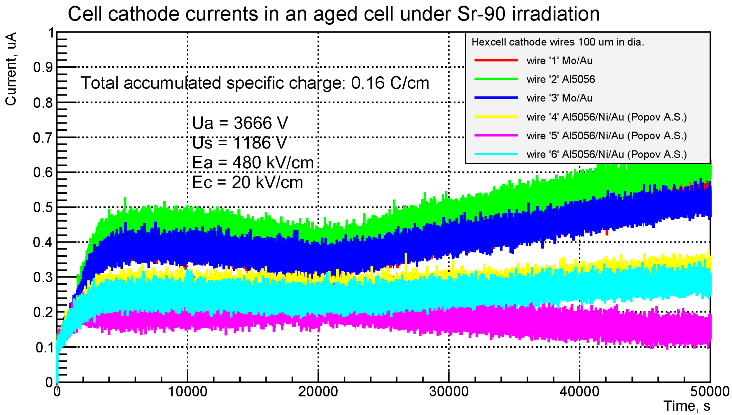
Anode	•	20 um WRe20/Au
Cathodes	● (red)	100 um Al5056 or Mo/Au
	● (green)	100 um Al5056
	● (blue)	100 um Al5056 or Mo/Au
	● (yellow)	100 um Al5056/Ni/Au
	● (magenta)	100 um Al5056/Ni/Au
	● (cyan)	100 um Al5056/Ni/Au
Shields	○	150 um Ti/Cu/Au

- Anode wire is strained in the center of the chamber.
- High voltages of positive polarity are applied to the anode and shield wires.
- The cathode wires are grounded.
- In one study three bare (Al5056 unplated) cathode wires were strained, in another study - only one wire, while two neighboring ones were replaced by reference gold-plated wires (Mo/Au).



Al5056/Ni/Au 100 um in dia.

Aging tests. Results



- The time dependence (increase) of currents after irradiation of the cell with a dose of 0.16 C/cm is shown.
- The current on the middle gold-plated (cathode '5') wire is more than 2 times less than on the unplated one (cathode '2').