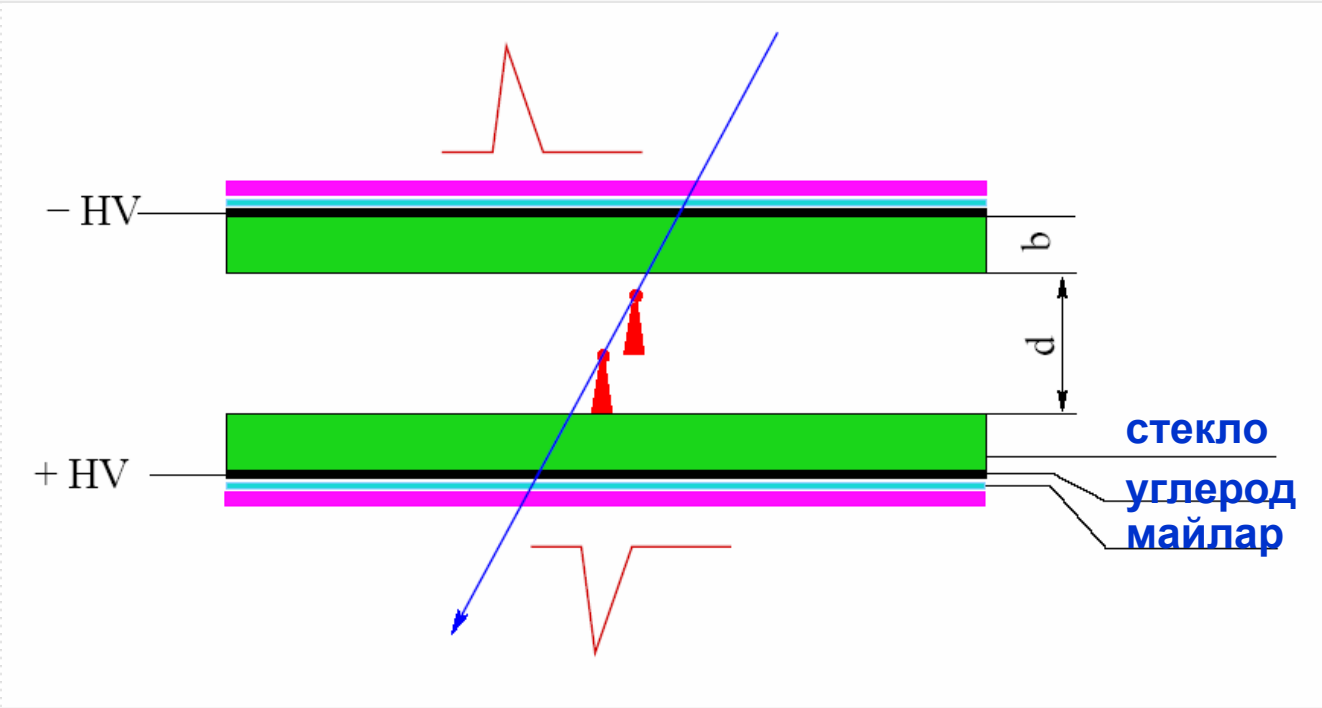
Resistive Plate Chamber (RPC) for TOF measurements

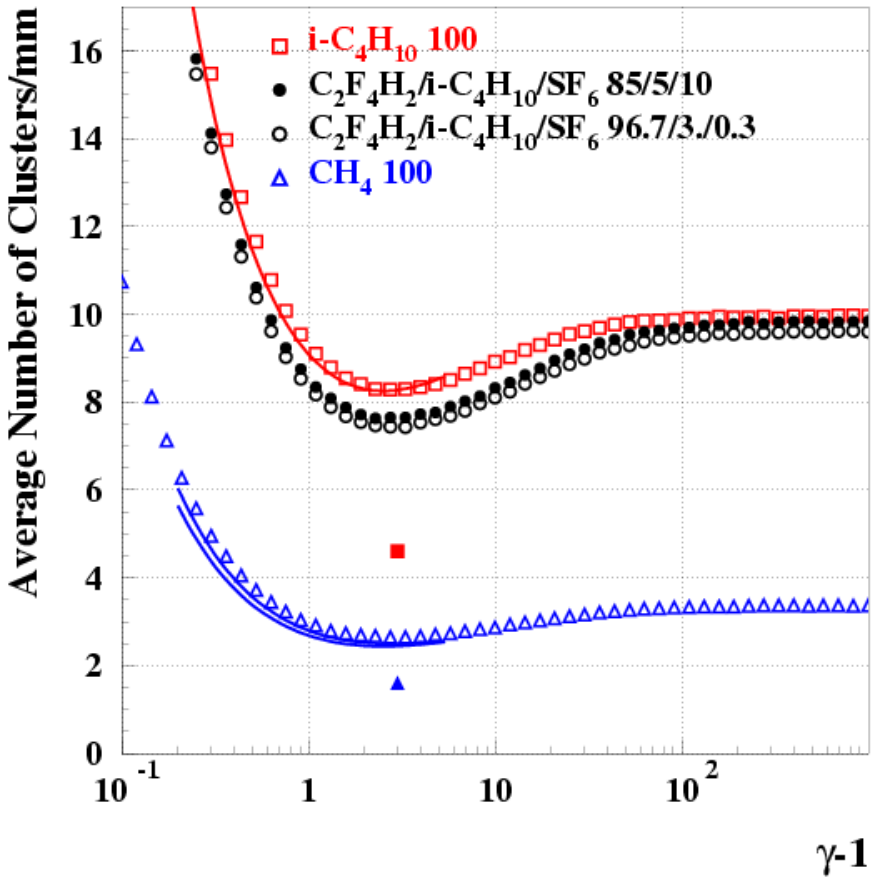
- Физические процессы
- газовые смеси
- конструкция
- основные характеристики (временное разрешение, загрузки, эффективность..)
- старение
- R3B

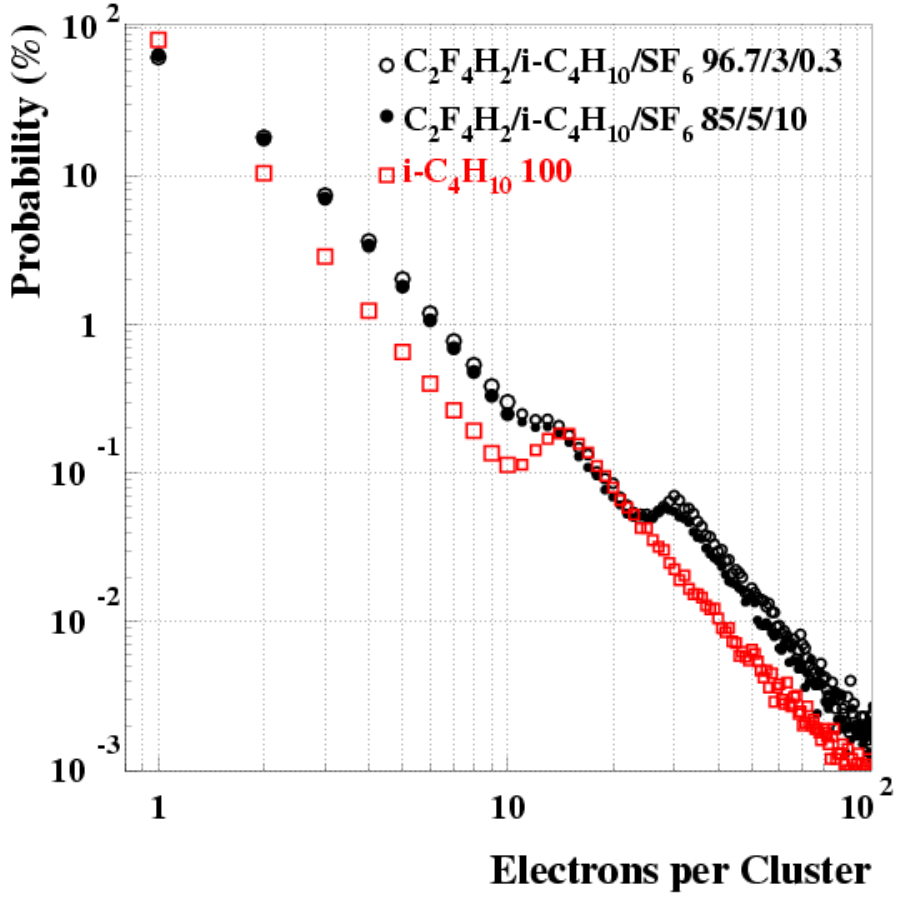
Resistive Plate Chambers



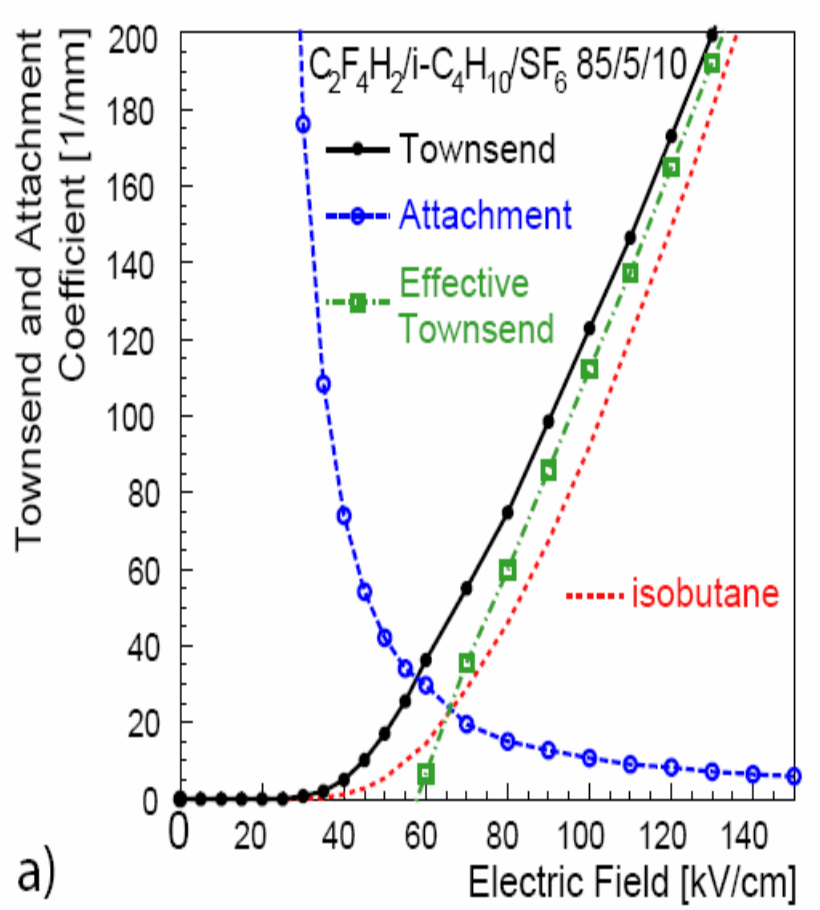
$\rho \sim 10^{10} - 10^{13}\ \Omega^*cm$

Первичная ионизация





Лавина



$$N(t) = N_0 e^{(\alpha-\eta)\upsilon\circ t}$$

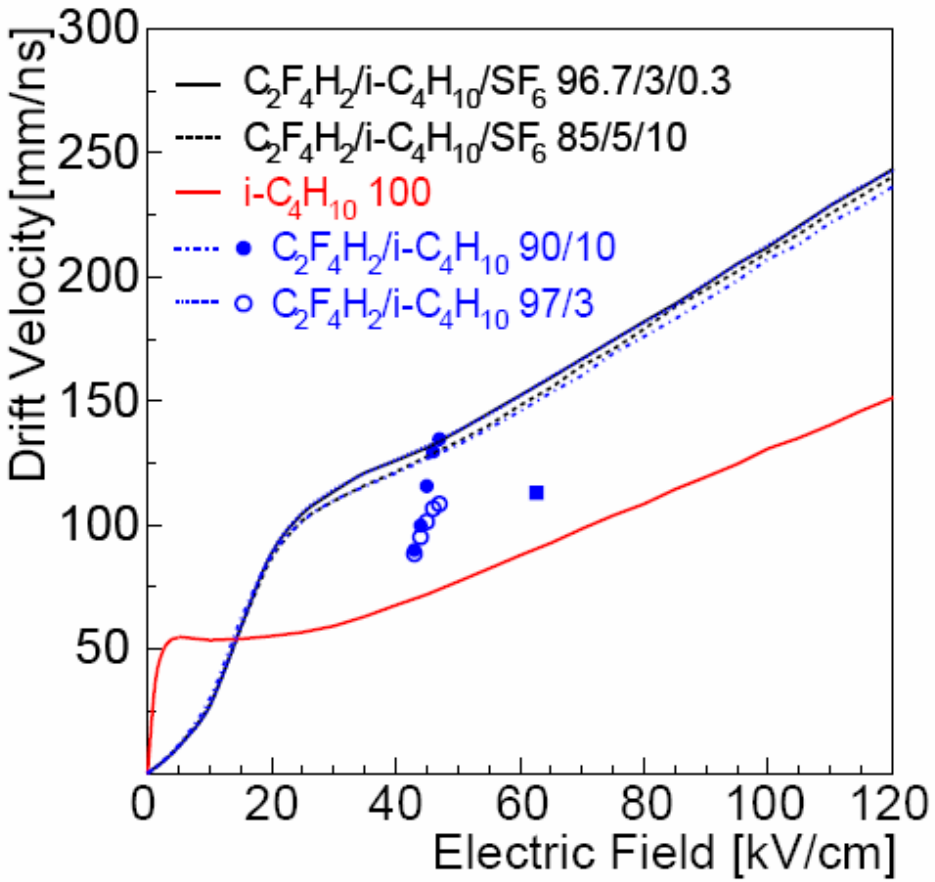
N_0 - Число электронов в кластере

α - Townsend коэффициент

η - attachment коэффициент

υ - скорость дрейфа

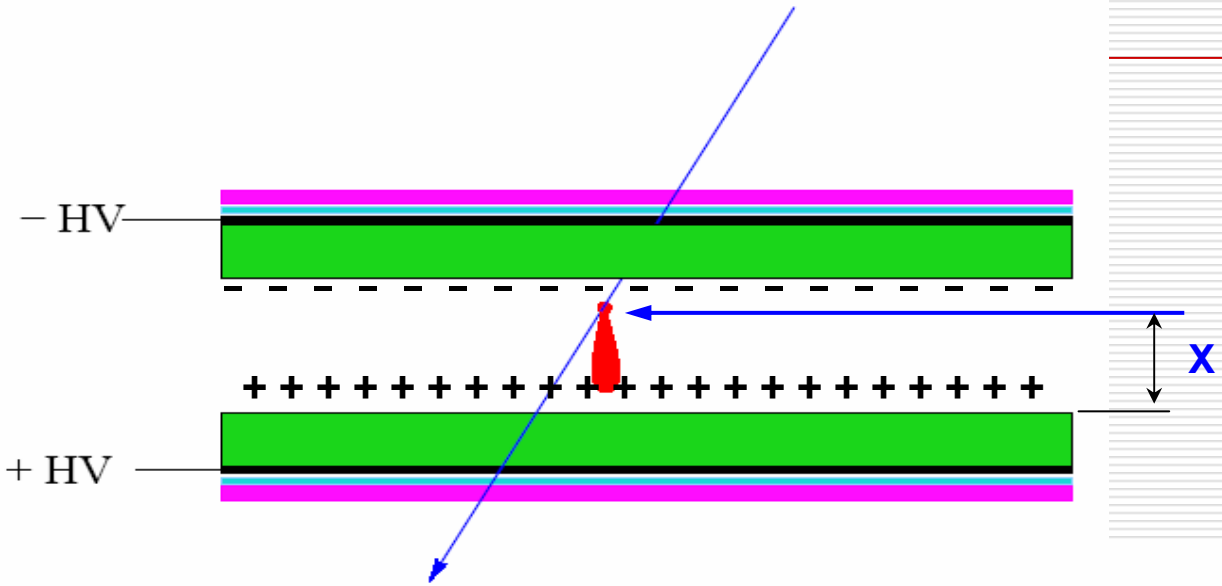
Скорость дрейфа



0.3mm Timing RPCs, 100 kV/cm:

υ **= 210 μm/ns**

Заряд



$$Q_{tot}(t) = q_e N_e(t)$$

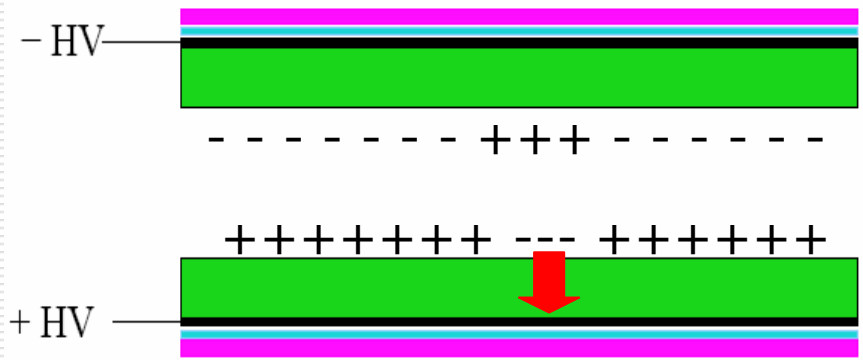
$$= q_e N_0 e^{(\alpha-\eta)x}$$

$$Q_{anode} = Q_{tot} e^{-t/\tau}$$

$$\tau = \rho \varepsilon_0 \varepsilon_r$$

$\rho = 10^{12}\,\Omega\,cm$, τ =1 сек

$S \sim 0.1 cm^2$



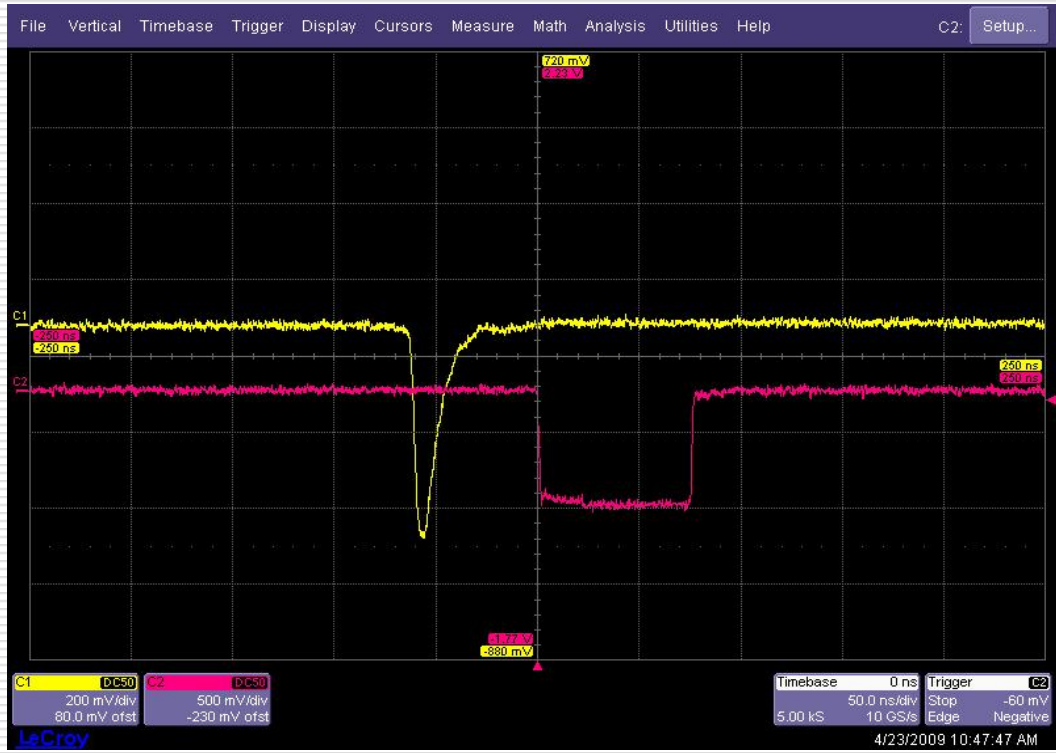
Индуцированный сигнал

$$i(t) = \frac{\varepsilon_r}{2b + d\varepsilon_r} \upsilon q_e N_e(t)$$

ε_r - диэлектрическая проницаемость стекла

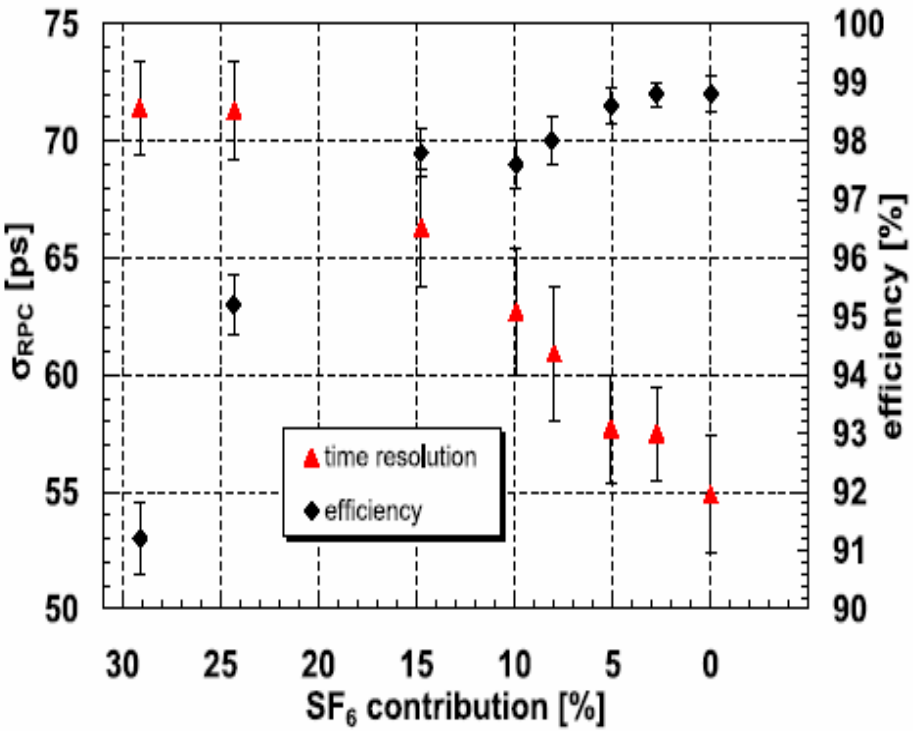
b – толщина стекла

d - величина газового зазора



Газовая смесь

FS6 contamination



«стандартная» газовая смесь:

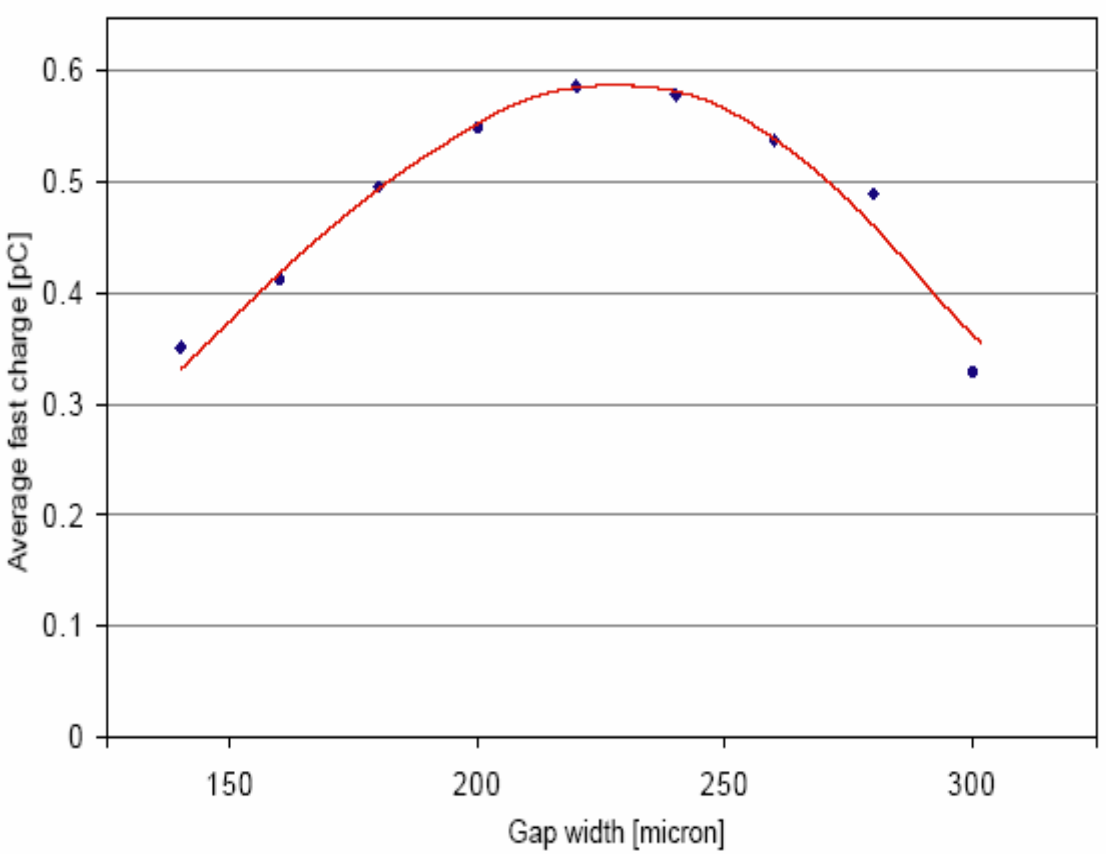
Тетрафторэтан $C_2H_2F_4$

Изобутан $i\text{-}C_4H_{10}$

Гексафторит серы SF_6

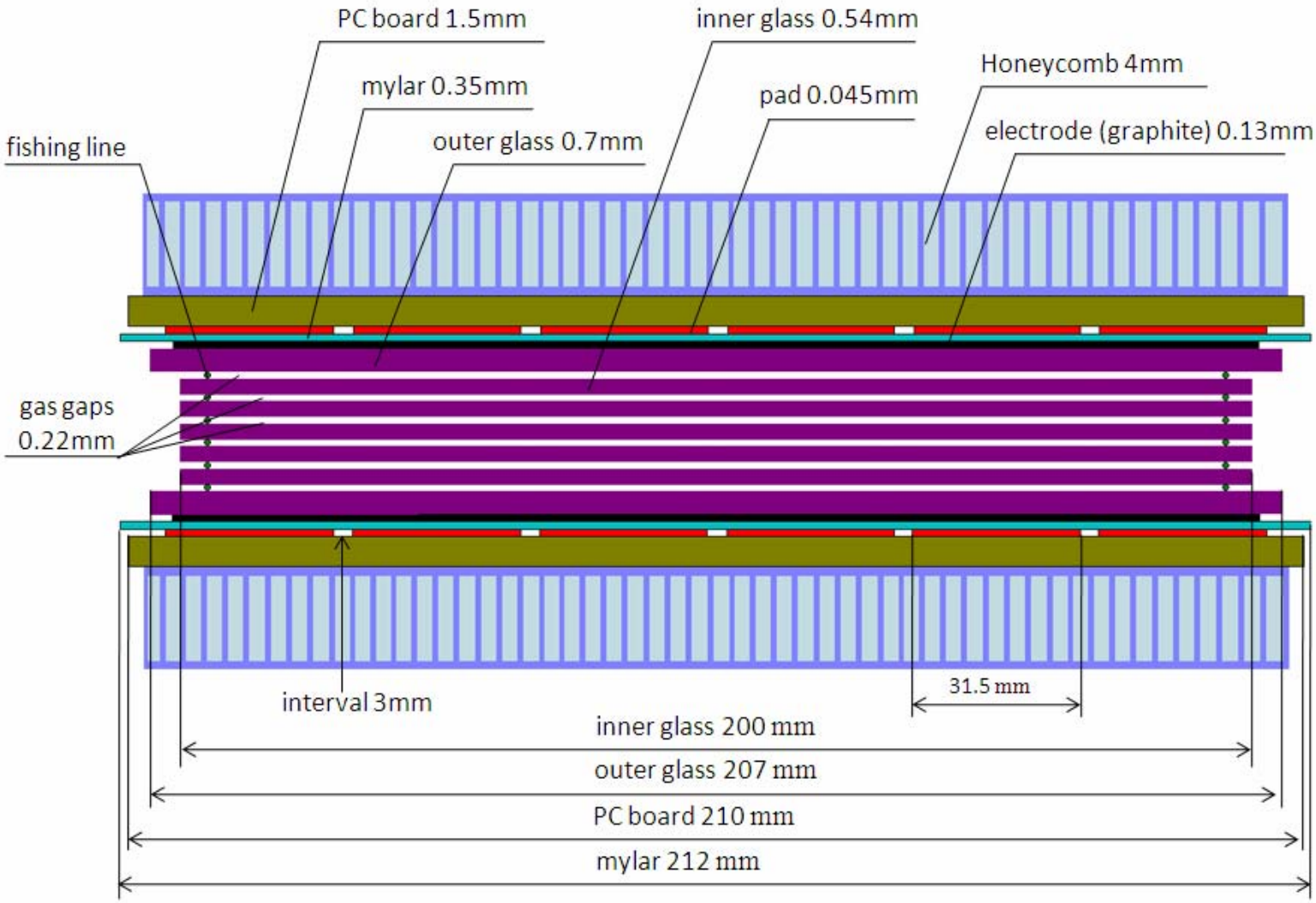
Пропорции ~ 96.7:3:0.3 %

Gap width

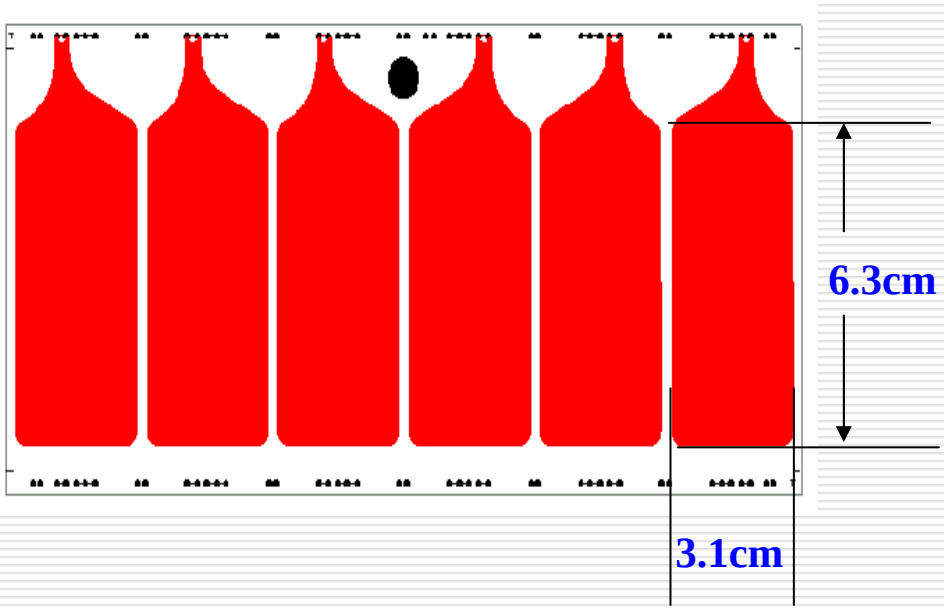


Оптимальный зазор – 220-250 μm

STAR-type CBM prototype MRPC



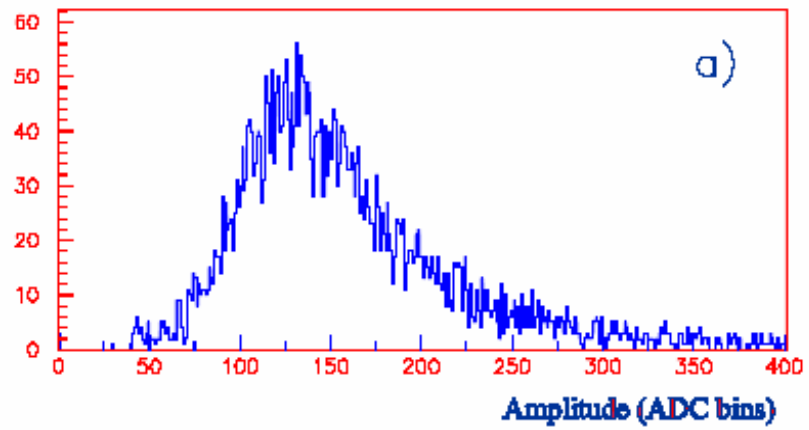
STAR-type CBM prototype MRPC

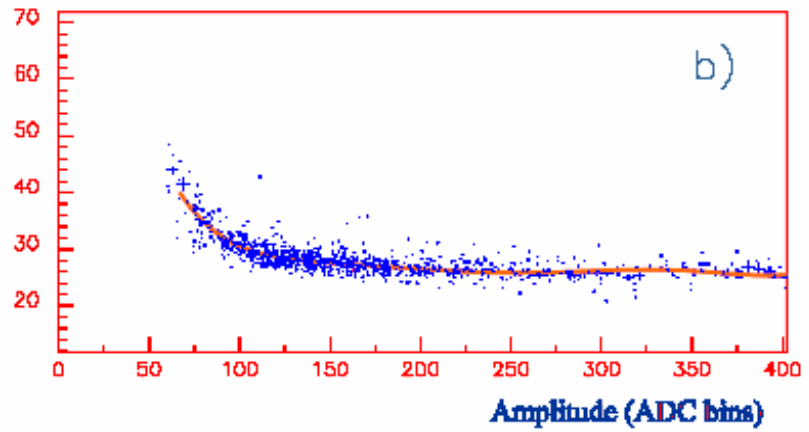


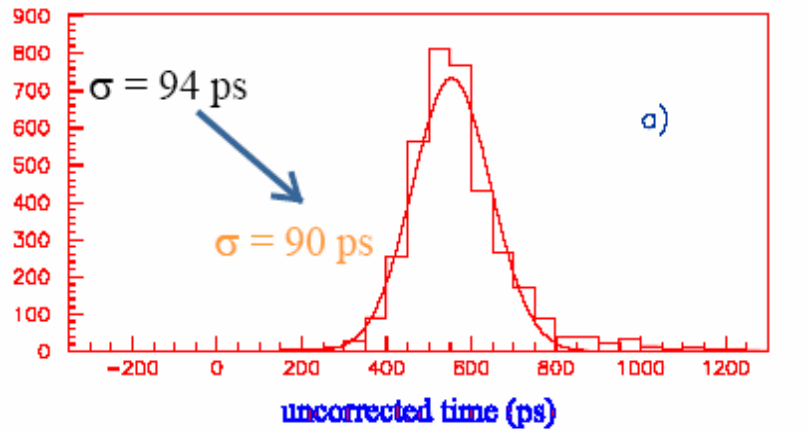
- Glass: $\sim 4 \times 10^{12} \Omega$.cm
- Gas gap: 6×0.22mm
- Working gas: 95% F134a+5% iso-butane
- Time resolution: ~70ps
- Efficiency >95%
- Rates capability: <500Hz/cm2

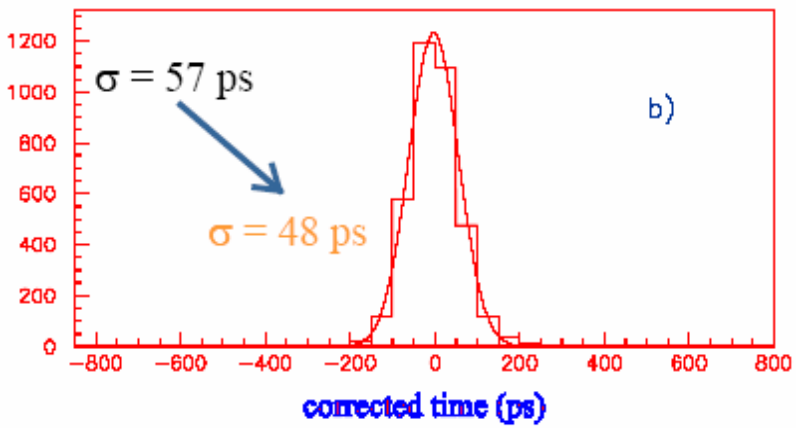
→ noise < 30 Hz/channel (pad 20cm^2)
→ dark current < 7 nA/module (140cm^2) was measured.

ADC-TDC correction



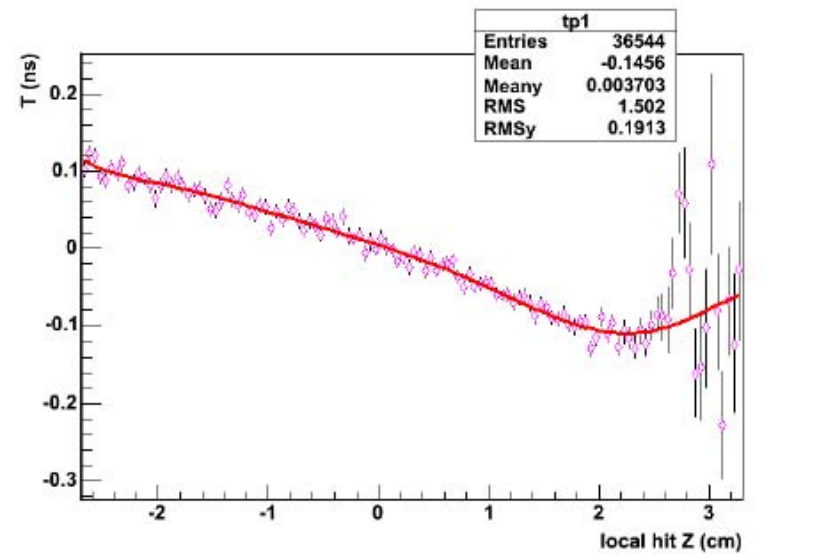




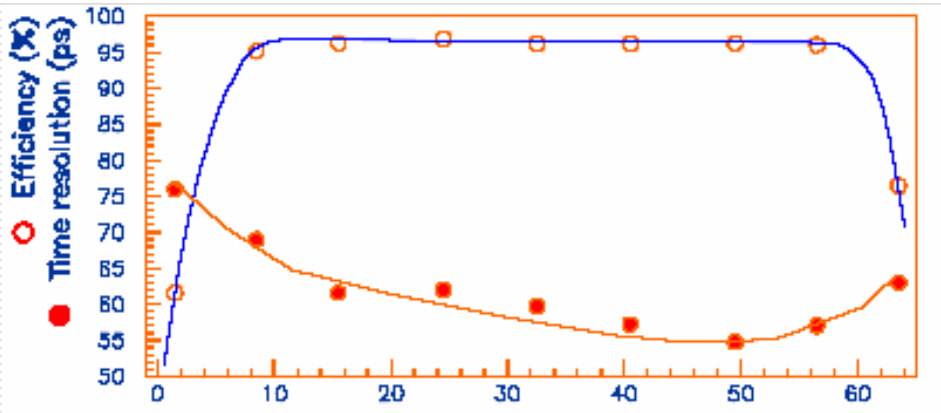


Hit dependence

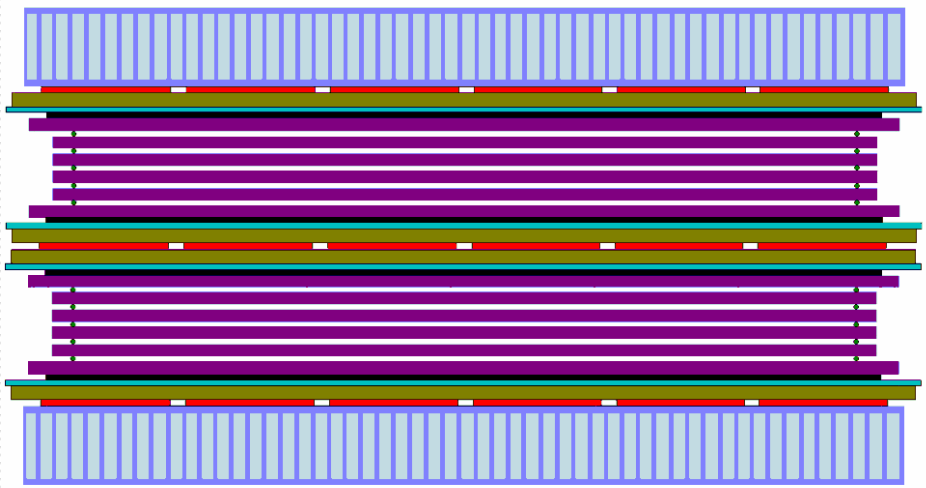
Time – hit position

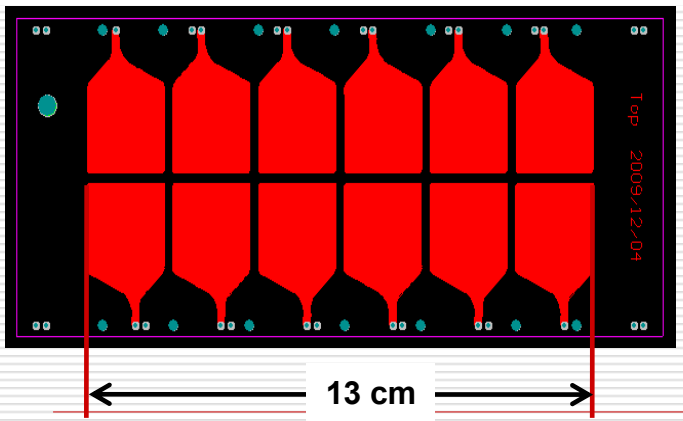


Efficiency & TOF resolution
vs
hit position

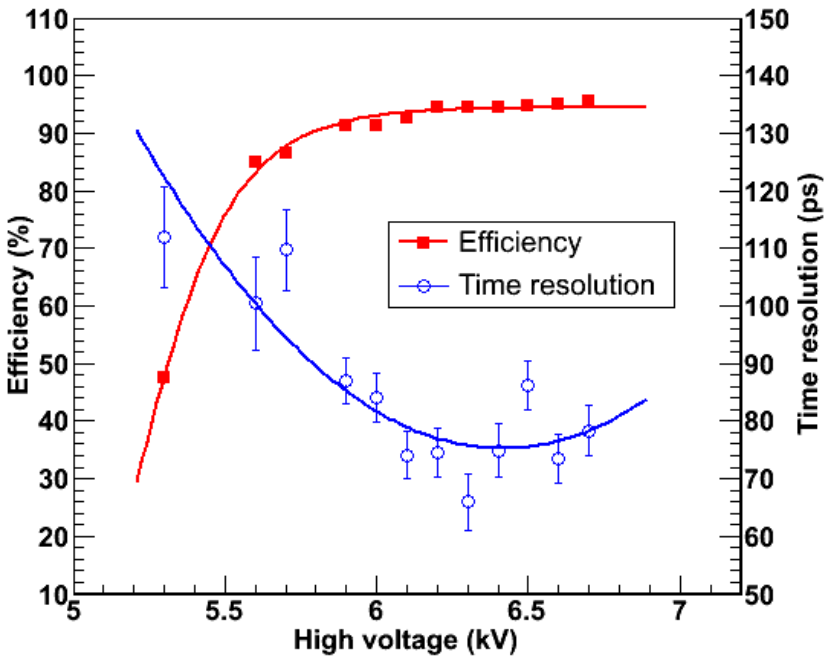


CBM prototype (High rate MRPC)

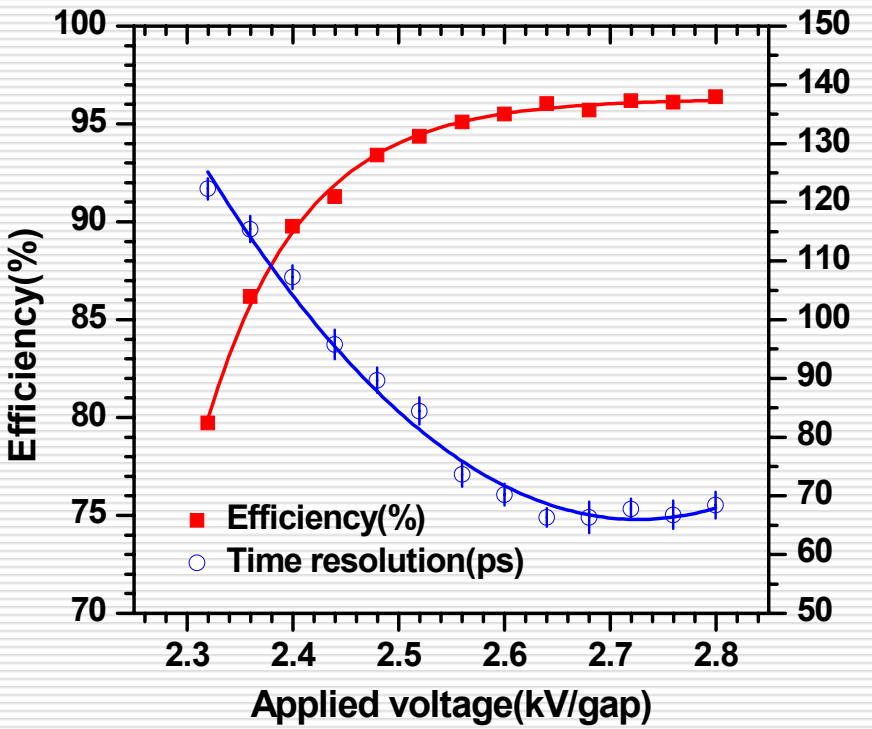




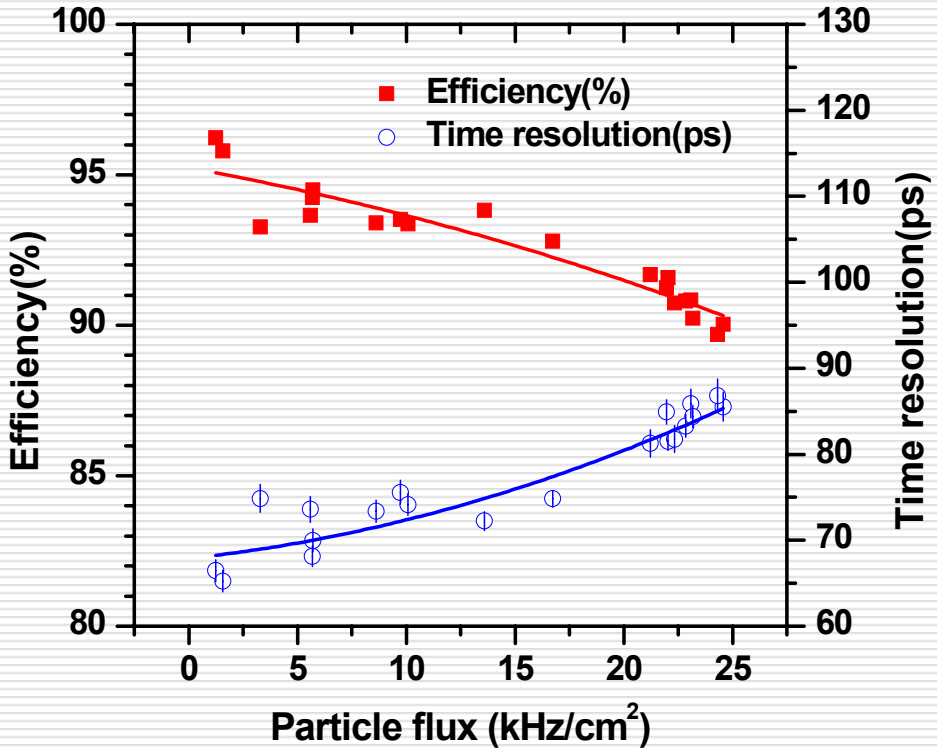
Number of gaps: 10x0.25mm
Glass thickness: 0.7mm
resistivity: ~10^{10}Ω.cm
Gas mixture: Freon/iso-butane/SF6
92 / 3/ 5%



Performance of high rate MRPC

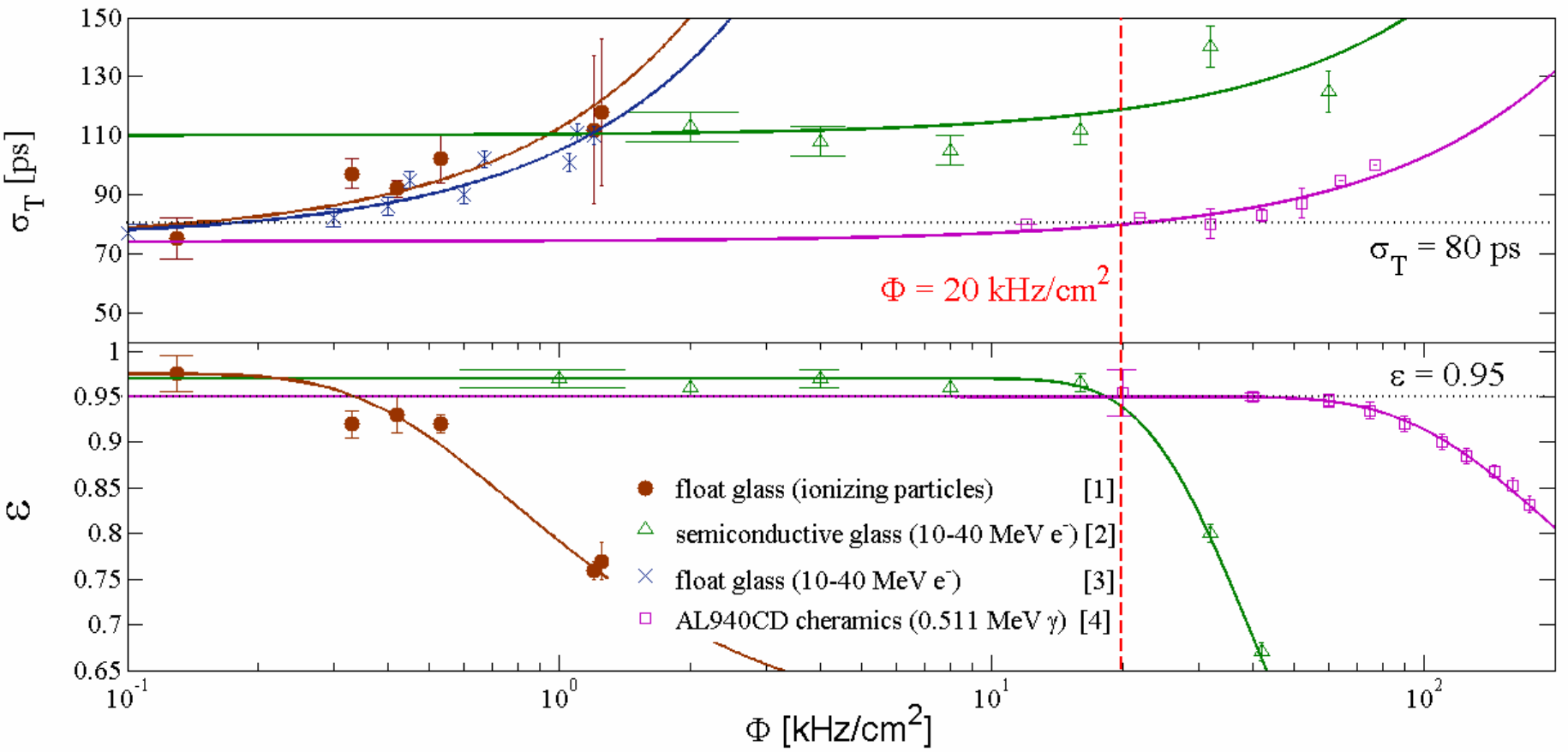


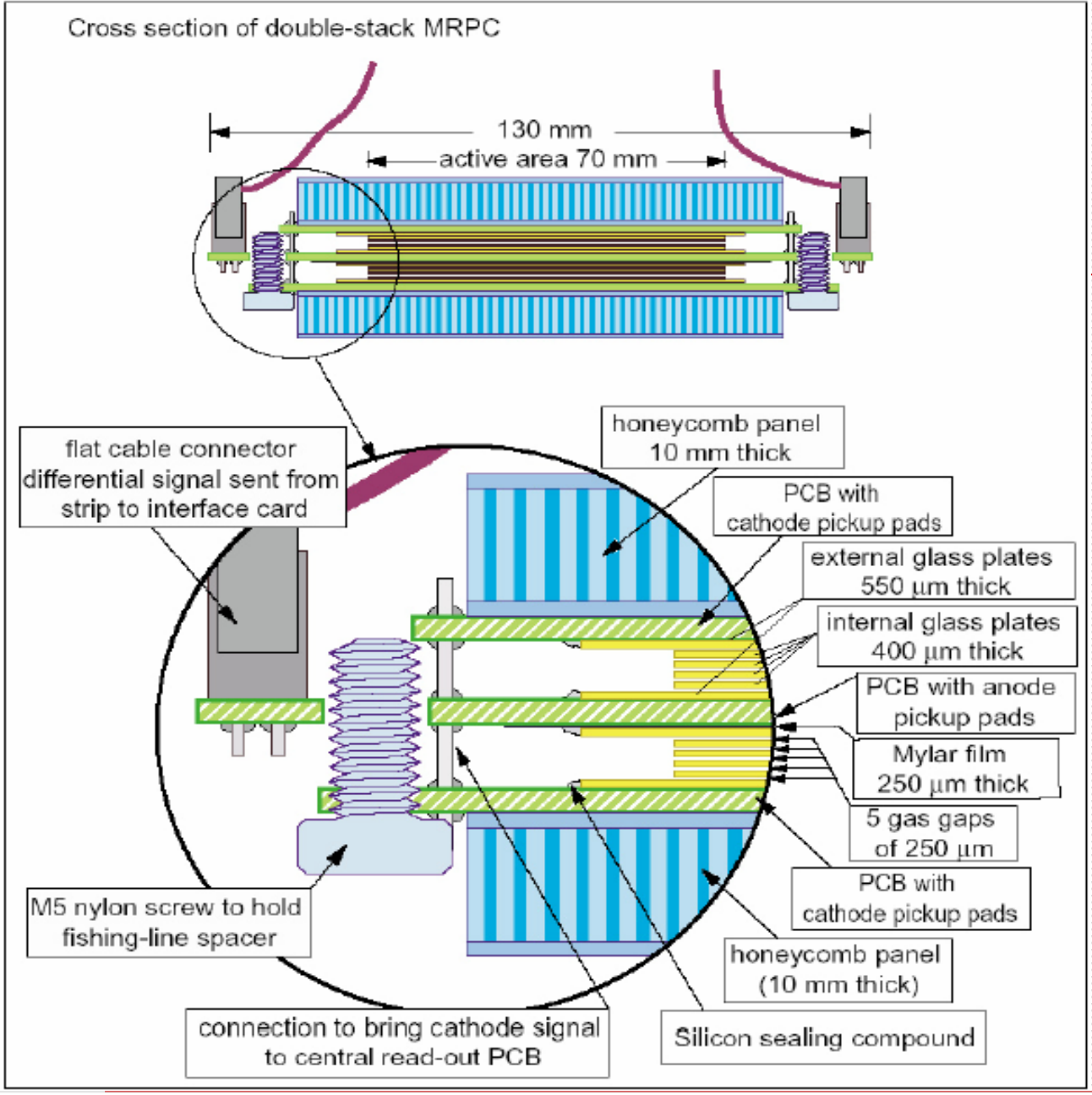
Efficiency and time resolution as a function of high voltage at a rate of about 800Hz/cm^2



When the particle flux increases every 5 kHz/cm^2, the efficiency decreases by 1% and the time resolution deteriorates by 4 ps.

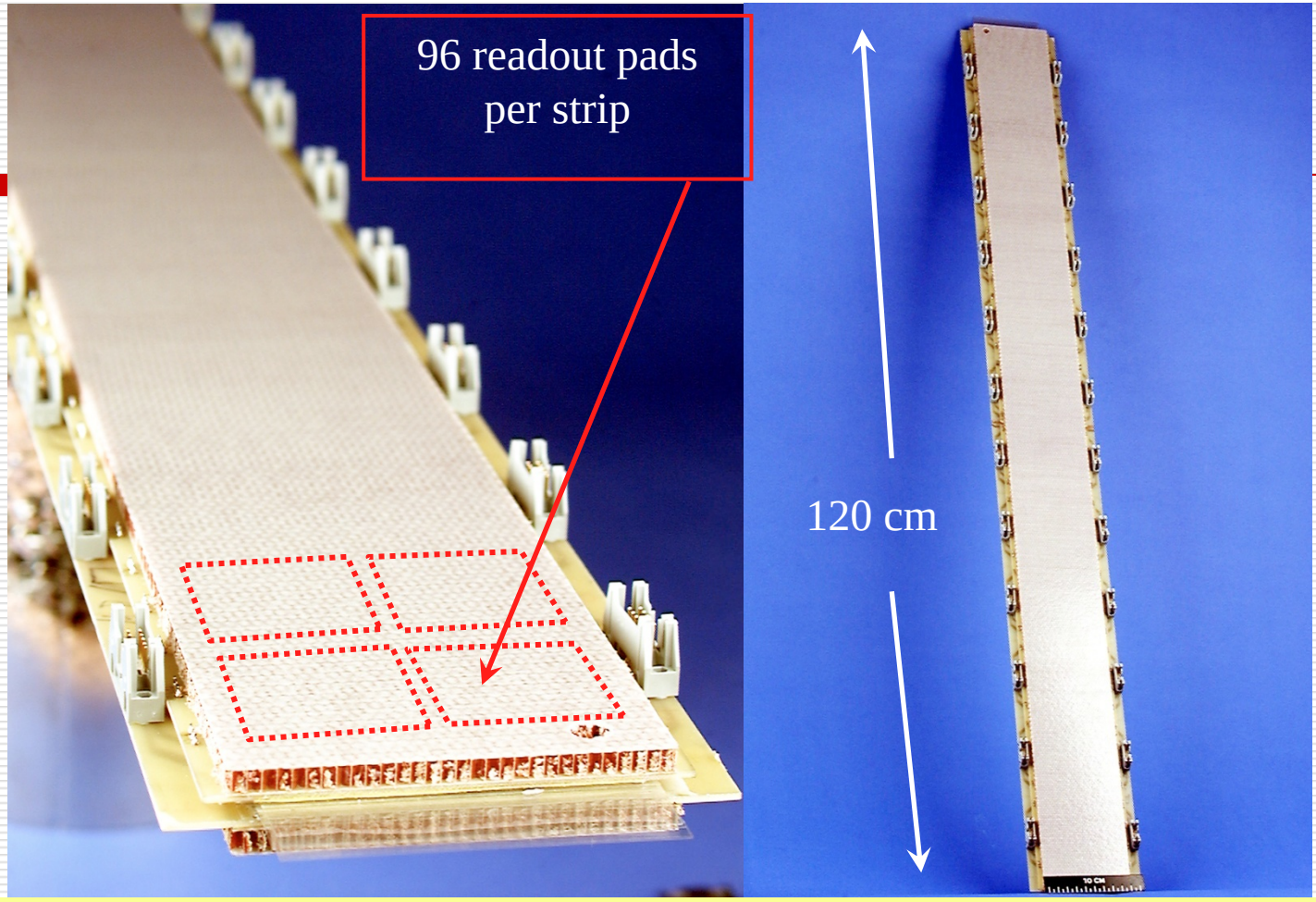
Rates capability





ALICE TOF

Необходимо перекрытие



Boundaries potential problem (loss in efficiency, double hits)
~ 10 km of boundary for 160 m^2 detector
~ 30 % of area ± 2.5 mm to a boundary

Старение

В результате старения:

- увеличение темнового тока
- уменьшение эффективности
- отложения на поверхности стекол

690 дней при 300 Hz/cm^2

^{60}Co, совокупный заряд > 20mC/cm^2

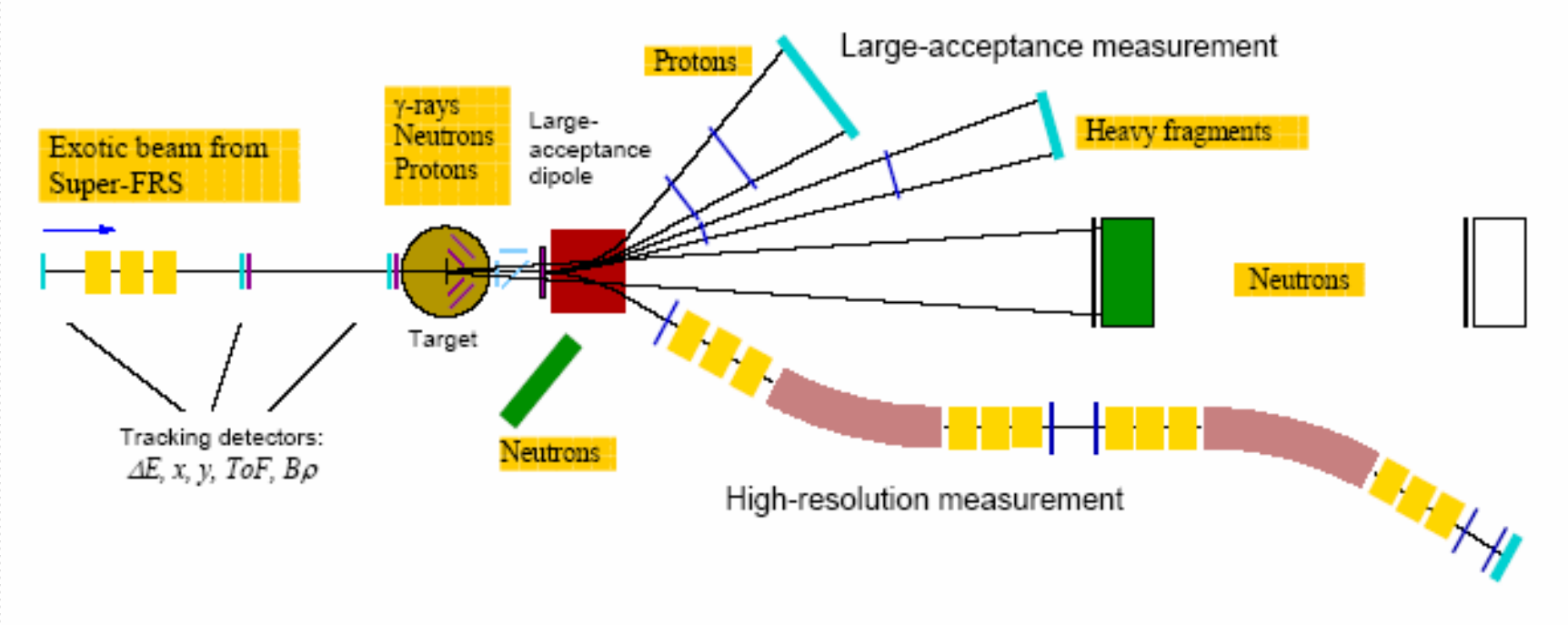
темновой ток -не увеличился

на стекле – отложения из различных сочетаний ядер C, H, F

MRPCs used in hadron experiment

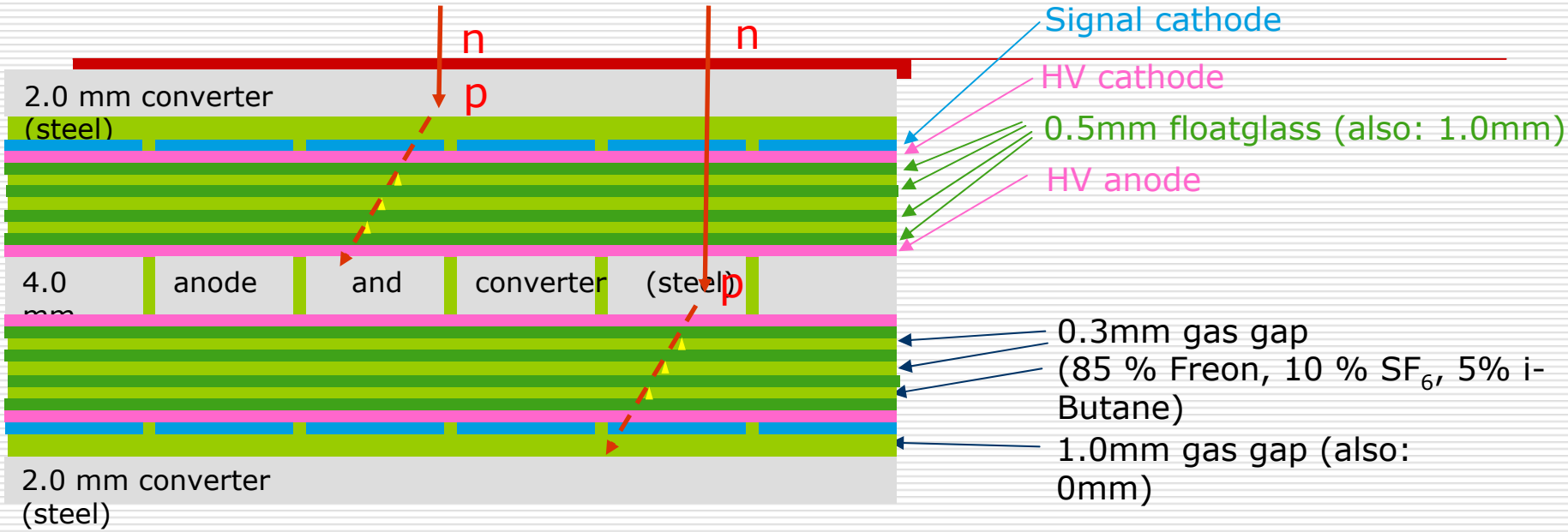
Detector	HARP	ALICE	STAR	FOPI	HADES
N_{gaps}	4	10	6	6	4
gap size [mm]	0.3	0.25	0.22	0.3	0.3
gas[$C_2F_4H_2/SF_6/C_4H_{10}$]	90/5/5	90/5/5	**95/0/5**	85/10/5	98.5/1/0.5
electric configuration	cat-an-cat	cat-an-cat	an-cat	cat-an-cat	cat-an-cat
cell size [cm×cm]	22×10.6	2.5× 3.7	6.3× 3.1	90×0.34	60×2
detector size	10 m^2	150 m^2	60 m^2	5 m^2	8 m^2
$N_{channels}$	368	160000	$\simeq$ 30000	5000	$\simeq$ 2100
HV/gap	3.0 kV	2.4 kV	2.35 kV	3.3 kV	3.2 kV
ε	99%	99.9%	95-97%	97 $\pm$ 3%	>95%
plateau length	300 V	2000 V	500 V	600 V	$\gtrsim$ 200 V
σ_T	-	90 ps	120 ps	-	100 ps
σ_T (after slewing corr.)	150 ps	40 ps	60 ps	73 $\pm$ 5 ps	70 ps
cross-talk/neighbor	< 10%	-	-	-	< 0.5%
3-σ tails	-	-	-	< 2%	6%
space resolution [cm^2]	-	-	-	-	0.6×0.6
experiment rates	1 Hz/cm^2	50 Hz/cm^2	10 Hz/cm^2	50 Hz/cm^2	700 Hz/cm^2
dark rate [Hz/cm^2]	< 0.1	-	< 0.3	< 1	2–3
rate capability [Hz/cm^2]	$\leq$ 2000	$\leq$1000	-	-	350
$\rho\ d$ [$10^{12}\ \Omega \times cm^2$]	10 × 0.105	- × 0.04	5 × 0.055	- × 0.15	5 × 0.1
$\bar{q}$	-	2 pC	-	-	-
$\bar{q}_{prompt}$	-	-	-	-	0.7 pC
material budget (x/X_o)	-	-	-	-	12-24%
resistive material	float glass	float glass	float glass	float glass	float glass

NewLAND detector



Time Resolution	< 100 ps
Position Resolution	~ 1 cm
Excitation Energy Resolution	~ 100 keV
x,y – Same Size as LAND	2 m x 2 m
z – Length	< 1 m
Neutron Efficiency	> 90% for 1-n hits

The NeuLAND MRPC prototypes, some details



NeuLAND design goals:

- Active area 200cm x 200cm
- Depth ~100cm (~60 iterations of above structure)
- 90% efficiency for 0.2-1.0 GeV neutrons
- Time resolution $\sigma < 100$ ps
- Spatial resolution $\sigma_x \leq 1$ cm
- Multi-hit capability

Tested solutions:

- 2 x 3 gap structure (also: 2 x 2)
- 4mm thick central anode (signal readout and converter for second half of MRPC)
- Spacing of gaps 3.0mm (also: 0.3mm)
- Gas: 84% Freon, 10% SF_6, 6% i-butane