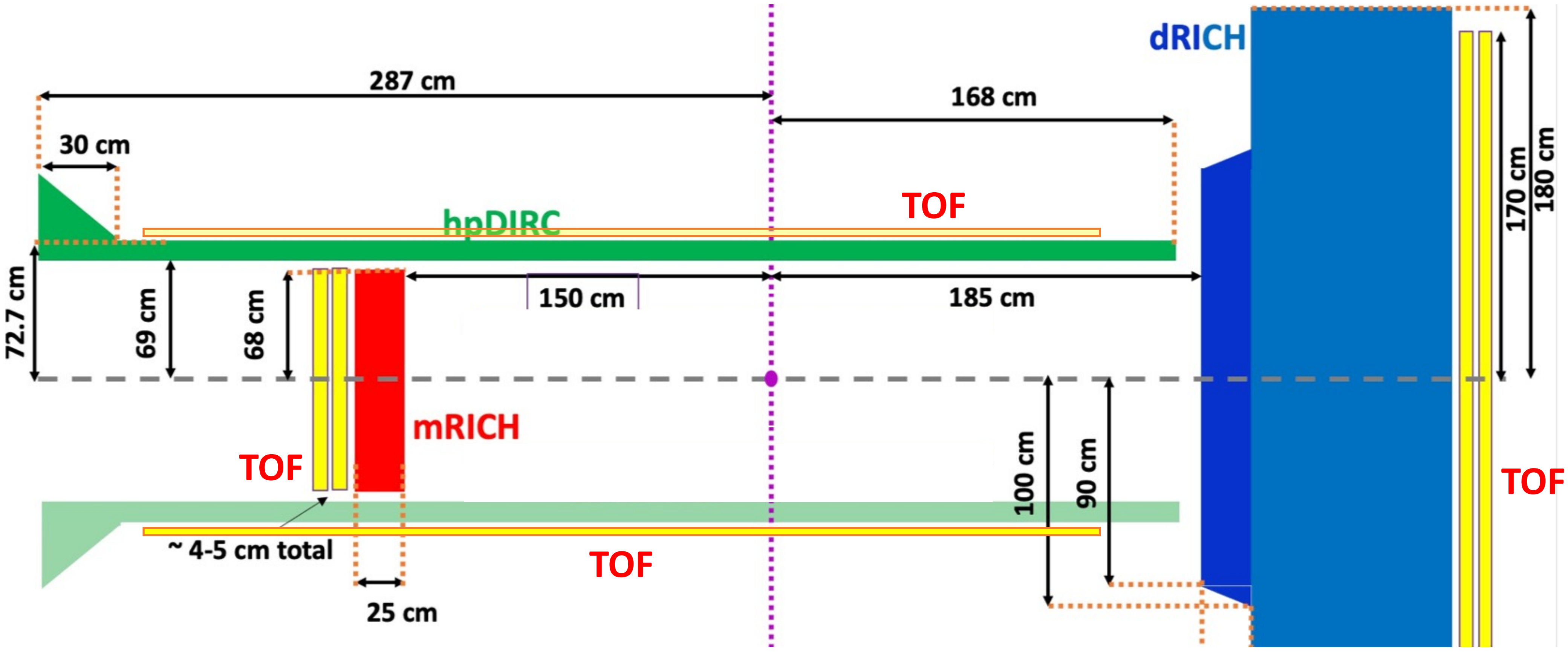
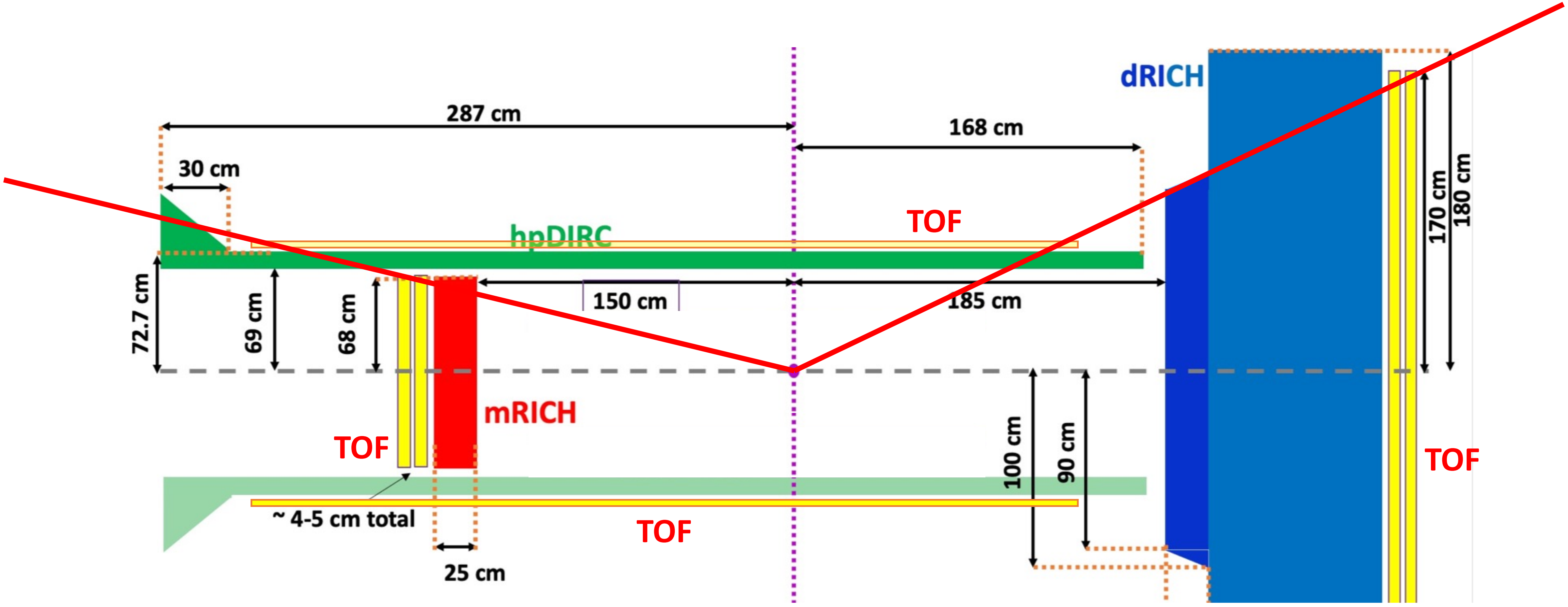
ECCE PID: Cherenkov + TOF



ECCE PID: Cherenkov + TOF



CHERENKOV PID COVERAGE

TOF PID COVERAGE

- **h-endcap: dRICH**

Ring imaging:

- **π/K < 50 GeV/c**
- **e/π <15 GeV/c**

"Veto" mode:

- **e/ π above few MeV/c** (up to ~15 GeV/c)
- **π/K,p above 0.7 GeV/c** (or ~1 GeV/c at "full efficiency")
- **K/p > 2.5 Gev/c** (or ~3 GeV/c at "full efficiency")

e/π covered by dRICH

π/K < 1 (2) GeV/c need ~230 (65) ps resolution (3m path)

K/p < 3 (4) GeV/c need ~80 (45) ps resolution (3m path)

- **e-endcap: mRICH**

Ring imaging:

- ***π/K: 2-8 GeV/c***
- **e/π : 0.6-2./2.5 GeV/c**

"Veto" mode:

- **k/π : 0.6-2 GeV/c**
- **e/π : <0.6 GeV/c**
- **k/P <3.8 GeV/c**

e/π covered by mRICH (@ low-p)

π/K < 0.6 (1) GeV/c need ~380 (150) ps resolution (1.75m path)

K/p < 3.8 GeV/c covered by mRICH

- **barrel: hpDIRC**

Ring imaging:

- ***π/K <6-7 GeV/c***
- **e/π <1.2 GeV/c**

"Veto" mode:

- **e,k/π >0.2/0.3GeV/c**
- **k/P >1 GeV/c**

e/π < 0.3 (0.5) GeV/c need ~65 (25) ps resolution (0.8m path)

π/k < 0.3 (0.5) GeV/c need ~500 (230) ps resolution (0.8m path)

K/p < 1 (2) GeV/c need ~160 (45) ps resolution (0.8m path)

TOF Technologies

Barrel (20m^2):

- AC-LGAD (~20ps). [~$13M*]
- LYSO (~30ps). [~$4M* + uRWELL cost]
- mRPC (~ 30 – 60ps) [~$3M** + uRWELL cost]

Endcap (10.5m^2, 1.0$^{e\text{-}cap}$ + 9.5$^{h\text{-}cap}$):

- AC-LGAD (~20ps) [~$6.8M*]
- mRPC (~ 30 – 60ps) [~$1.6M** + uRWELL cost]

* Scaling CMS cost from LHCC-P-009: https://cds.cern.ch/record/2296612/files/LHCC-P-009.pdf

** eRD14 assumed 200k/m^2 [eRD14: http://phynp6.phy-astr.gsu.edu/eRD14/index.php/Time_of_Flight_Detector_(TOF)]; Recent estimates are ~150k/m^2.

LYSO (Barrel)

<u>Base unit:</u> 2.5mm – 3.75mm thick LYSO ‘pixels’ \w SiPM+ASIC readout.

<u>Total thickness:</u> 2.5 cm (crystal+SiPM+readout +service). ~ 0.5% X_0.

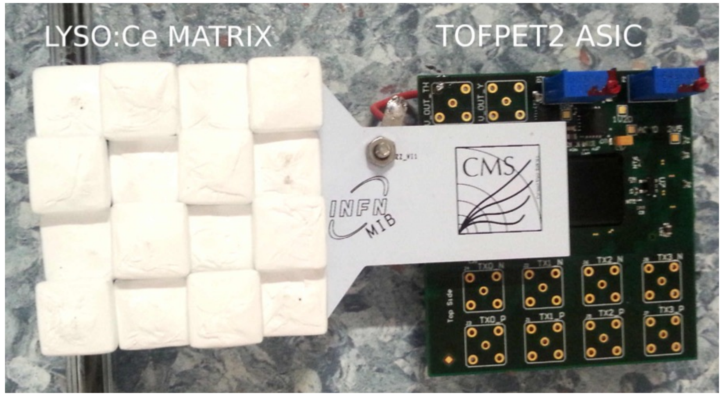
<u>TOF Performance:</u> ~30ps resolution (established).

<u>Efficiency:</u> close to 100%.

<u>Risk:</u> Minimal. Builds on (copy from) CMS.

<u>Cost:</u> $4M (scaling CMS cost of $8M for 40m²).

<u>Cost Saving:</u> ~$1M by using YAG:Ce instead of LYSO (R&D still ongoing).



LHCC-P-009: https://cds.cern.ch/record/2296612/files/LHCC-P-009.pdf

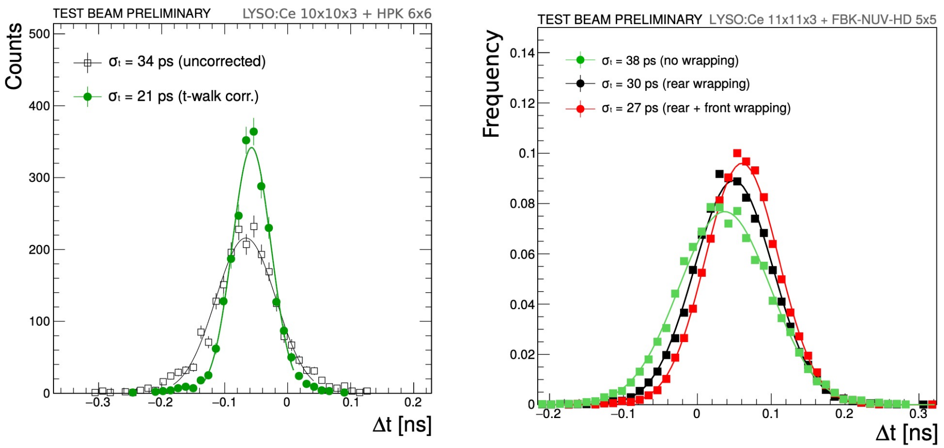


Figure 2.5: Distribution of the time difference in a pair of LYSO:Ce tiles exposed to a 3 mm wide beam of MIPs hitting the centre of the tiles. Left: Results before and after time walk correction for $10 \times 10 \times 3$ mm^3 crystals read out with 6×6 mm^2 HPK SiPMs. Right: Results for $11 \times 11 \times 3$ mm^3 crystals read out with 5×5 mm^2 FBK SiPMs under different wrapping configurations.

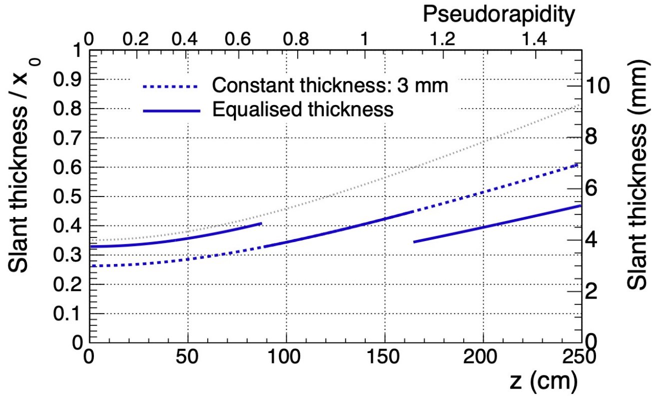


Figure 2.2: Slant thickness of the barrel timing layer as a function of the z (lower abscissa) and η coordinates (upper abscissa) for tiles of variable thickness (continuous line), of 3 mm (dotted line) and of 4 mm (gray line) thickness.

Table 2.1: Crystal tile thickness and weight in different η sections of the barrel timing layer, and contribution to the weight of one module.

$\lvert\eta\rvert$ region	Crystal thickness [mm]	Crystal weight [g]	Module count	Module weight [g]
< 0.7	3.75	3.9	1–19	250
0.7–1.1	3.0	3.1	20–35	200
> 1.1	2.4	2.5	36–54	160

LYSO (Barrel)

Base unit: 2.5mm – 3.75mm thick LYSO 'pixels' \w SiPM+ASIC readout.

Total thickness: 2.5 cm (crystal+SiPM+readout +service). ~ 0.5% X_0.

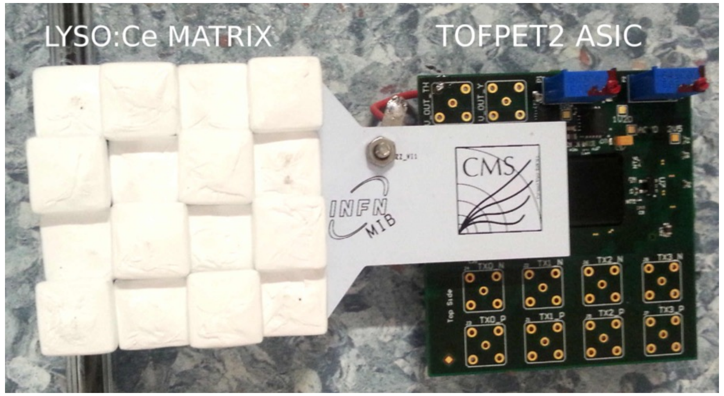
TOF Performance: ~30ps resolution (established).

Efficiency: close to 100%.

Risk: Minimal. Builds on (copy from) CMS.

Cost: $4M (scaling CMS cost of $8M for 40m^2).

Cost Saving: ~$1M by using YAG:Ce instead of LYSO (R&D still ongoing).



LHCC-P-009: https://cds.cern.ch/record/2296612/files/LHCC-P-009.pdf

Table 4.3: Summary of core costs for the barrel and endcap timing layers.

	Item	cost [kCHF]
Barrel	Crystal	3057
	SiPM	1493
	FE cards	1573
	FE optical links	188
	BE cards	231
	BE mTCA	64
	Power supplies	568
	Cables	177
	Supporting trays	150
	Cooling services	535
	Total	8036

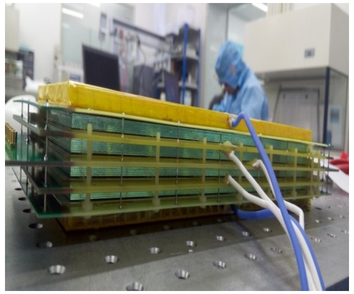
Table 2.1: Crystal tile thickness and weight in different η sections of the barrel timing layer, and contribution to the weight of one module.

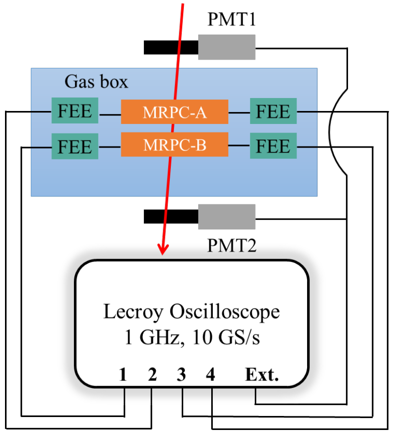
$\|\eta\|$ region	Crystal thickness [mm]	Crystal weight [g]	Module count	Module weight [g]
< 0.7	3.75	3.9	1–19	250
0.7–1.1	3.0	3.1	20–35	200
> 1.1	2.4	2.5	36–54	160

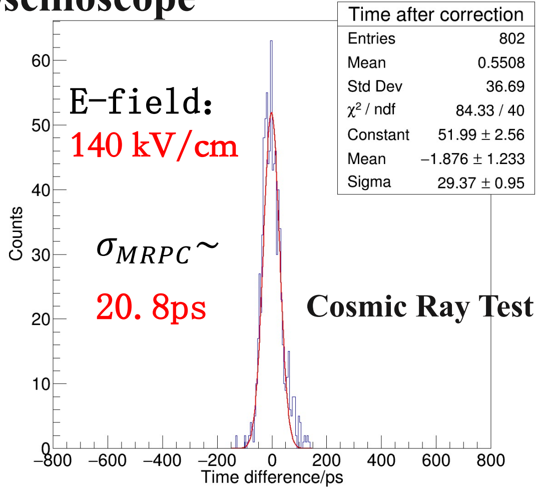
mRPC (Tsinghua U.)

- **Base unit:** 128um gas-gap (**90% $C_2H_2F_4$ + 5% i-C_4H_{10} + 5% SF_6**) * 8-layers * 4 stacks; thin glass (400um); Readout-Strip: 7mm (width)+3mm (gap);
- **Total thickness:** ~10cm, ~ 0.1% X_0.
- **TOF Performance:** $\sigma_{MRPC} \sim 20ps$ achieved in cosmic ray tests; $\sigma_{TOF} = \sqrt{\sigma_{MRPC} + \sigma_{electronics}}$
- **Readout Electronics**: USTC Fast FEE, SCA, DRS4,…
- **Detection Efficiency**: 97%@140kV/cm
- **Risk**: Low; Mature technology; Fully automatic manufacture-line at Tsinghua;
- **Cost**: \$0.6M (detector modules for ECCE-Barrel 20m²) + \$2.4M (Readout electronics, 5000 channel)
- **Ongoing R&D Activities**: Improved design & beam-test at Jlab in Spring 2022

❖ **Cosmic Ray Test:**
mRPC + USTC FEE + Lecroy Oscilloscope

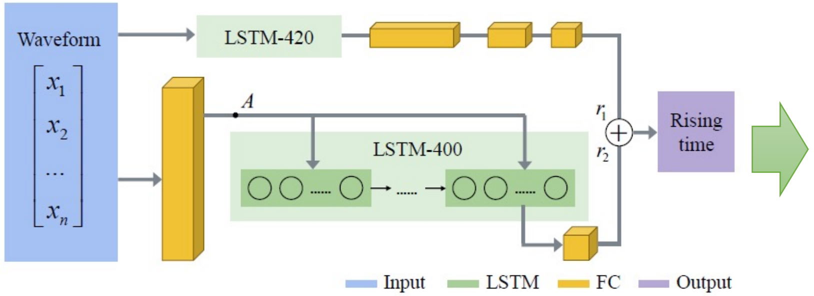


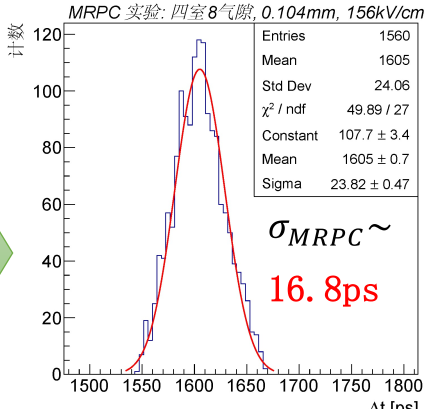




❖ **R&D#1**: Low-resistive glass (for high rates)

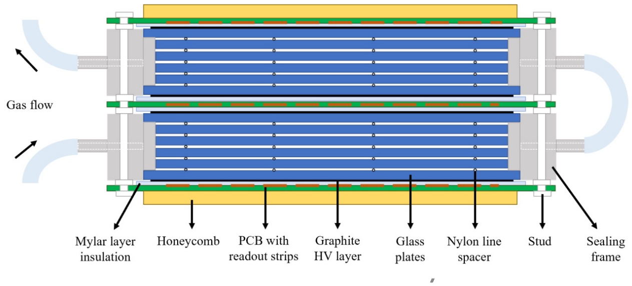
❖ **R&D#2:** Analysis with Neural network





❖ **R&D#3**: Sealed-mRPC (reduce pollution effect)

❖ **R&D#4**: Replacement of NONE green-house gas



MRPC (the PHENIX TOF.W)

Base unit: 37 cm x 12 cm in x-y, but could be other
Thickness of MRPC in PHENIX: 6-gaps with 0.55mm glass, 0.23 mm gas gaps; honeycomb, signal pick-up boards → 3 cm

Total thickness: 7.6 cm with feedthrough boards, readout electronics, Al gas box; X0 is 0.05 for detector and 0.13 with support structure and services. Can be optimized further.

TOF Performance: Established ~60 ps resolution (intrinsic), but ~ 84 ps in situ Au+Au collisions with start time and electronics; similar numbers reported by ALICE in PbPb. We were aiming at 100 ps. This can be improved significantly with better electronics and modifications to the glass stack.

Detection efficiency: ~ 95% with 14 kV/cm 95% freon+5% isobutane

Risk: Low. The detector worked for 10 years in PHENIX without an incident. We have facilities and expertise to engage in R&D and production of mRPC TOF for ECCE

Cost: most of the cost is in preamp and FEM electronics, HV supply and cables, machining of gas box, etc. I don't have a good estimate of today's cost, but Zhihong Ye's numbers seem right.

Phys.Rev.C 85 (2012) 064914

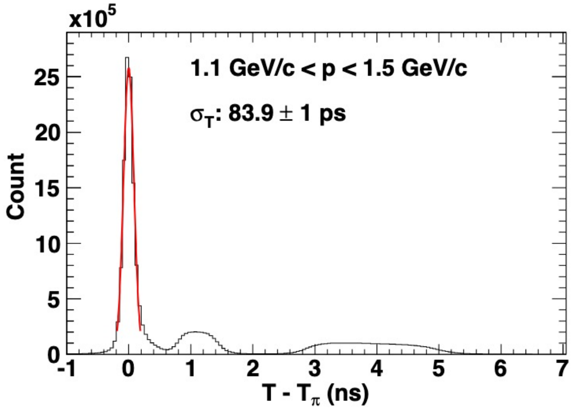


FIG. 2: (color online) Timing difference $T - T_\pi$, the difference between the measured time in the TOFw and the time calculated assuming each candidate track is a pion.

To Be Added:

slides on AC-LGAD

Slides on other considerations we should be making