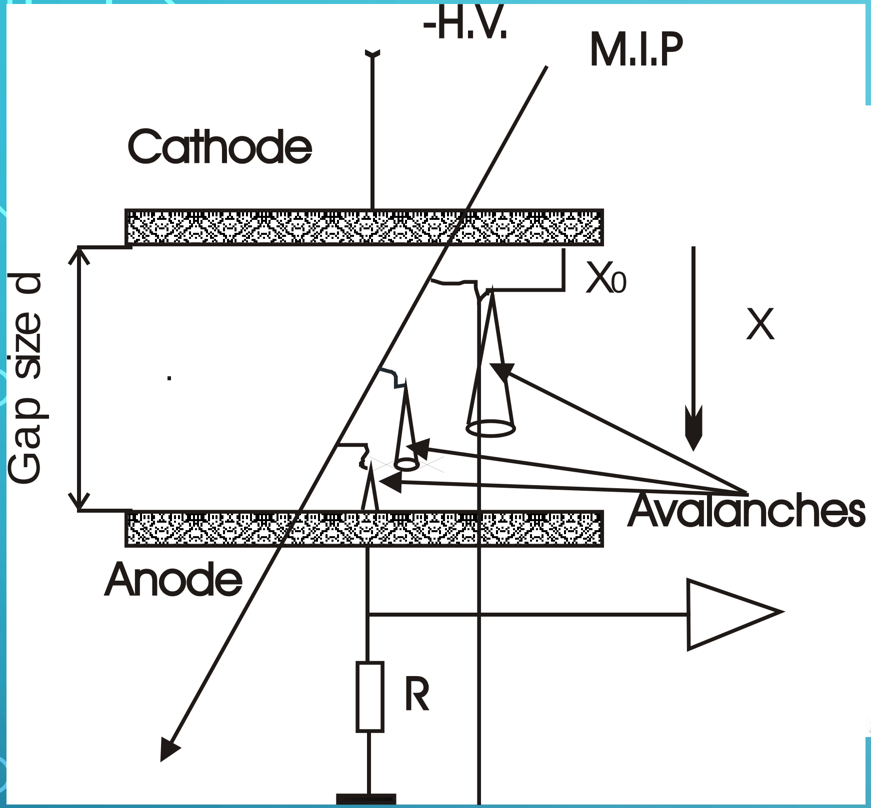
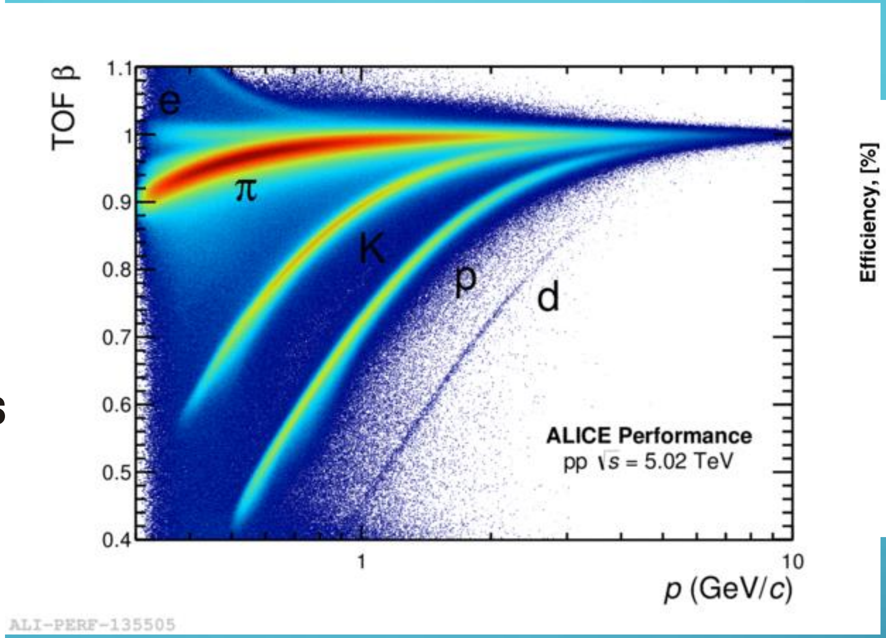
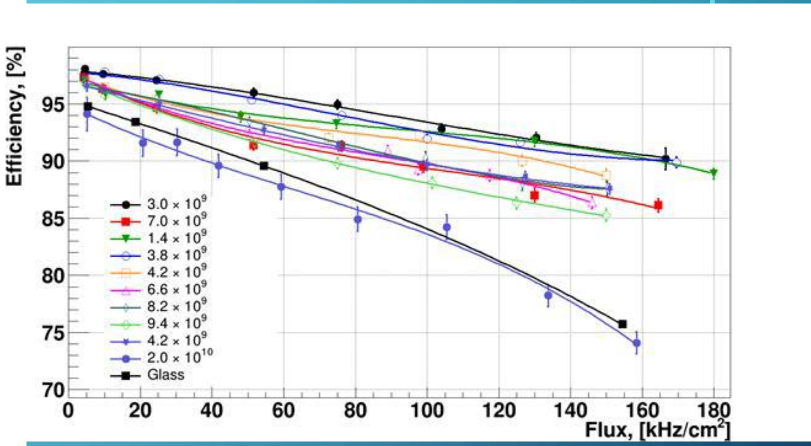






PID system for SPD detector and TOF technology for barrel and forward parts

Alexander Akindinov, NRC «Kurchatov Institute» - ITEP

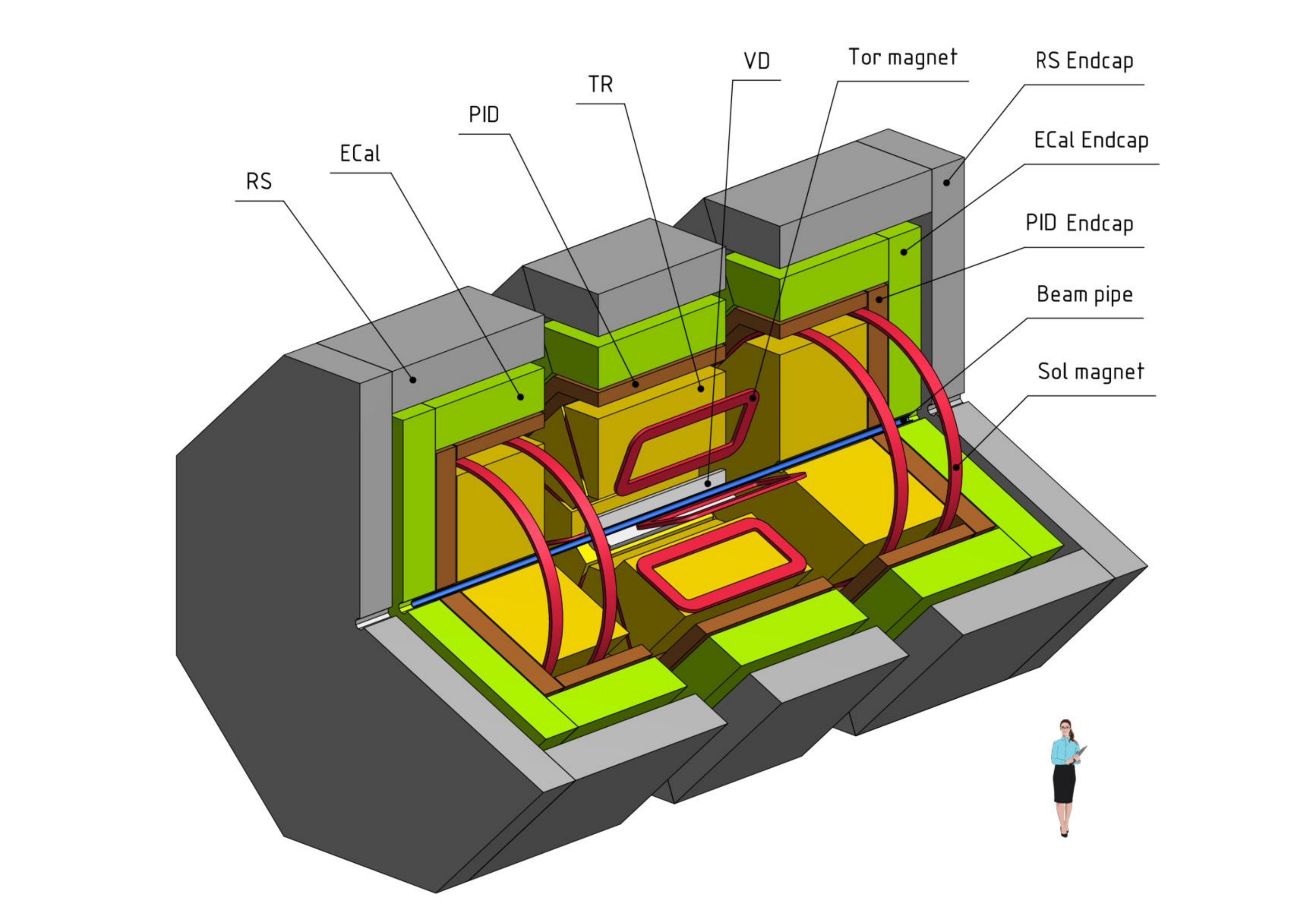
SPD at NICA-2019 meeting, 07 June, 2019

Outlook

- SPD PID
- Brief results of ALICE TOF R&D
- Key point for high-rate RPC – new low resistive material with high surface quality
- CMB R&D results for semiconductive ceramics and low resistive glass
- Search for optimal resistance using ceramic electrodes.
- First simulations for SPD PID
- Conclusion and future plans

SPD DETECTOR LAYOUT FOR THE MOMENT

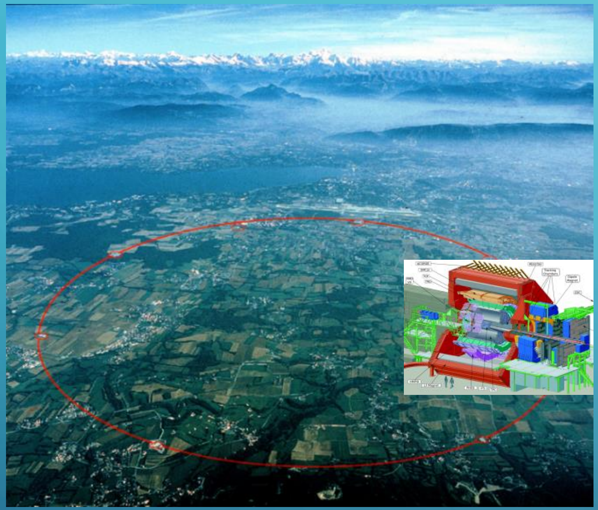
ITEP

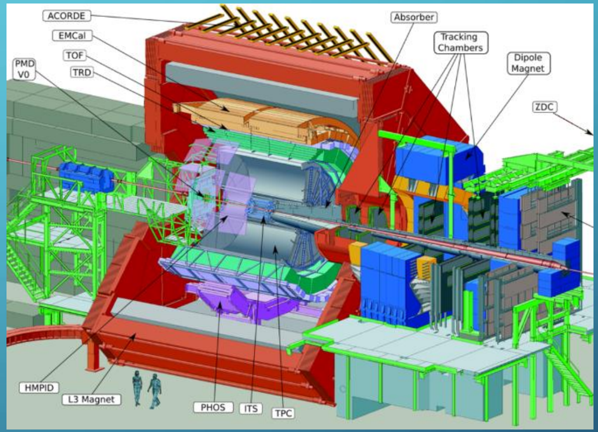


- PID has two rather different parts: barrel and forward
- PID should serve till maximum momentum of primary beam.
- PID should consist of TOF and HMPID.

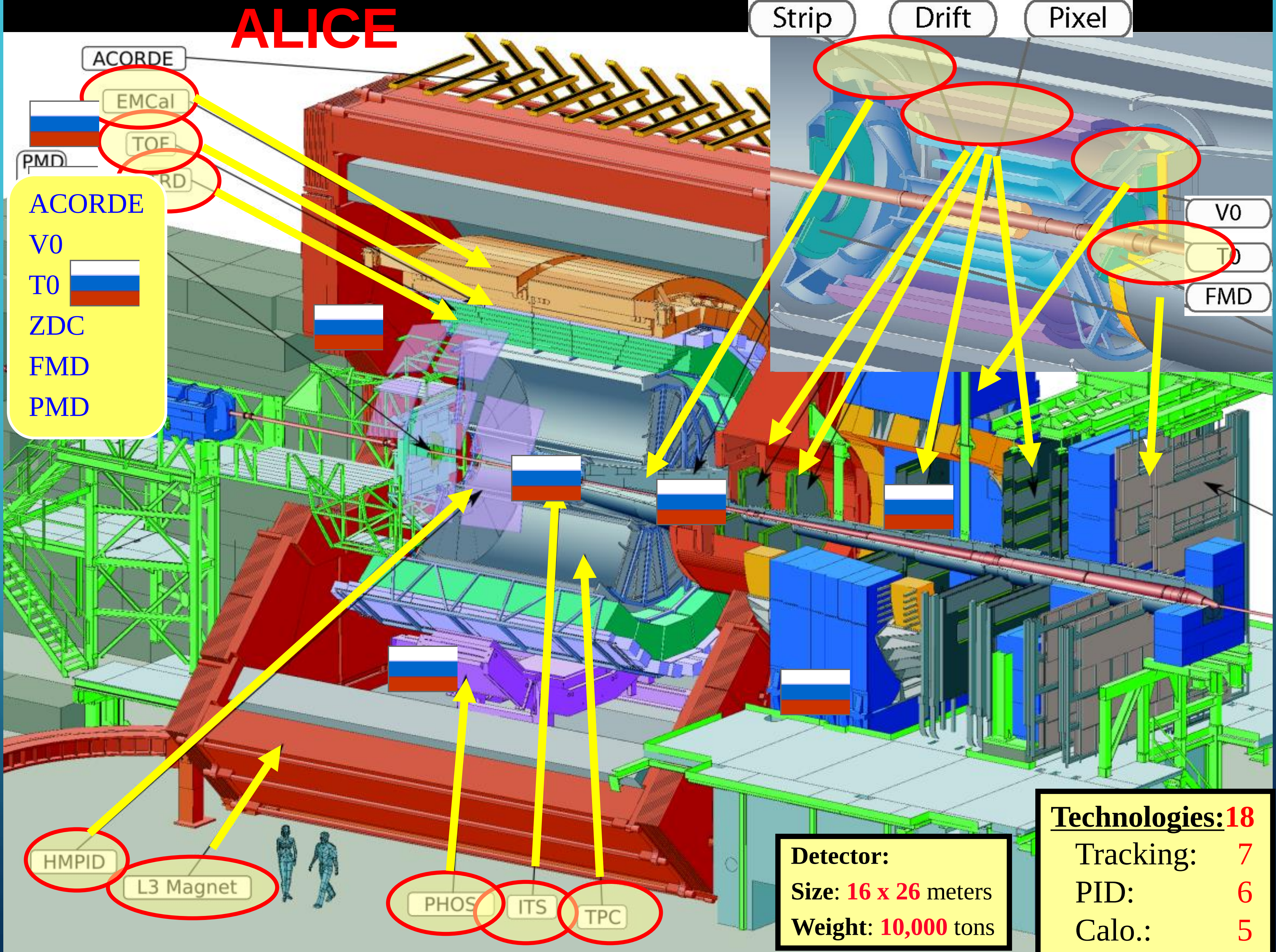
ITEP

BRIEF RESULTS OF ALICE TOF R&D





ALICE



ACORDE
V0
T0
ZDC
FMD
PMD

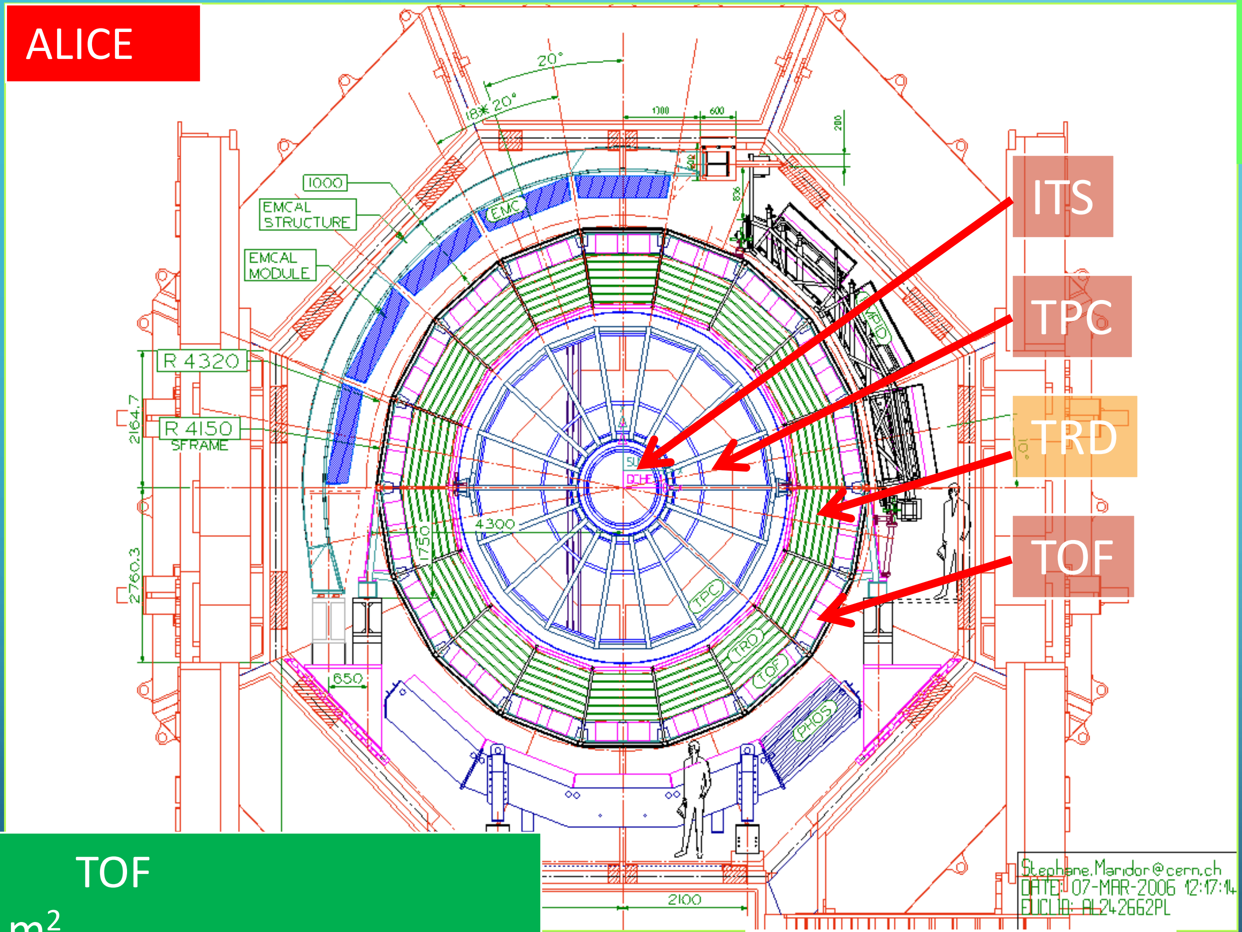
Detector:
Size: 16 x 26 meters
Weight: 10,000 tons

Technologies: 18

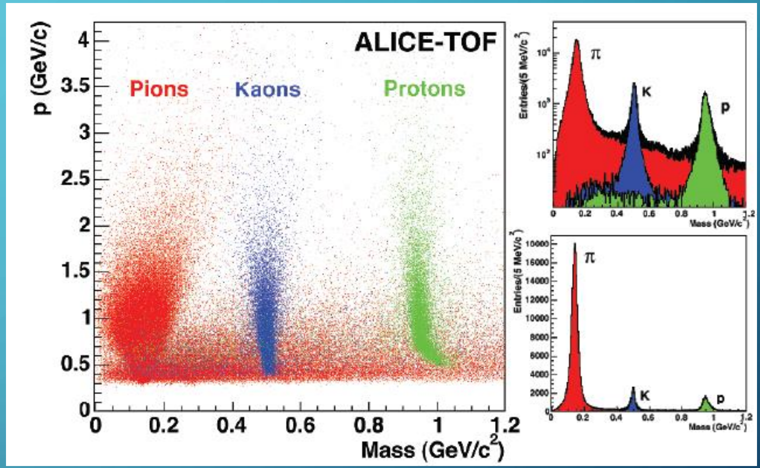
Tracking:	7
PID:	6
Calo.:	5

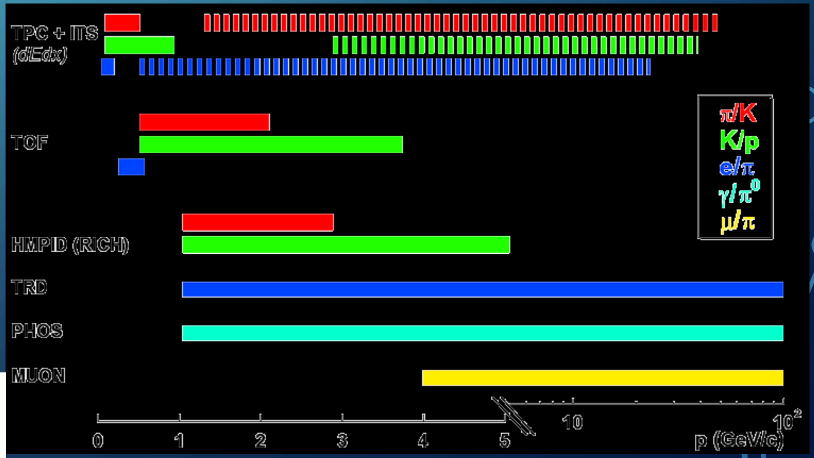
ITEP

TOF ALICE – huge Time-of-Flight system ever done



PID simulation for 100 ps time resolution





$$m = \frac{p}{c}\sqrt{\frac{c^2t^2}{L^2} - 1}$$

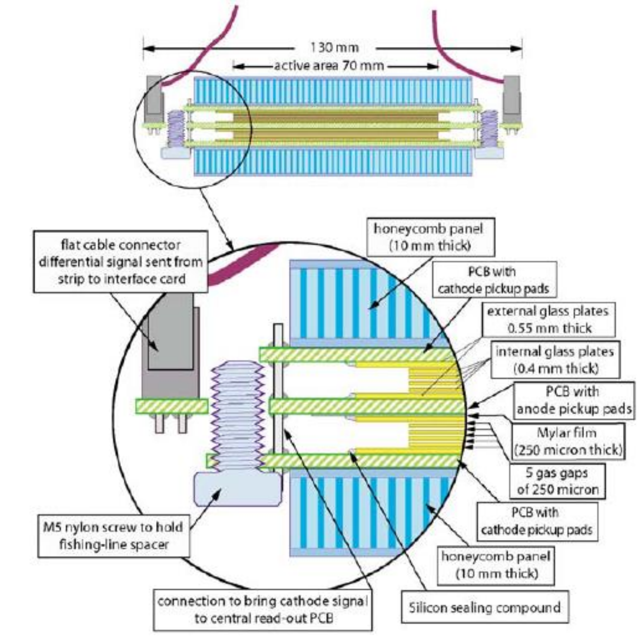
$$\left(\frac{\delta m}{m}\right)^2 = \left(\frac{\delta p}{p}\right)^2 + \left(\gamma^2\frac{\delta L}{L}\right)^2 + \boxed{\left(\gamma^2\frac{\delta t}{t}\right)^2}$$

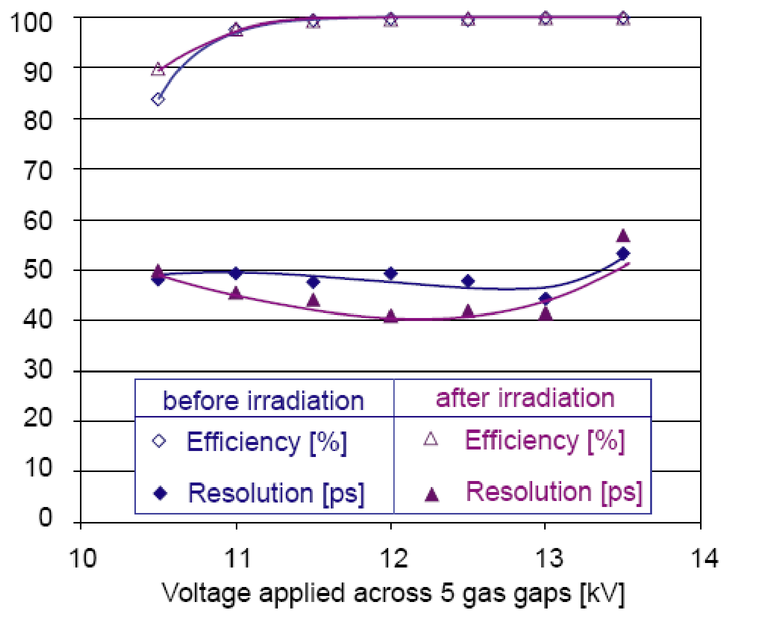
TOF

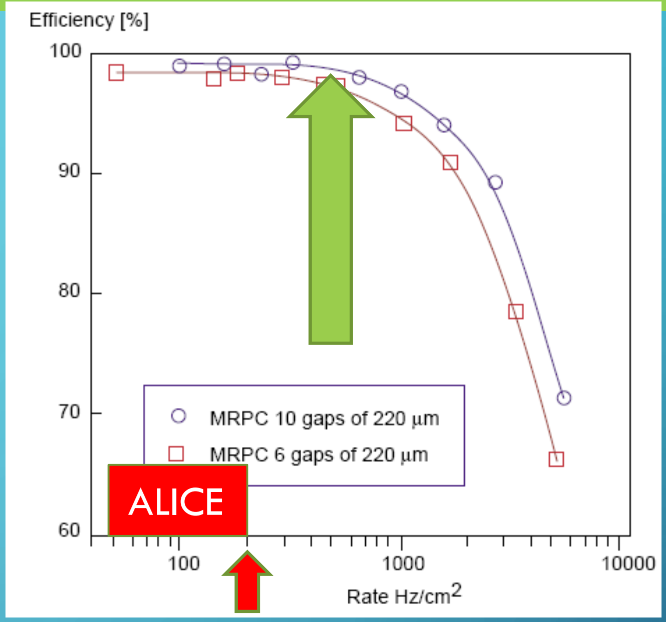
- Full area >140 m^2
- Number of channels 150 000 (~granularity ≈4x4 см)
- from 0.5 to 2.5 ГэВ/c L=3.8 m
- σ ~100 ps.

BOLOGNA DESIGN FOR ALICE TOF(AS EXAMPLE FOR BARREL PID)

ITEP







Float glass

~10^{13} Ohm*cm

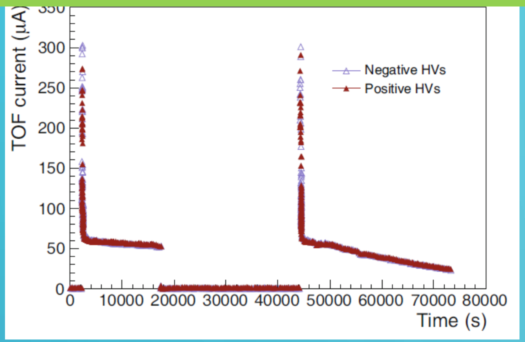
Creation of new technology and its adaptation for mass production

The detector is recognized as the main technological success of the ALICE collaboration

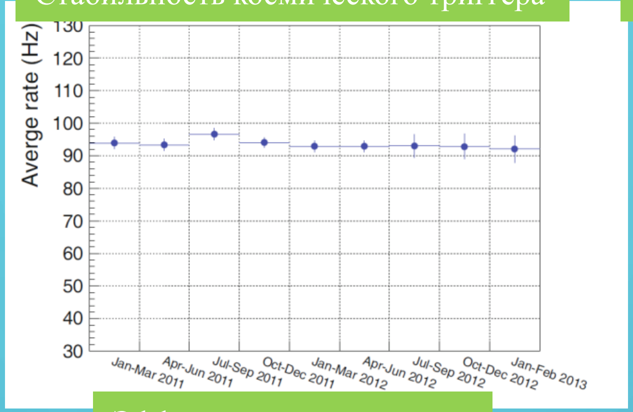
PERFORMANCE OF THE ALICE TIME-OF-FLIGHT DETECTOR AT THE LHC

ITEP

Величина тока системы в течение набора

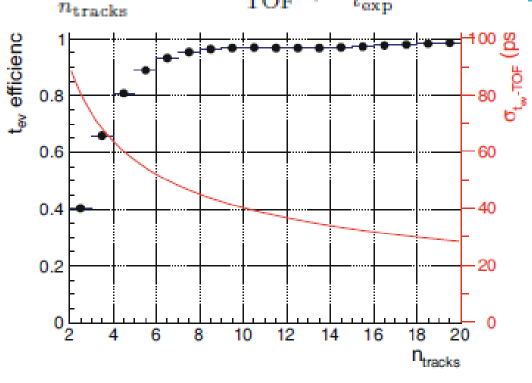


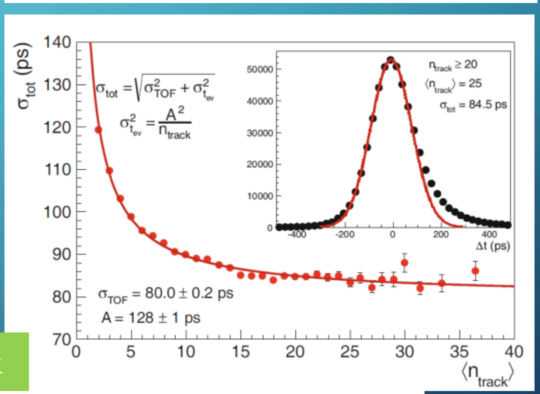
Стабильность космического триггера



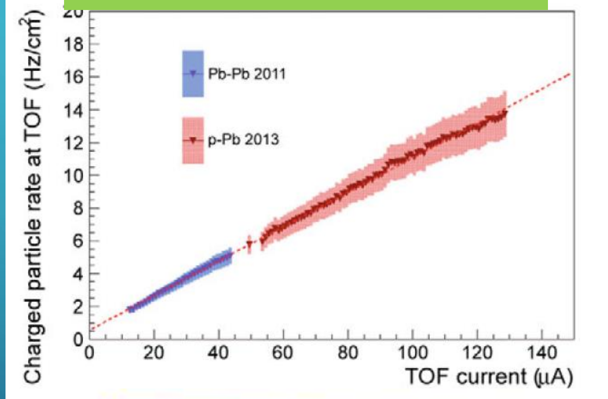
Стартовое время и временное разрешение

$$\chi^2 = \sum_{n_{\text{tracks}}} \frac{((t_{\text{TOF}} - t_{ev}) - t_{\text{exp}}(m_i))^2}{\sigma^2_{\text{TOF}} + \sigma^2_{t_{\text{exp}}}},$$

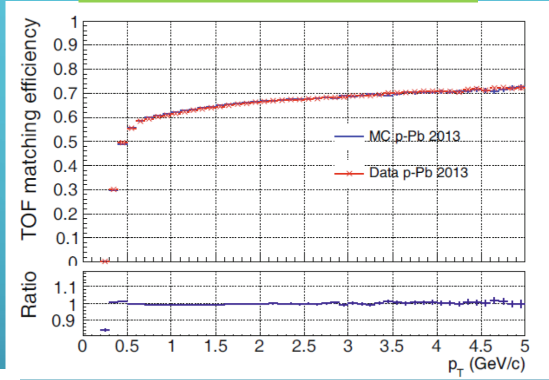


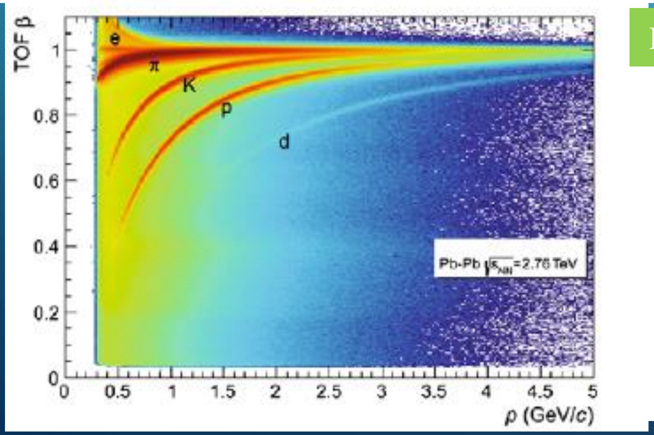


Величина тока и величина счета

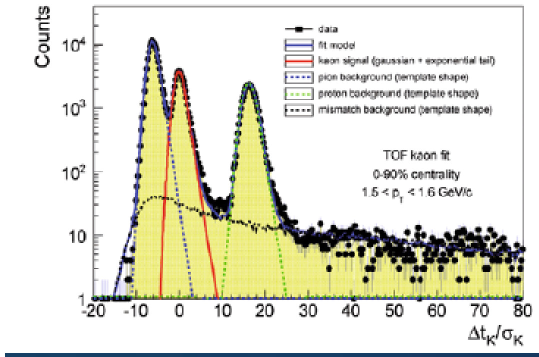


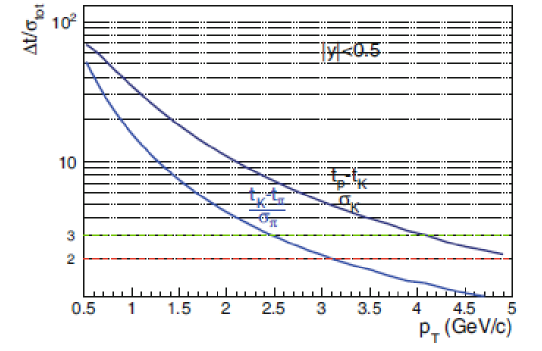
Эффективность детектора





Разделение частиц в ион-ионных столкновениях

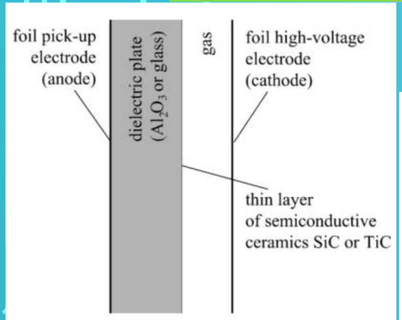


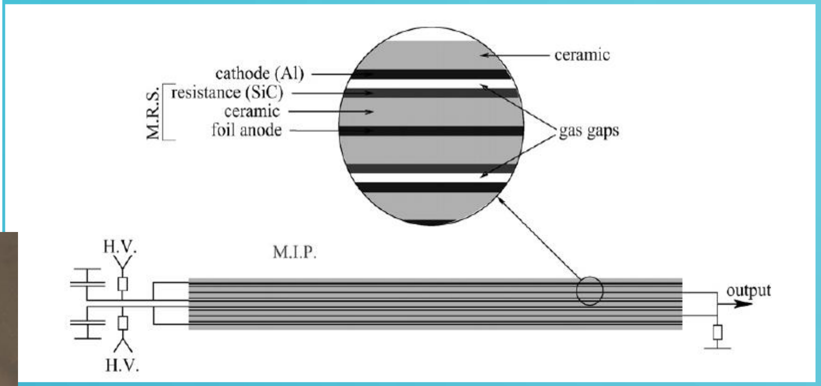


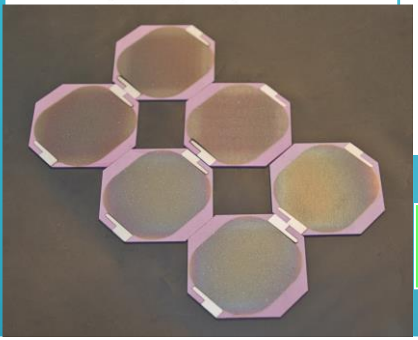
KEY POINT FOR HIGH-RATE RPC – NEW LOW RESISTIVE MATERIAL WITH HIGH SURFACE QUALITY

NEW LOW RESISTIVE MATERIAL SEARCH

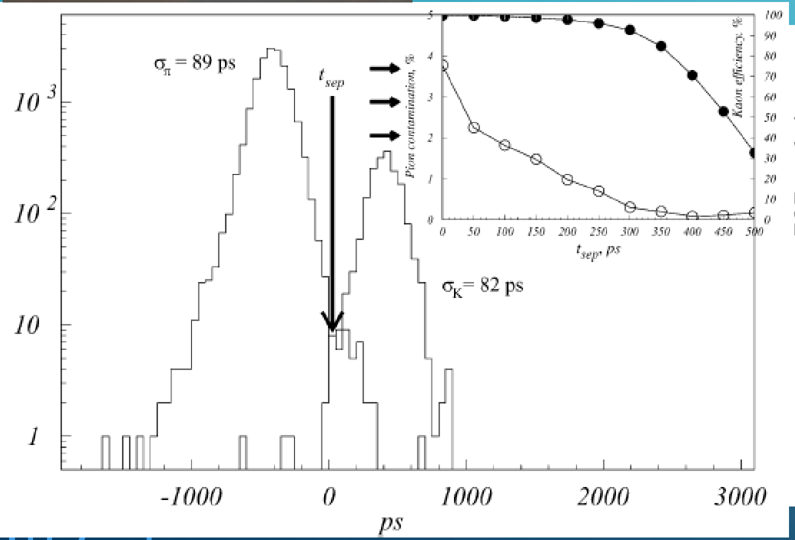
Ceramic

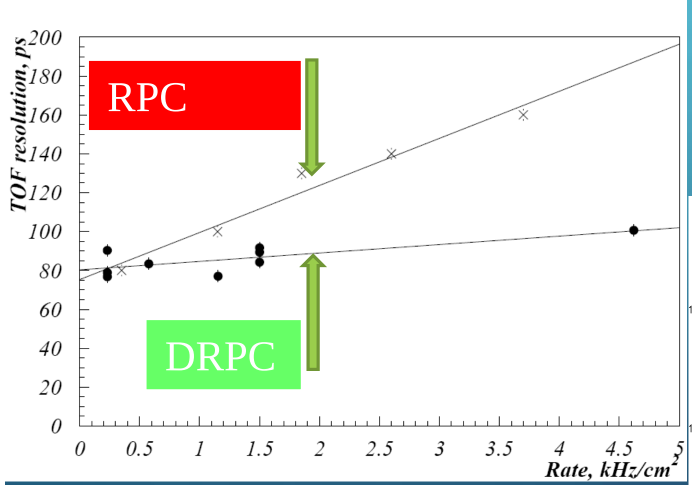




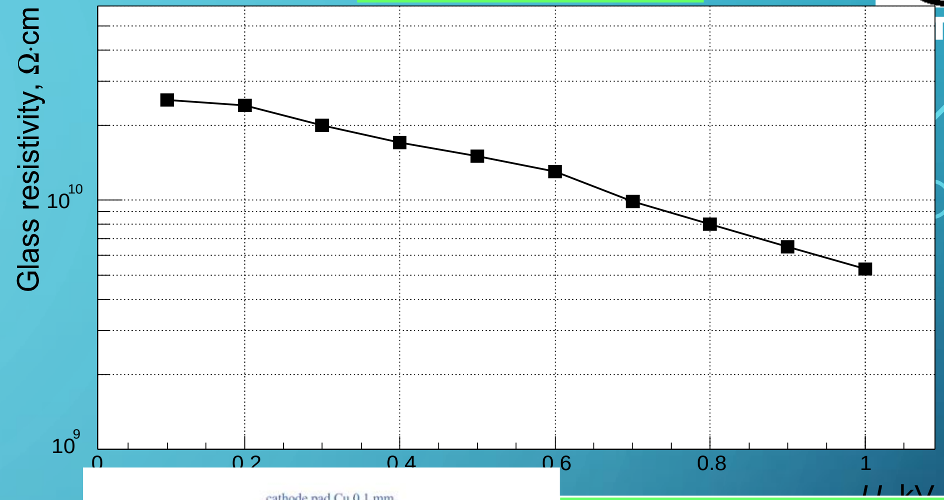


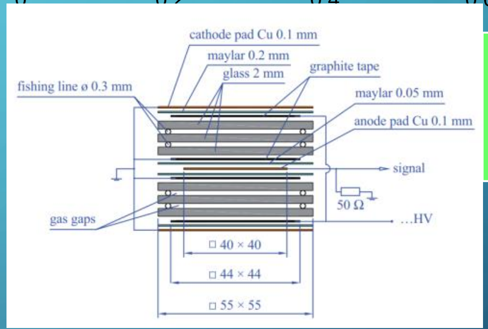
4 gaps (300 μm) ρ= 10^{11} Ohm/□ SiC



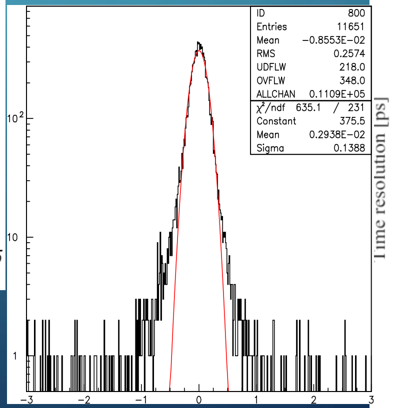


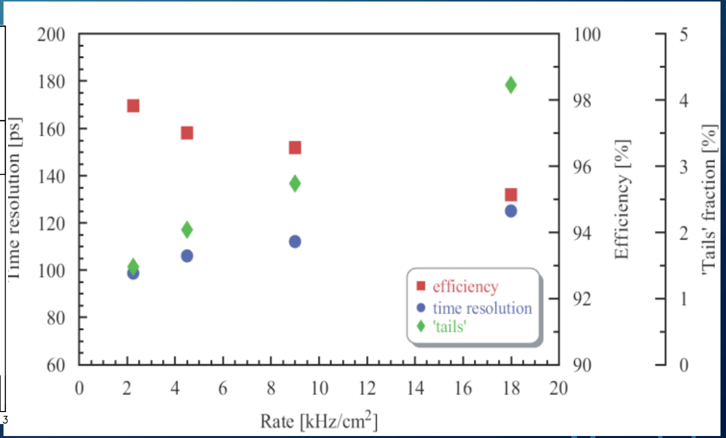
Phosphate glass





4 gaps (300 μm) ρ= $3*10^{10}$ Ohm*cm



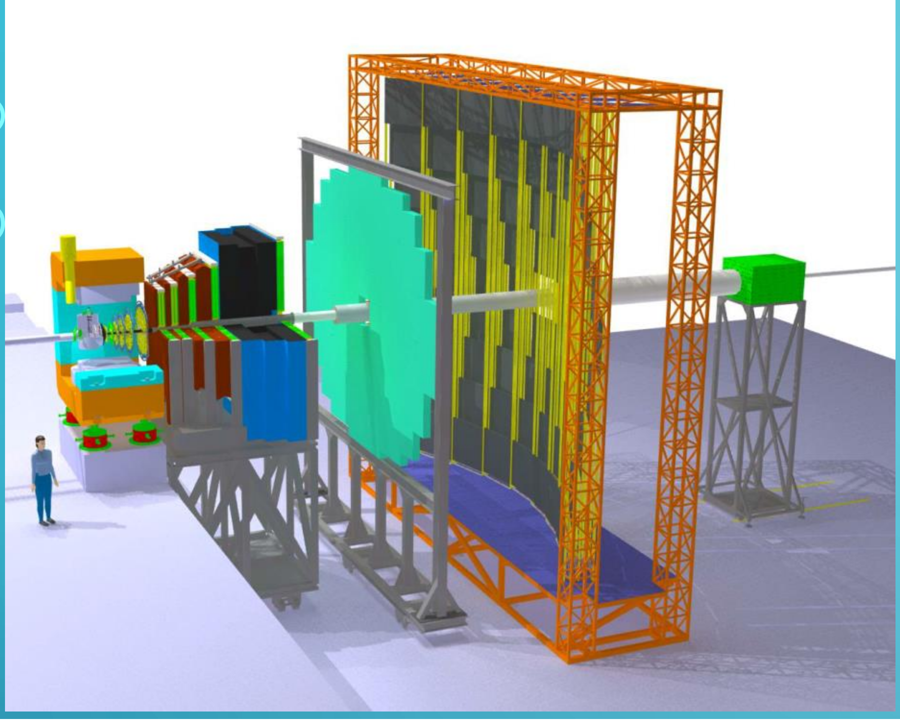


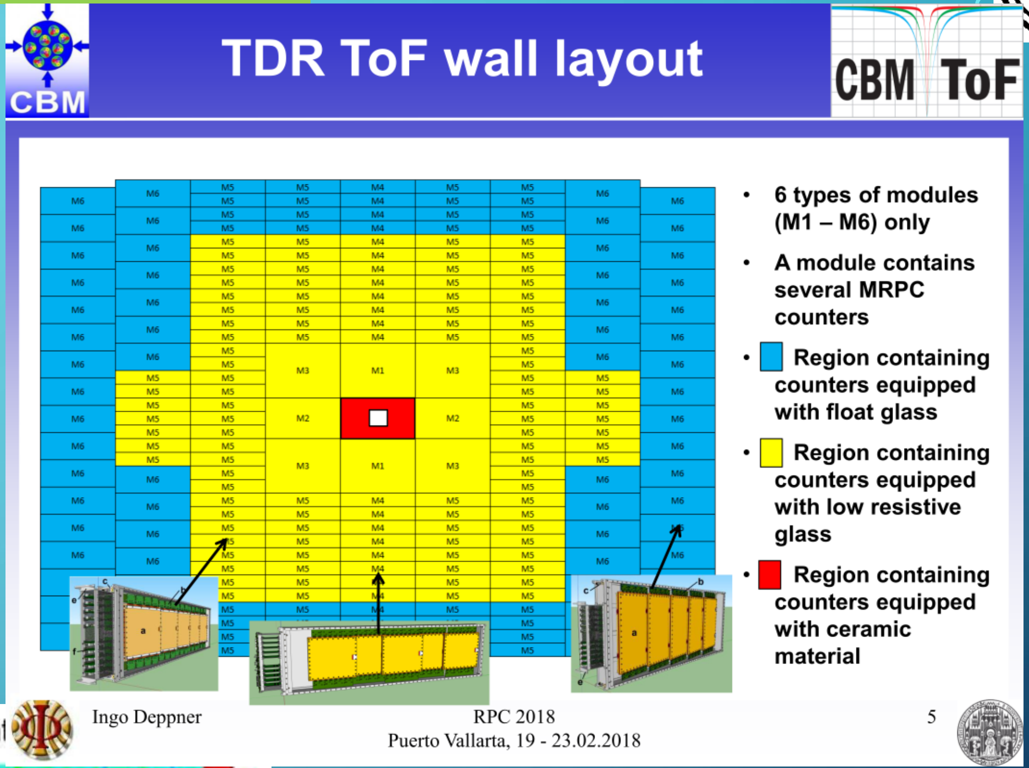
A. Akindinov, V. Golovine, A. Martemianov, et al., Nucl. Instr. and Meth. A 494 (2002) 474-479

A. Akindinov, V. Ammosov, V. Gapienko, et al., Nucl. Instr. and Meth. A 572 (2007) 676-681

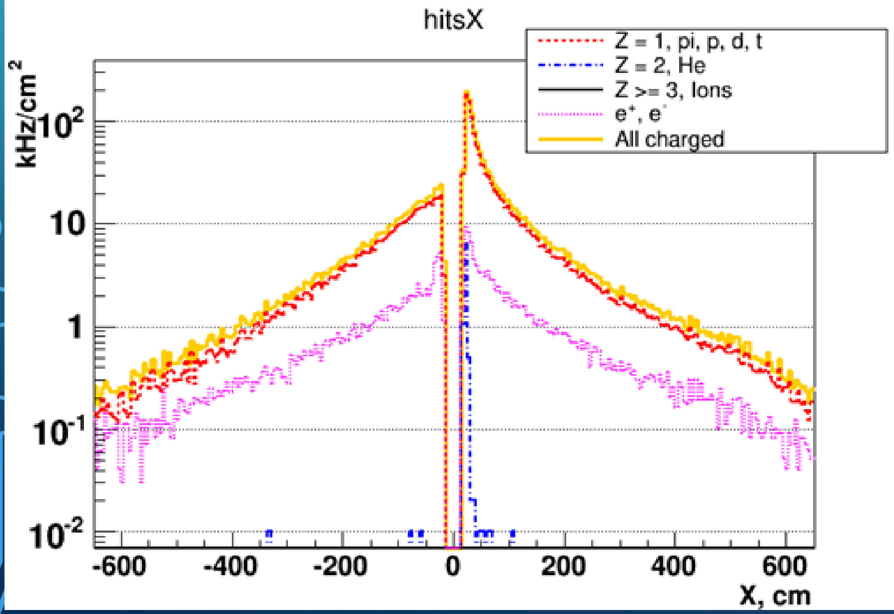
CMB TOF R&D RESULTS FOR SEMICONDUCTIVE CERAMICS AND LOW RESISTIVE GLASS

CBM TOF

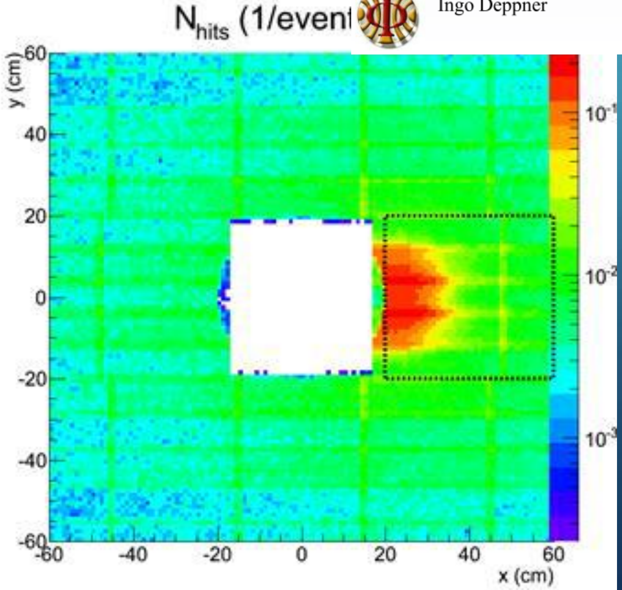




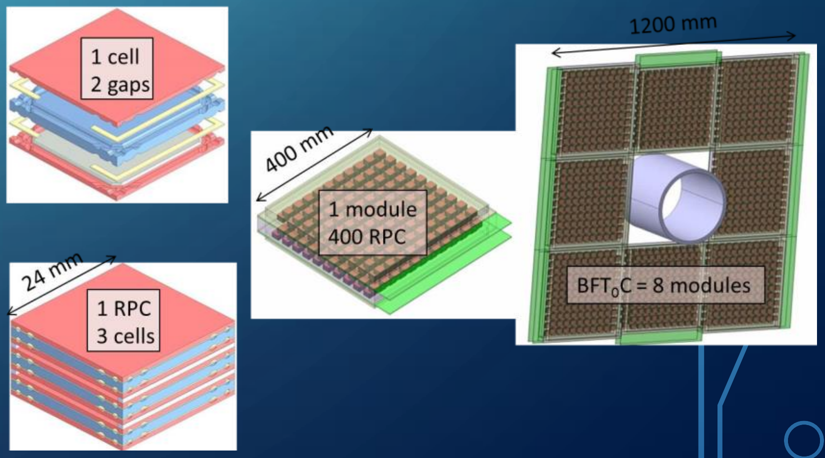
CBM
TDR ToF wall layout
CBM ToF
M1 M2 M3 M4 M5 M6
• 6 types of modules (M1 – M6) only
• A module contains several MRPC counters
• Region containing counters equipped with float glass
• Region containing counters equipped with low resistive glass
• Region containing counters equipped with ceramic material
Ingo Deppner
RPC 2018
Puerto Vallarta, 19 - 23.02.2018
5



hitsX
Z = 1, pi, p, d, t
Z = 2, He
Z >= 3, Ions
e+, e-
All charged
kHz/cm2
X, cm



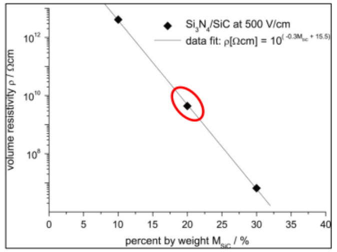
Nhits (1/event)
y (cm)
x (cm)



1 cell
2 gaps
24 mm
1 RPC
3 cells
400 mm
1 module
400 RPC
1200 mm
BFT0C = 8 modules

Si_3N_4/SIC CERAMIC

- Size ≤ 20 x 20 cm²
- Thickness d = 2 mm
- Thickness uniformity 10 µm
- Surface roughness 100 nm
- Bulk resistivity $\rho = 10^7 - 10^{12}\ \Omega\cdot cm$
- Permittivity ε_r = 10 - 20
- Rad. hardness proved at $10^{13}\ n_{eq}/cm^2$
- DC measurement (> 1 C/cm²) shows non-ohmic behavior



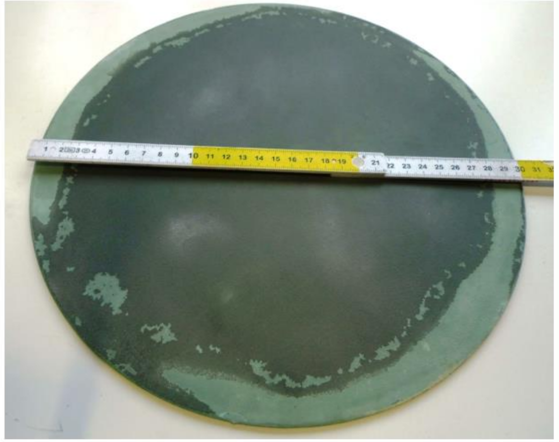
L. Naumann et al., NIM A 628 (2011) 138
A. Laso Garcia et al., JINST 7 (2012) 10012

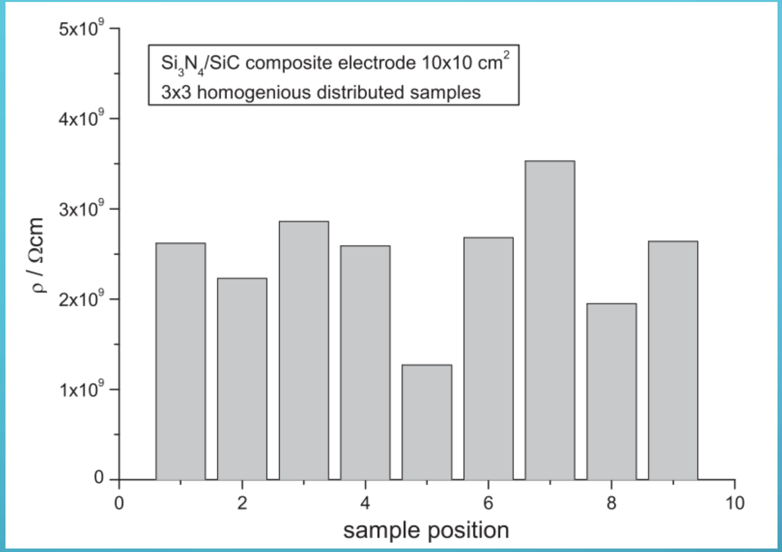
rough ceramics as sintered:

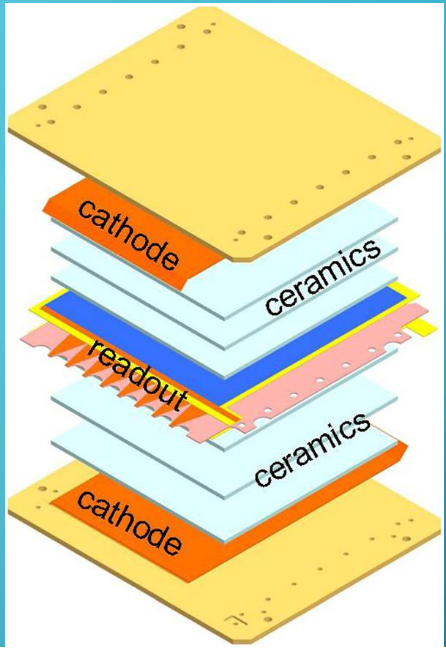
- Ø ≈ 30 cm
- d ≈ 3.5 mm

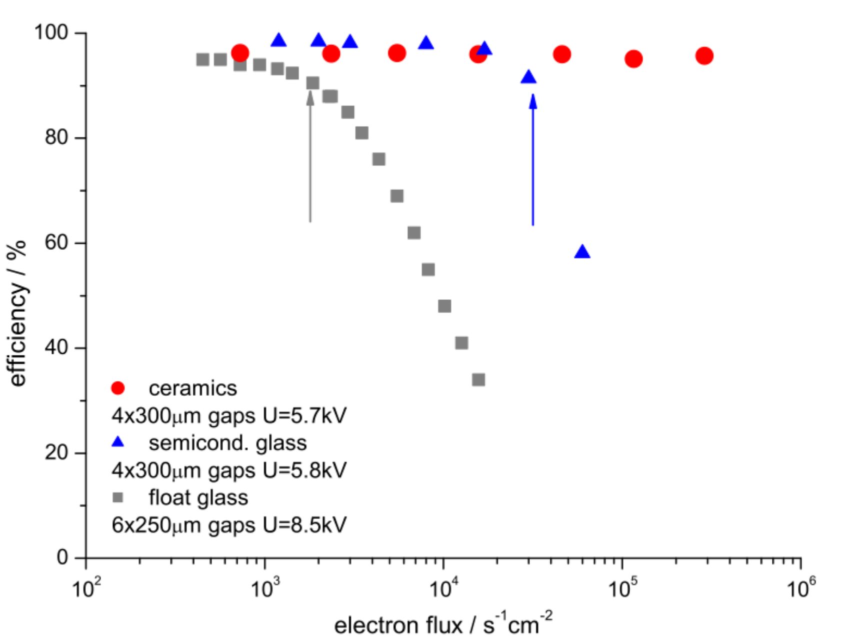
mixing ratio:

- Si_3N_4/SiC (80%/20%)





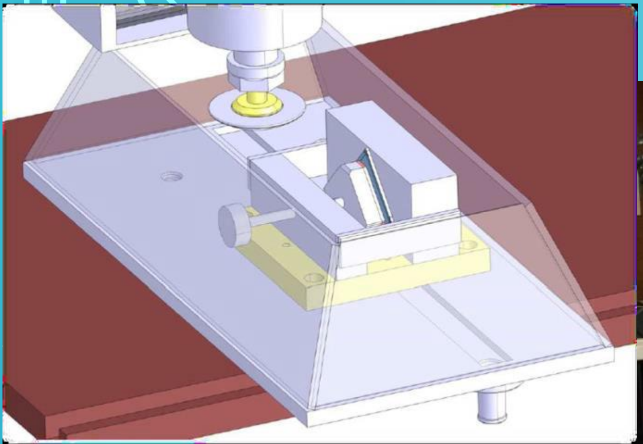


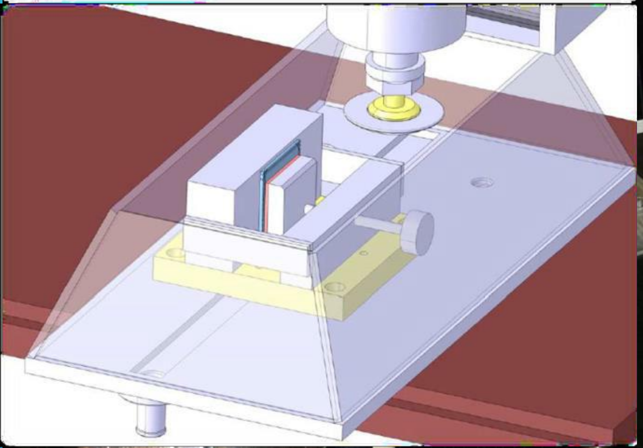


Four-gap device with 300 mm gas gaps. Resolution 110 ps for U=5.7 kV
!!!But very high level of dark current > 100 µA!!!

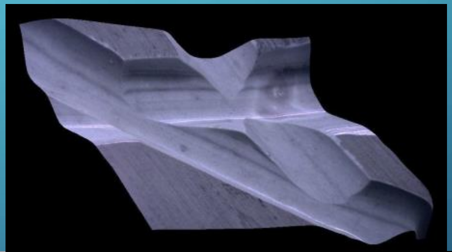
L. Naumann , R. Kotte, D. Stach, J. Wustenfeld Nuclear Instruments and Methods in Physics Research A 635 (2011) S113–S116

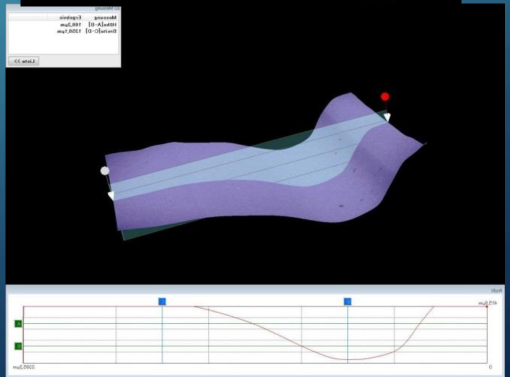
IMPROVE OF TECHNOLOGY



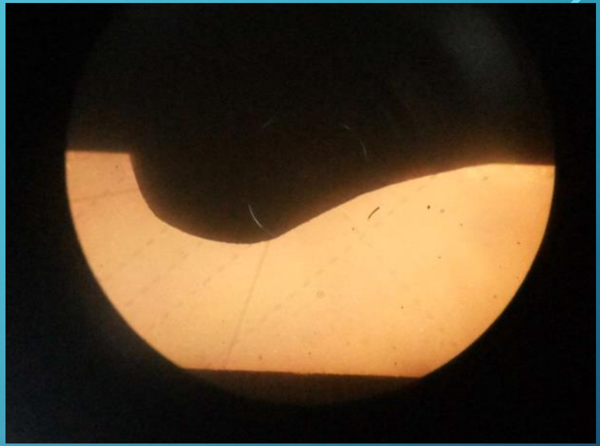


20 000 r.pm. rotation speed and 15 mm/min processing speed

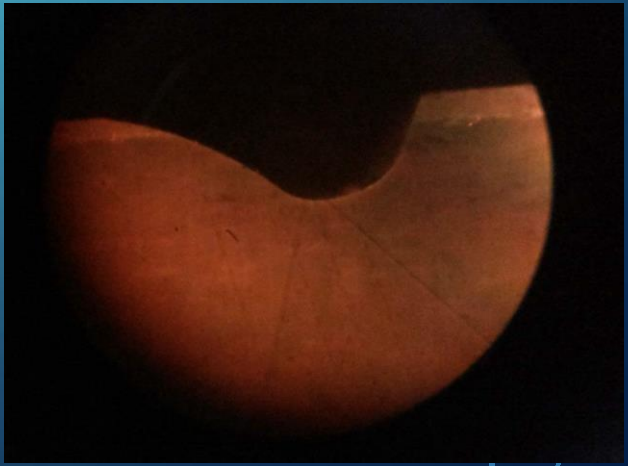




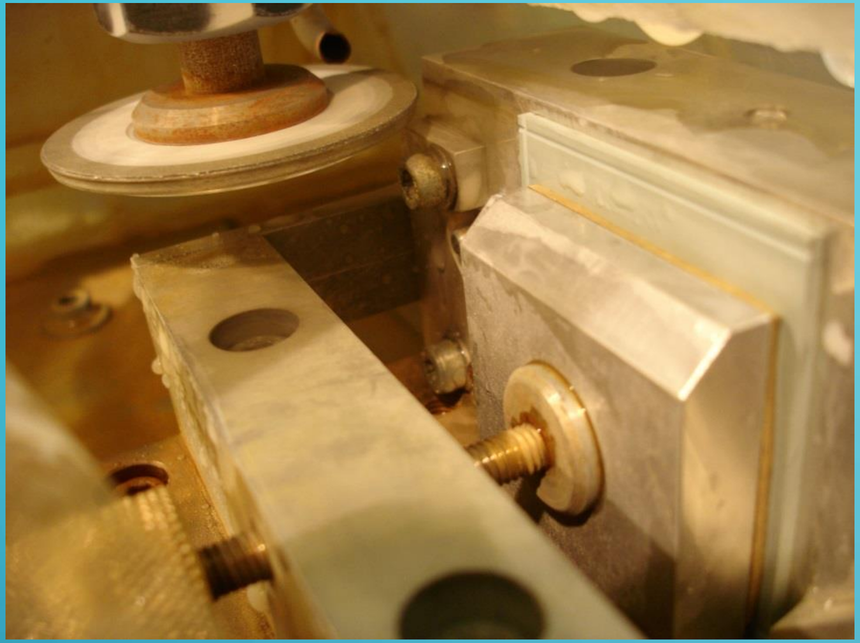
Al2O3

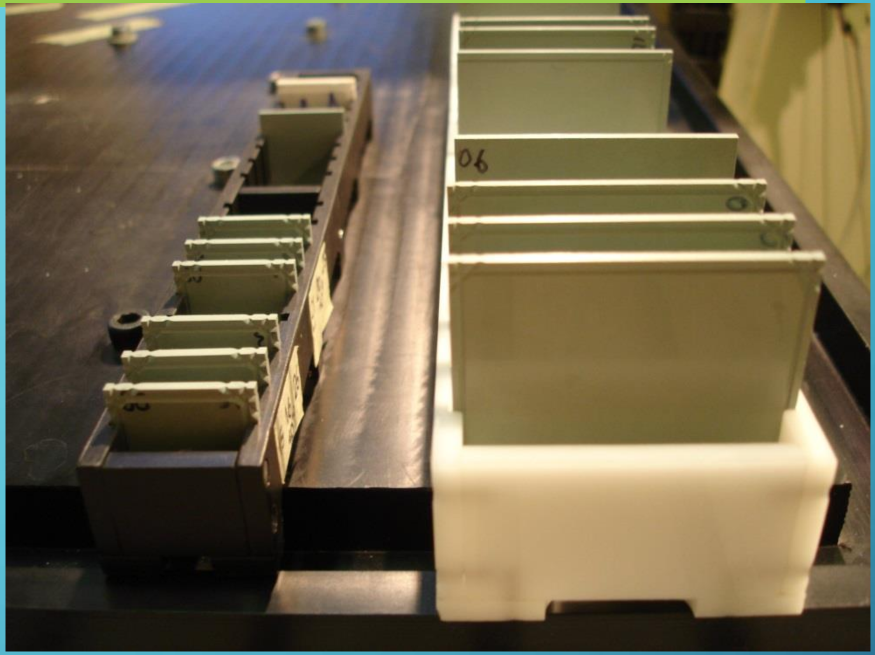


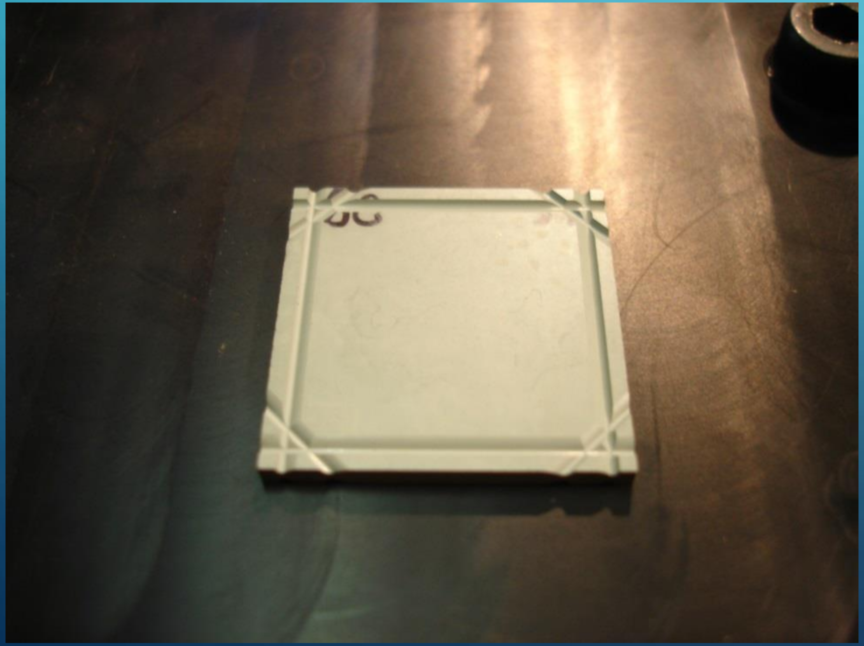
Si3N4/SiC



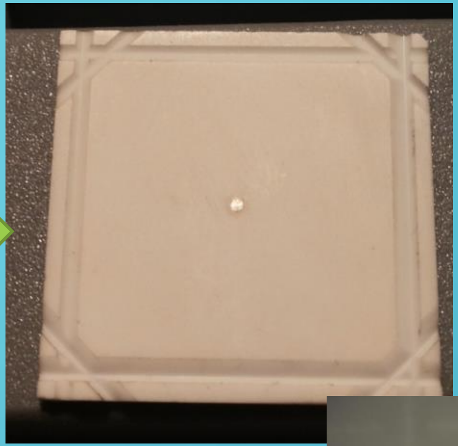
ROSSENDORF ELECTRODES 24X24 MM^2 AND 50X50 MM^2

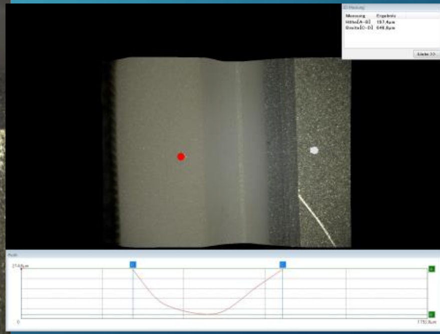






NEW AL_2O_3 ELECTRODES 24X24 MM^2(ACTIVE SIZE 20X20 MM^2)



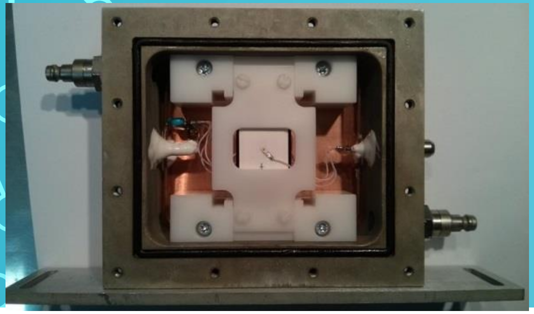


Al_2O_3 250 μm spacers

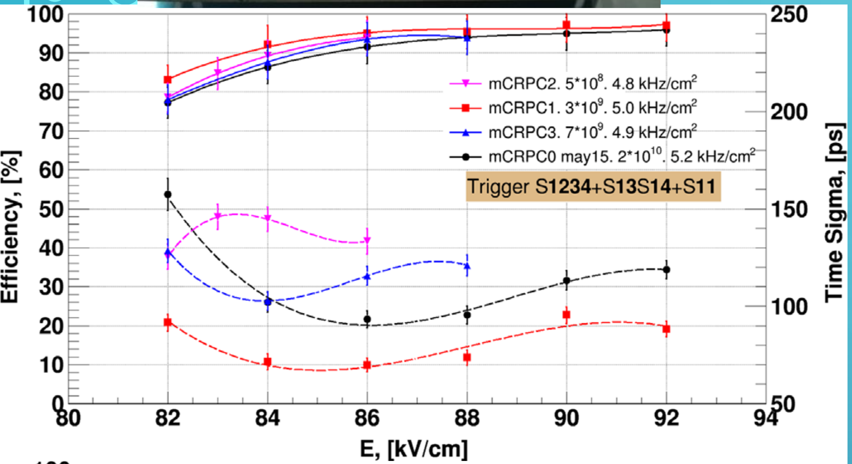
SEARCH FOR OPTIMAL RESISTANCE USING CERAMIC ELECTRODES

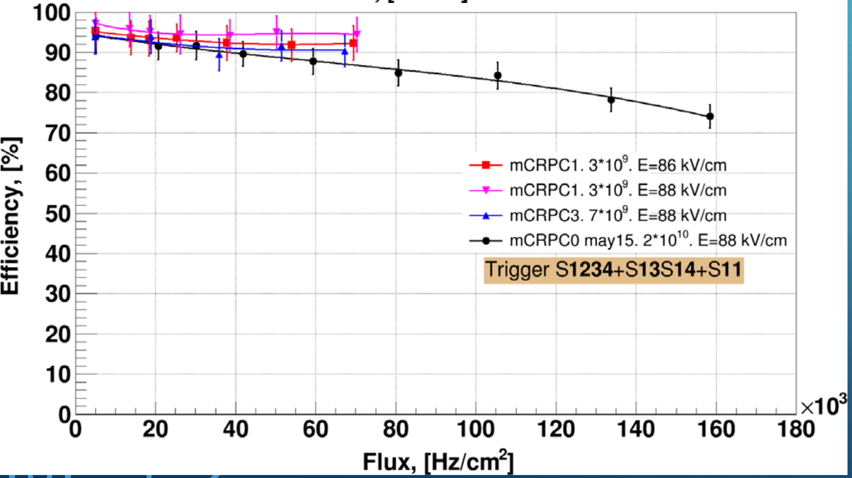
ITEP

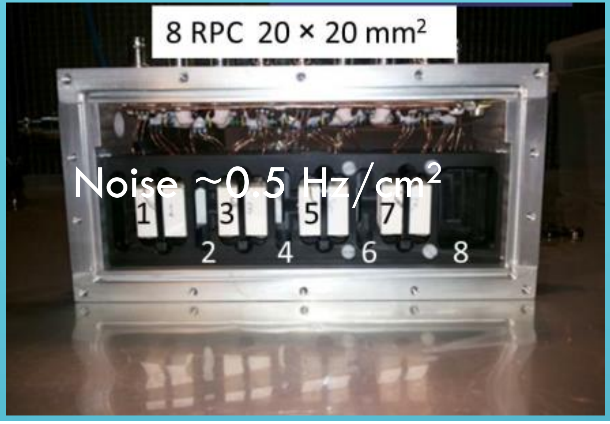
SEARCH FOR MINIMAL POSSIBLE RESISTANCE

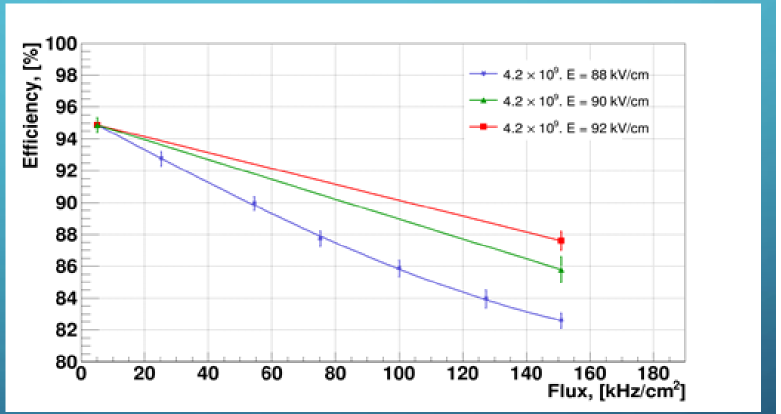


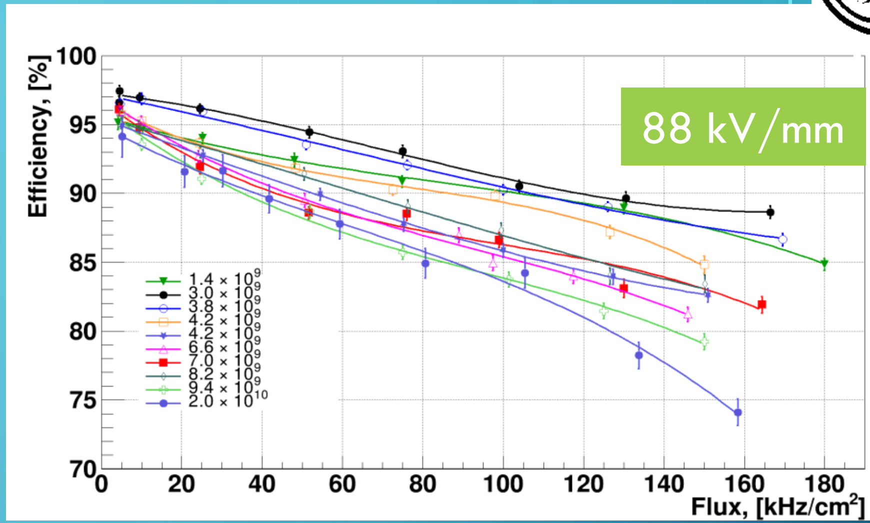
Measurements done with MAX3760

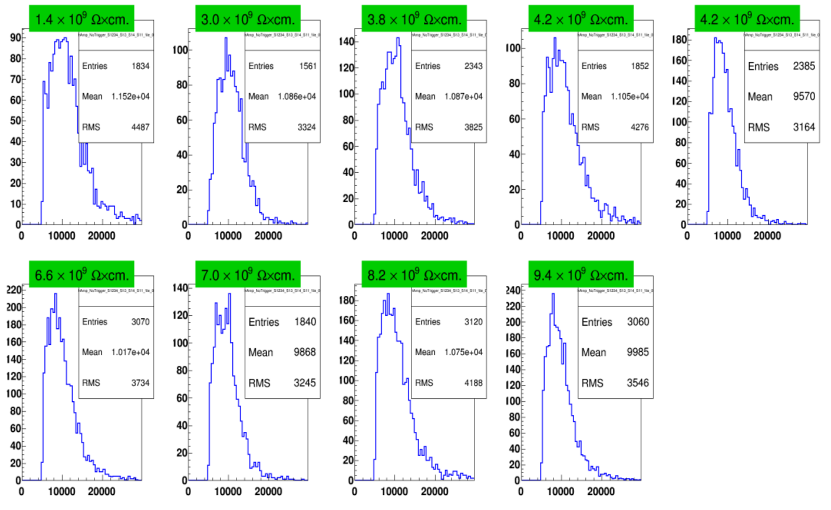










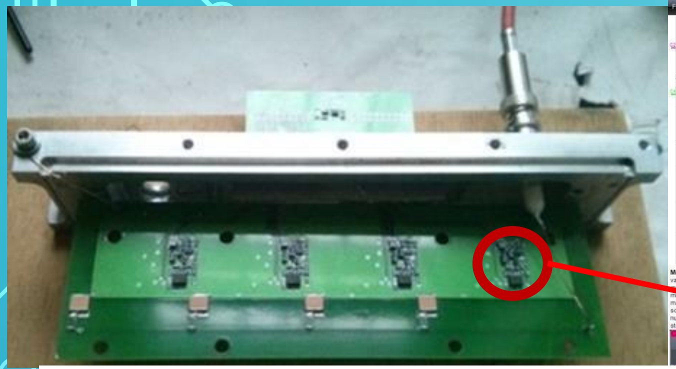


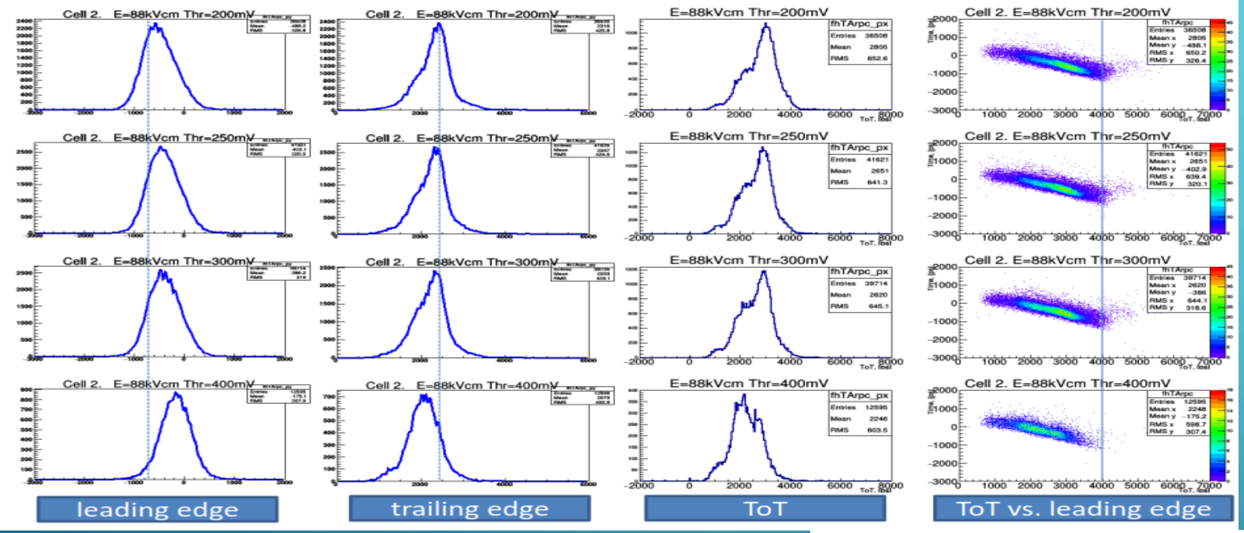
We selected value of resistance 4*10^9 Ohm*cm as minimal

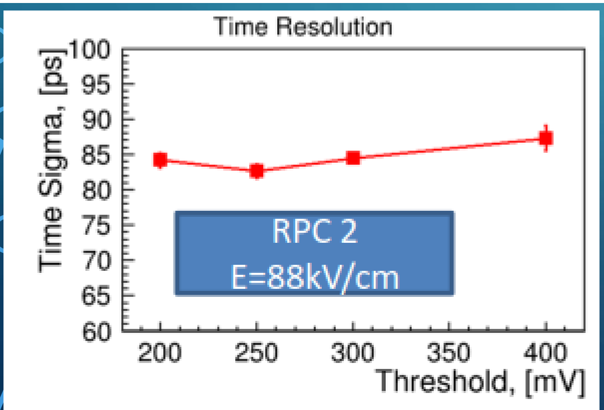
Nuclear Instruments and Methods in Physics Research A 845 (2017) 203–205

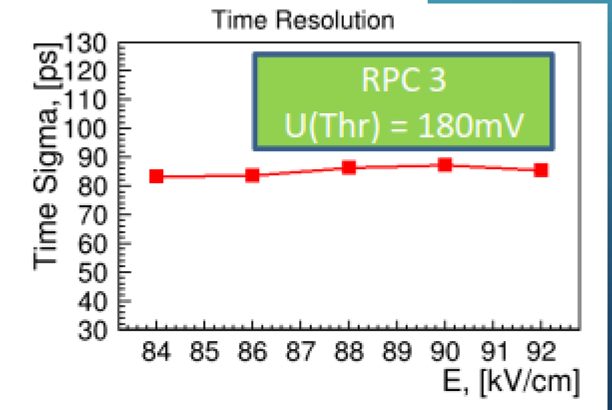
Journal of Physics: Conf. Series 798 (2017) 012136

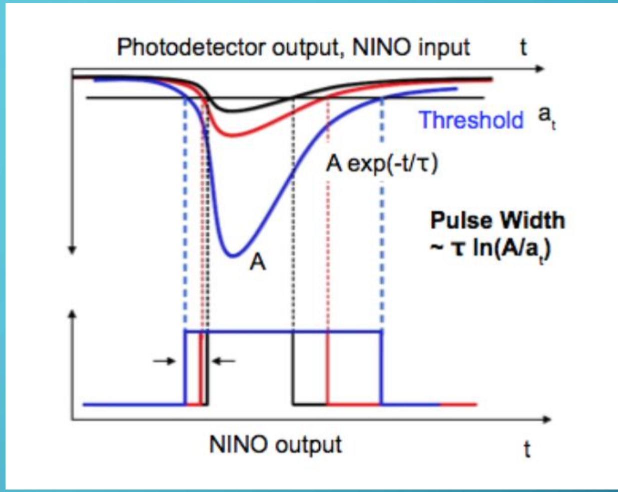
TESTS WITH PADI ELECTRONICS

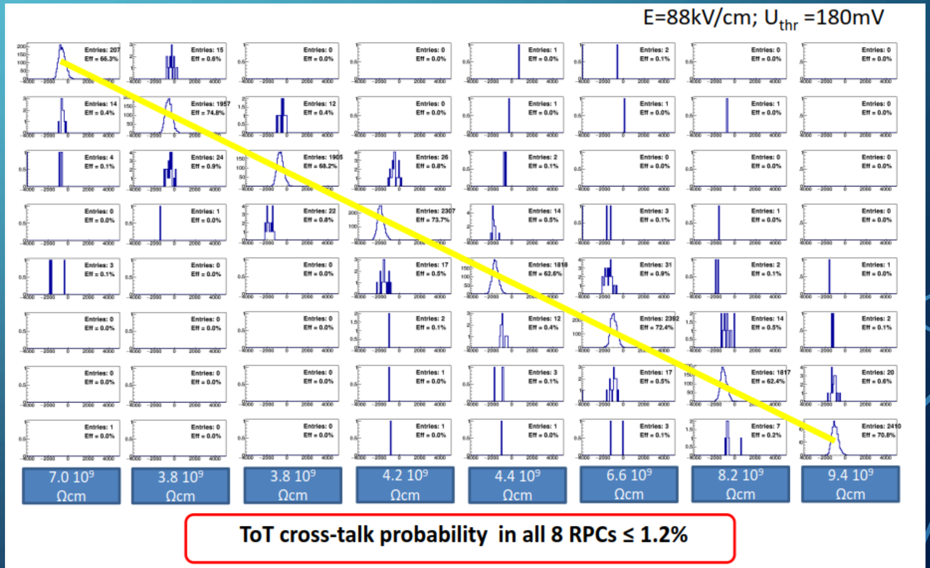












ITEP

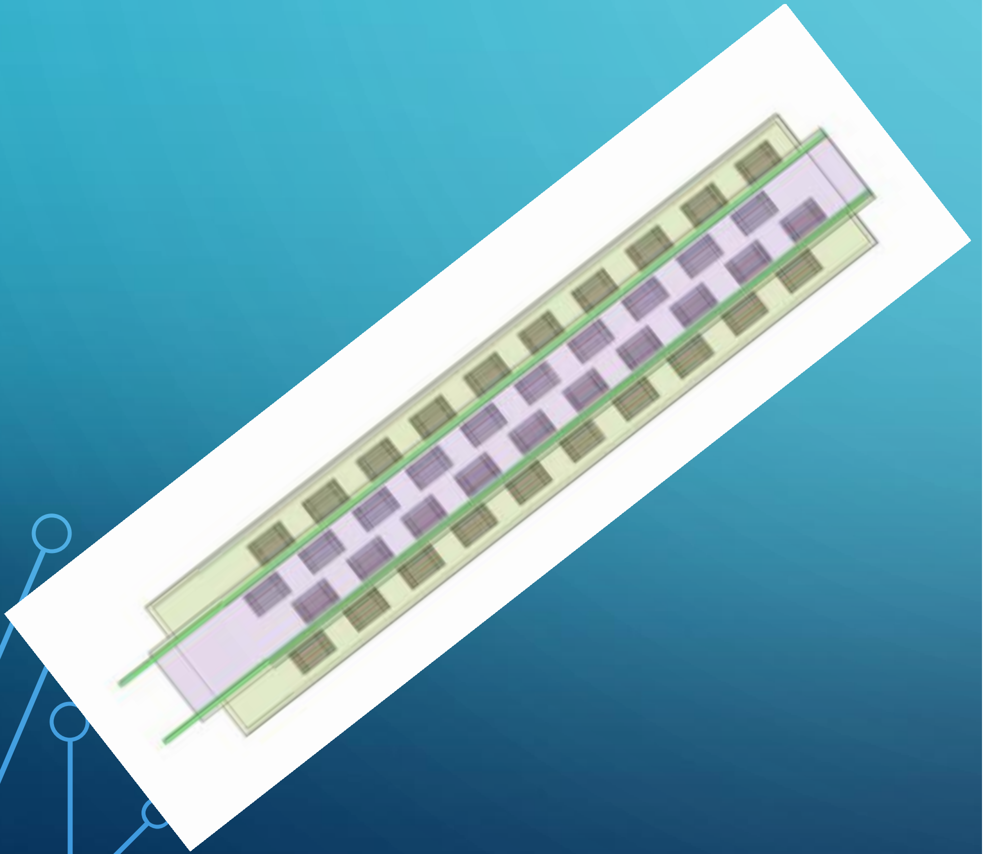
BFTC preproduction module

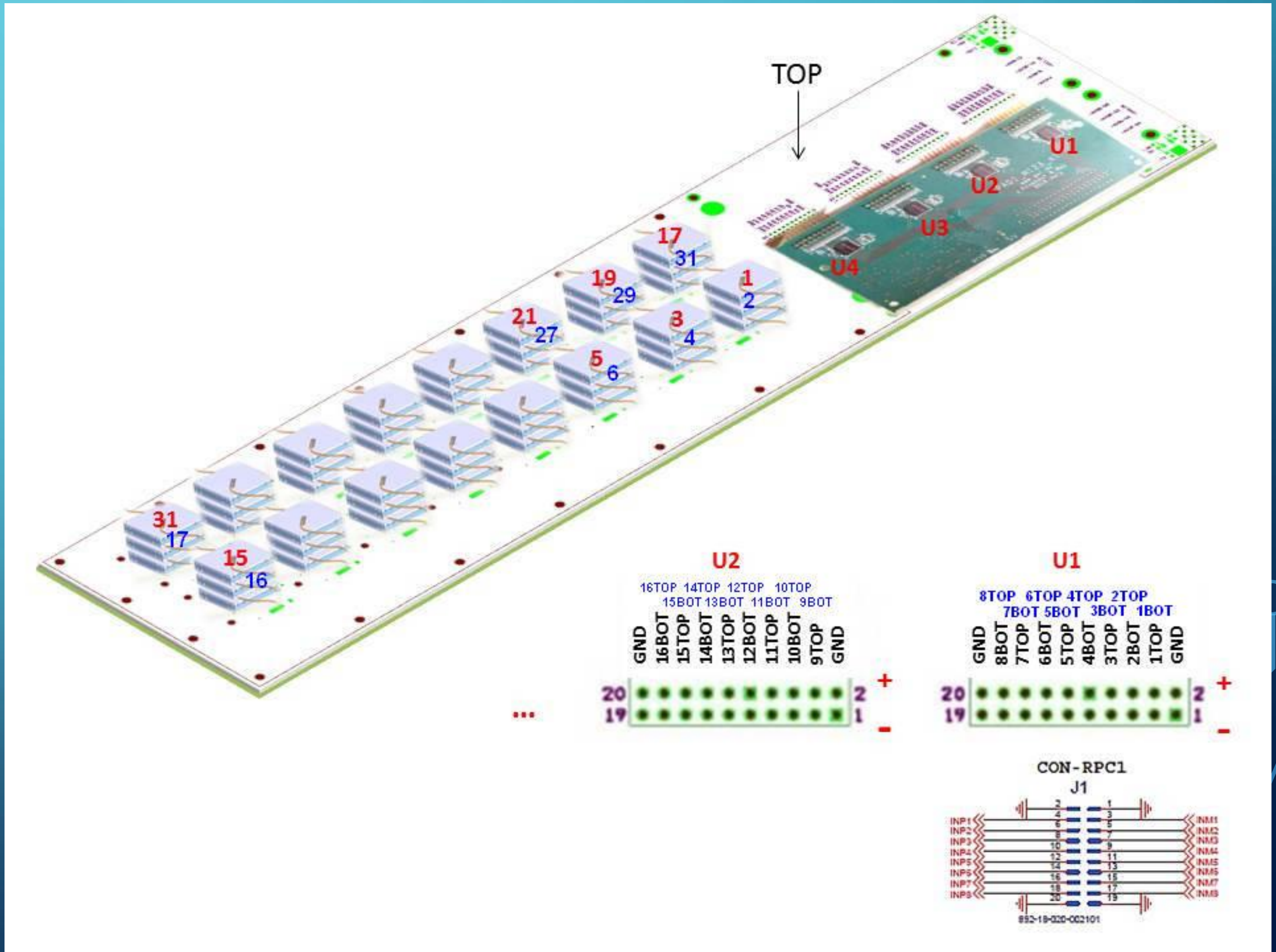
ITEP

Preproduction BFTC module is being developed.

64 channels, 32x8 cm active area. Two identical PCB, but one is flipped.

PCB board design is finished.





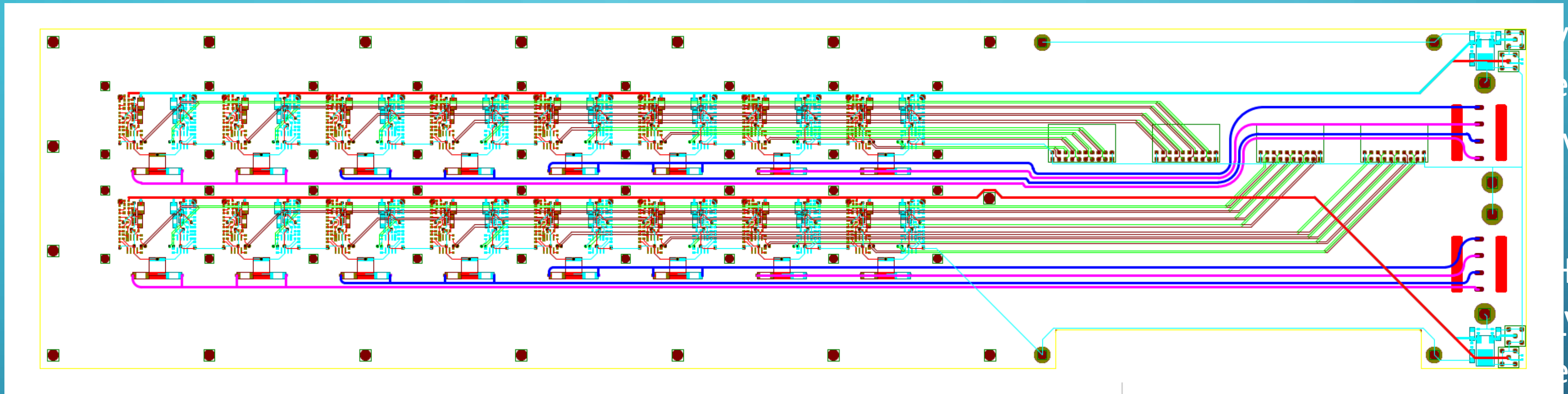
PCB layout

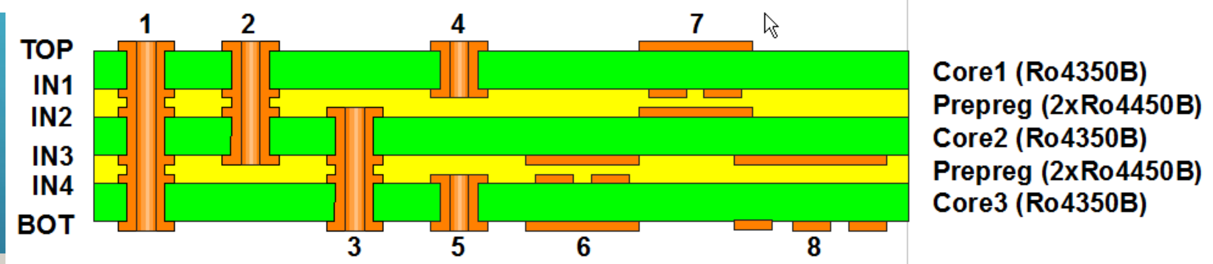
ITEP

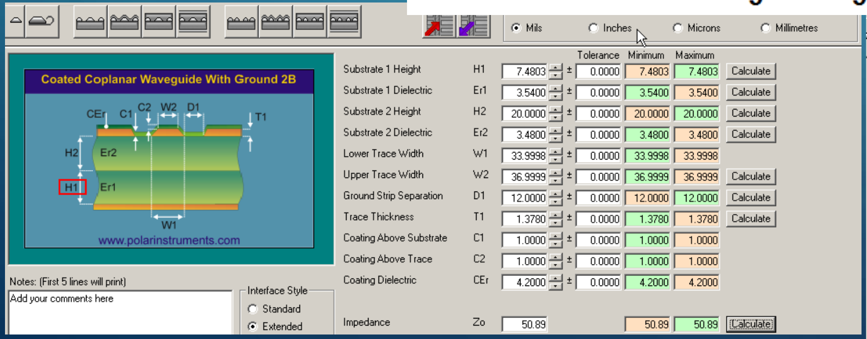
100 Ohm lines to transport signals to PADI.

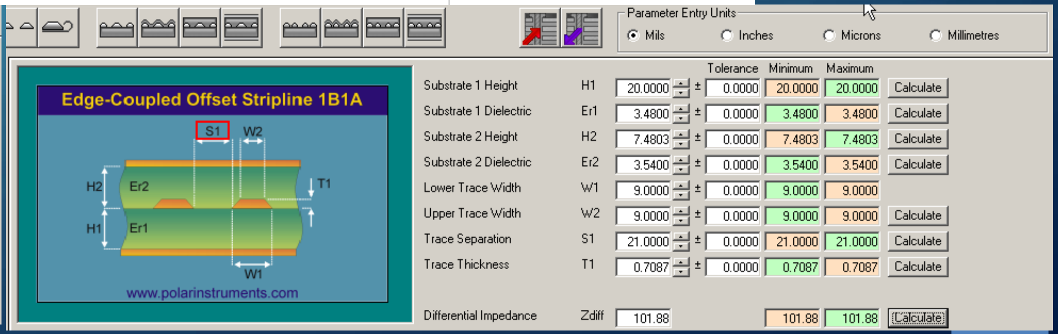
50 Ohm lines for test pulse.

6 layers PCB. 8 lines for HV (4 cells per one HV channel).

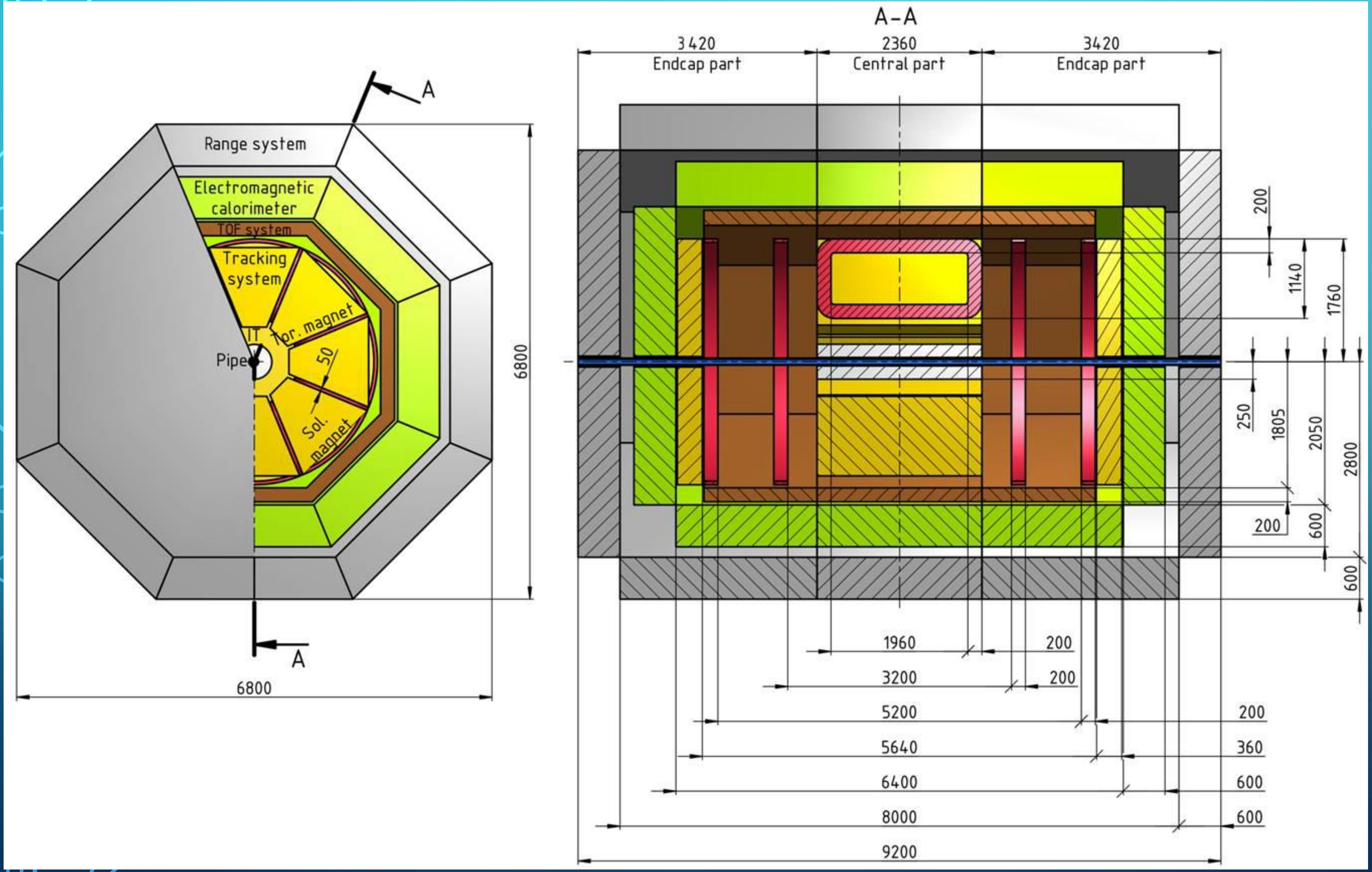








SIZE FOR PID SYSTEM



As we see PID should be thin
Not thick than 50 cm!

SIMULATION DONE SO FAR (BY SEREGEY KISELEV)

ITEP

URQMD p+p at maximum energy

No magnetic field

Simple plane at barrel and forward parts

=> mult. per ev.: 12.40 all, 7.78 charged (2.92 TOFbarrel, 4.86TOFend-cups)

$\Rightarrow$ TOF: barrel: S=6.33 * 10^5 cm^2, 4.61 * 10^{-6} tracks/cm^2,

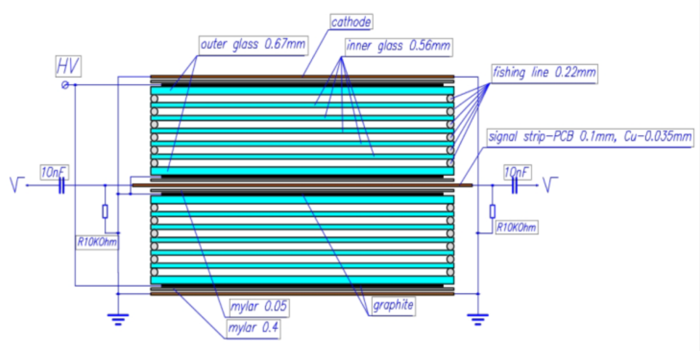
$\Rightarrow$ end-cups: S=2.04 *10^5 cm^2, 2.39*10^{-5} tracks/cm2,

===> at sigma_pp=40.0 mb and Lumi=2.0e^{32} cm^{-2} s^{-1} -----> 8.0e^{06} coll. per sec

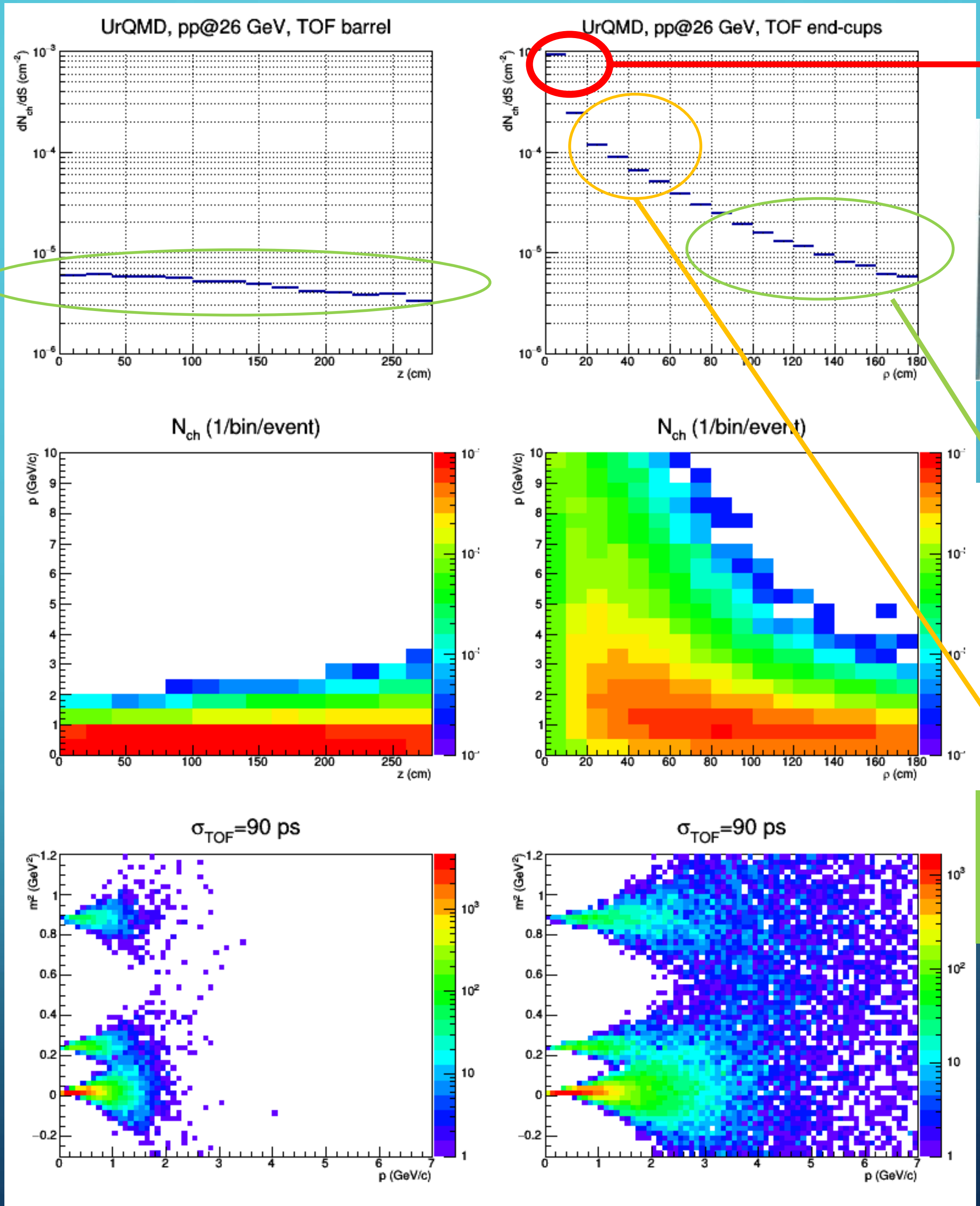
→ ~3 MHz (should be free-streaming readout)

$\sqrt{s}$, GeV	σ_{tot}, mb	Charged multiplicity	Neutral (γ) multiplicity
13	38.4	5.9	4.6 (3.8)
20	38.9	7.2	6.0 (5.0)
26	39.7	7.8	6.5 (5.5)

Conceptual design of the Spin Physics Detector
(For comparison)

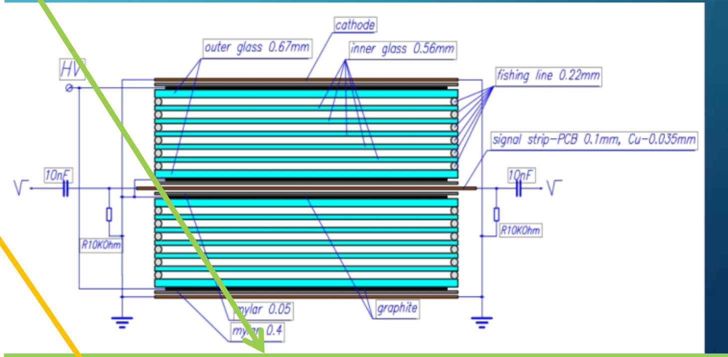


Strips readout (float glass)



>35 kHz/cm²

+



Pads +strips readout (float + low resistive glass)

+

HMPID (PANDA like DIRC?)

CONCLUSION+PLANS

ITEP

After very first simulation:

- We can use different TOF-RPC technic and we need to have HMPID:

1. Forward part Ceramic + MRPC (low resistive glass with pads and strips) + MRPC (float glass with strips)
2. Barrel part: MRPC (float glass with strips)

- At next step need more realistic simulation and production of first modules:

- Ceramic:

1. We have to estimate maximum cell size to avoid double hit
2. We need to know beam pipe diameter – to define maximum rate we can have
3. We have to understand maximum input frequency allow for FEE and TDC (rate per cm^2 * cell area)
4. Mass-production of Si_3N_4/SiC was confirmed! German grant for HZDR-IKT(Dresden) started from 1 of June2019 – liquid phase and hot pressing. Al_2O_3 will be produces in Dubna technologic park by C-Component.

- Glass chambers

Fixed value of resistance ($5*10^{10}$-$1*10^{11}$) Ohm*cm and maximal size 30x32 cm^2

1. Chamber design : no problem for float glass (even 1.2 meter long like in ALICE), but need to know maximum size for low resistive – if still maximum size about 30 cm?
2. Need to precise define region with rate < 500 Hz/cm^2 to find border between low resistive and float glass

- All of us should think what kind of HMPID we can use from point of view physics/cost
- First ceramic prototype we are going do design just after we defined cell size. PCB will be the same as for CBM BFTC.

THANK YOU FOR ATTENTION!