Status of the Beam-Beam (BeBe) monitoring detector for MPD-NICA experiment

- MexNICA Group
- April 12 2018

We report on the current status of the simulations to be used as an input for the proposal of a **Beam-Beam Monitoring Detector (BeBe)** for the MPD-NICA Project at JINR, as well as on the **prospects for theoretical and phenomenological studies**

MexNICA

- Mexican consortium of six institutions:

BUAP, CINVESTAV, UAS, UNAM, UNISON, UCOL

- We plan to join effort for the MPD-NICA contributing with the construction of a Beam-Beam (BeBe) monitoring detector as well as with theory/phenomenology and data analysis.

MexNICA

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I. Dominguez (Experiment/Simulations)
W. Bietenholz (Theory/Lattice)
L. Montaño (Experiment/Hardware)
E. Moreno (Experiment/Hardware)
M. Palomino (Experiment/Hardware)
M. Rodríguez (Experiment/Simulations)
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Beam-Beam monitoring detector for MPD-NICA

Main role: to produce a signal for the MPD Level-0 trigger.

Requirements

- radiation hard
- time resolution of order 50 ps

minimum required information

- time: in this sense, BeBe is a counter detector

Impact on MPD-NICA studies

- high: being a trigger system, BeBe will contribute to the selection of physical processes with the generation of a trigger signal (L0 level). It can be suitable to discriminate beam-gas interaction and background.

Beam-Beam monitoring detector for MPD-NICA

Main role: to produce a signal for the MPD Level-0 trigger.

Requirements

- radiation hard
- time resolution of 50 ps

minimum required information

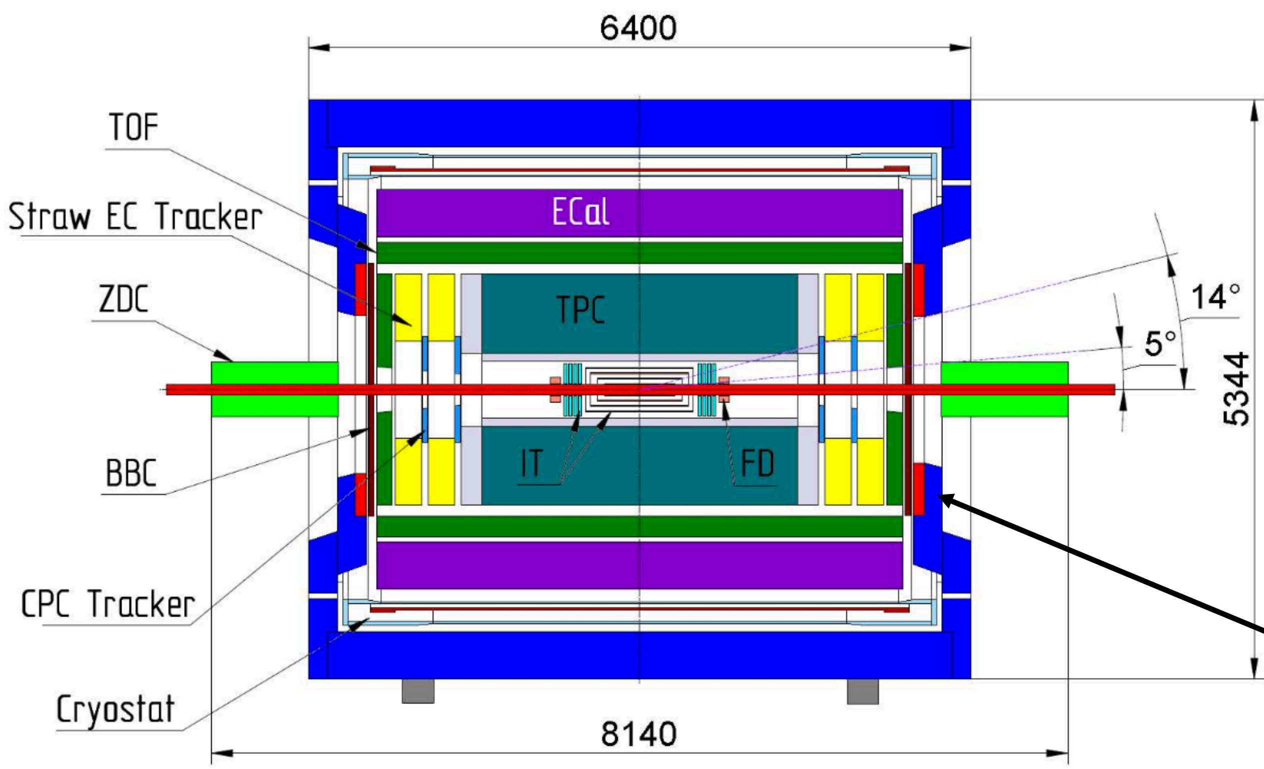
additional required information

- time: in this sense, BeBe is a counter detector + charge

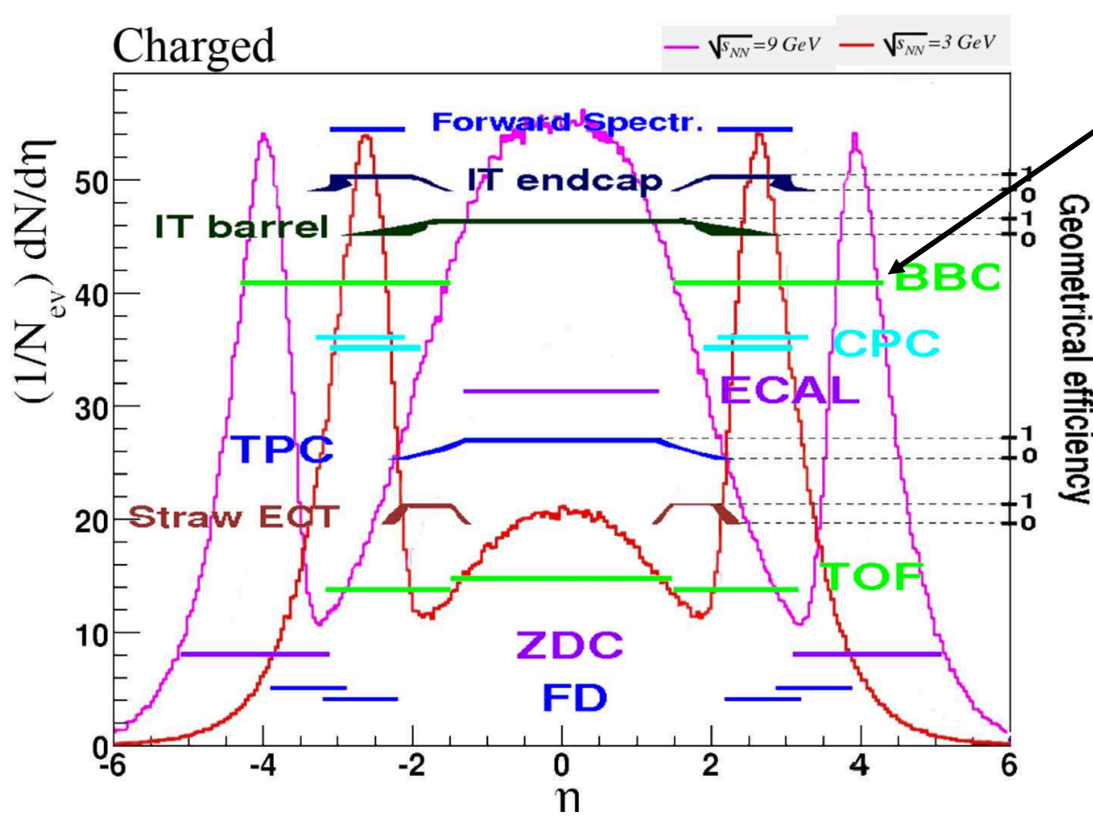
Impact on MPD-NICA studies

- high: being a trigger system, BeBe will contribute to the selection of physical processes with the generation of a trigger signal (L0 level). It can be suitable to discriminate beam-gas interaction and background.

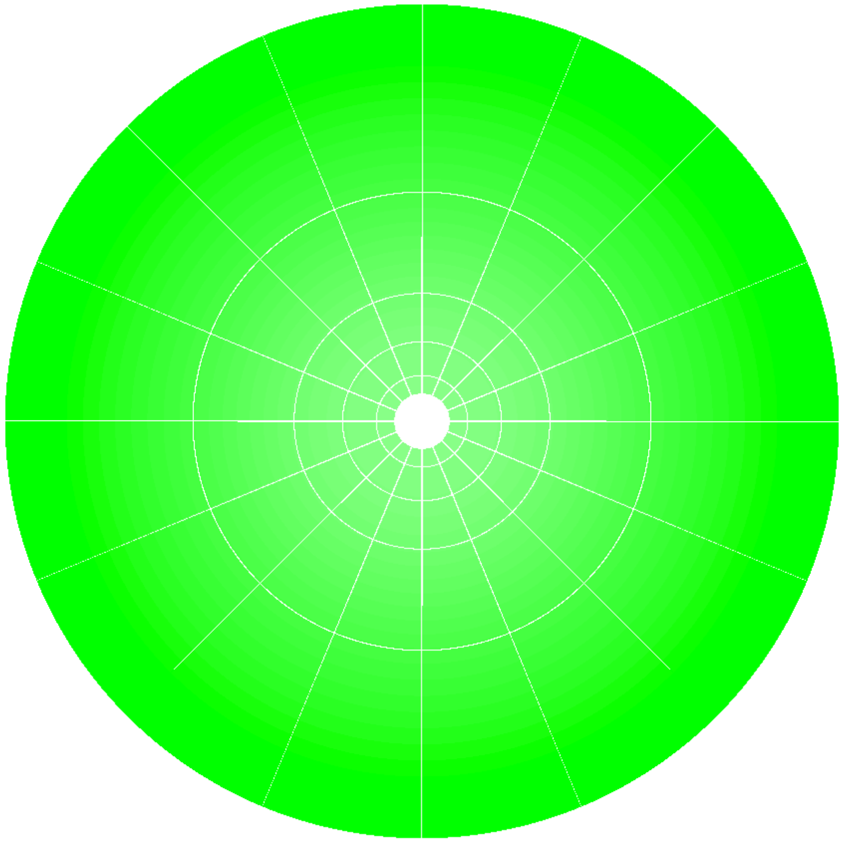
- can be used to setup trigger classes for centrality percentile + veto system for diffractive and electromagnetic processes
- BeBe could be able to reconstruct the multiplicity per cell (uselful for multiplicity reference estimators), reaction plane.
- BeBe could be used for dedicated studies on flow and event-by-event fluctuations



the acceptance of BeBe is expected to be 1.5 < |η| < 4.5. Not covered by the MPD-TPC

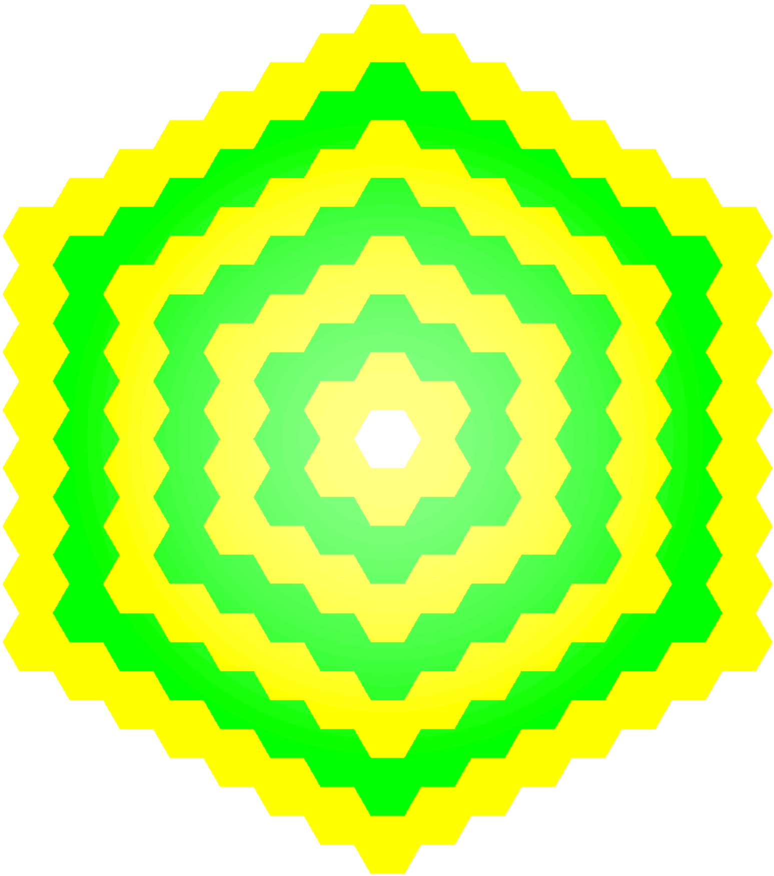


Beam-Beam monitoring detector geometry



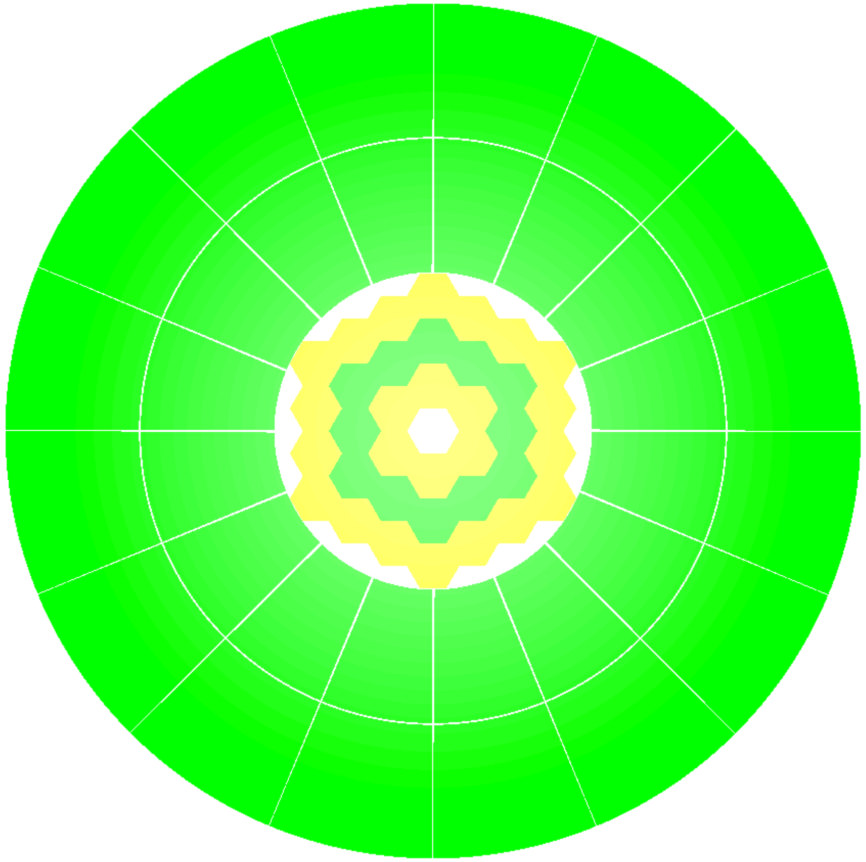
“pie slices” (LHC)

σ_{t1} = 1000 ps



“panal” (RHIC)

σ_{t2} = 100 to 170 ps



“hybrid” (LHC-RHIC)

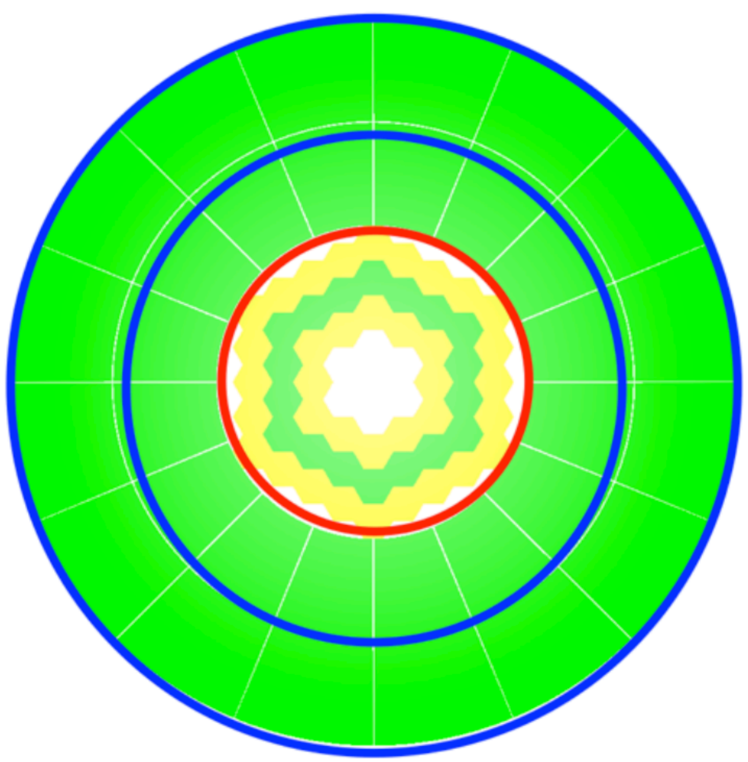
σ_{t3} = $0.5*\sigma_{t2}$ ps ?

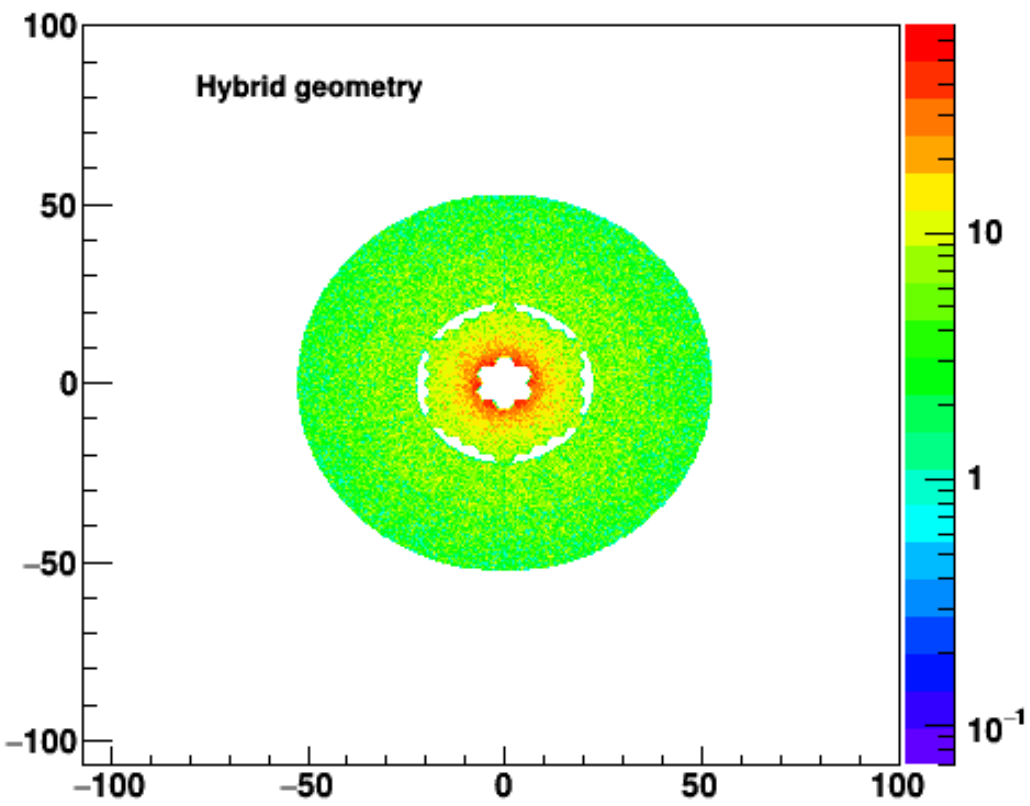
Beam-Beam monitoring detector geometry

To fulfill the trigger requirements of MPD, we propose the BE-BE geometry as follows

Inner part: Made of 54 hexagonal cells, 50 mm in height, arranged in three rings.

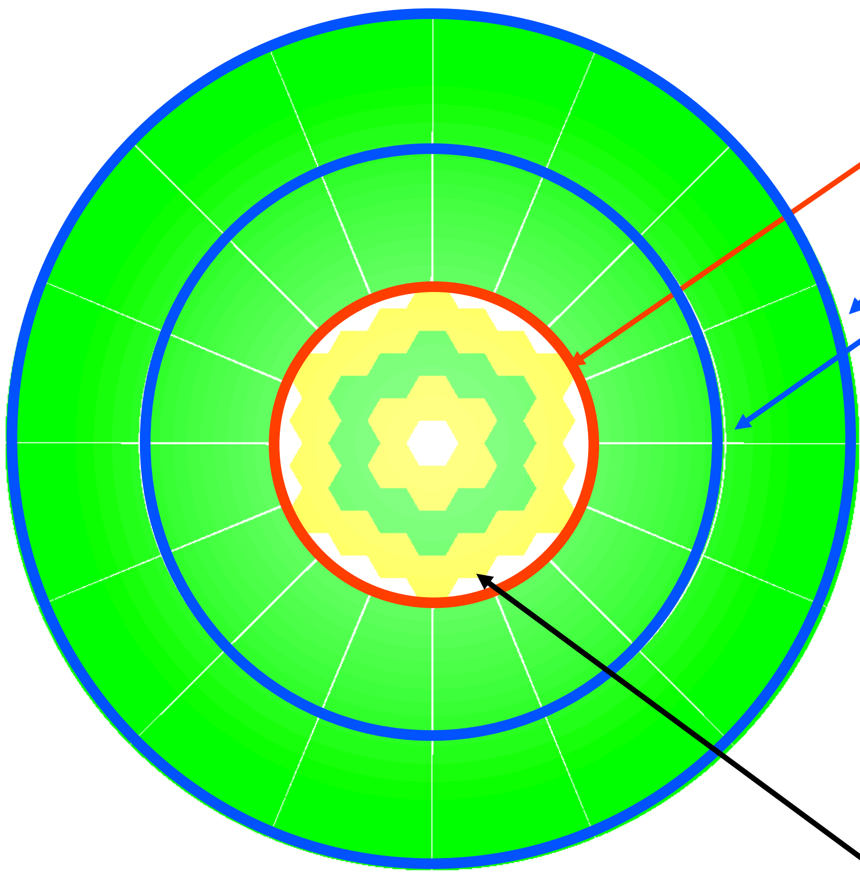
Outer part: Made of two rings segmented in 16 cells. These rings could be used to optimize the event plane resolution and centrality determination in heavy ion collisions.





Beam-Beam monitoring detector geometry

To fulfill the trigger requirements of MPD, we propose the BE-BE geometry as follows



the trigger signal will be generated by the inner part of the detector

the two outer rings will cover the pseudorapidity range needed by MPD:

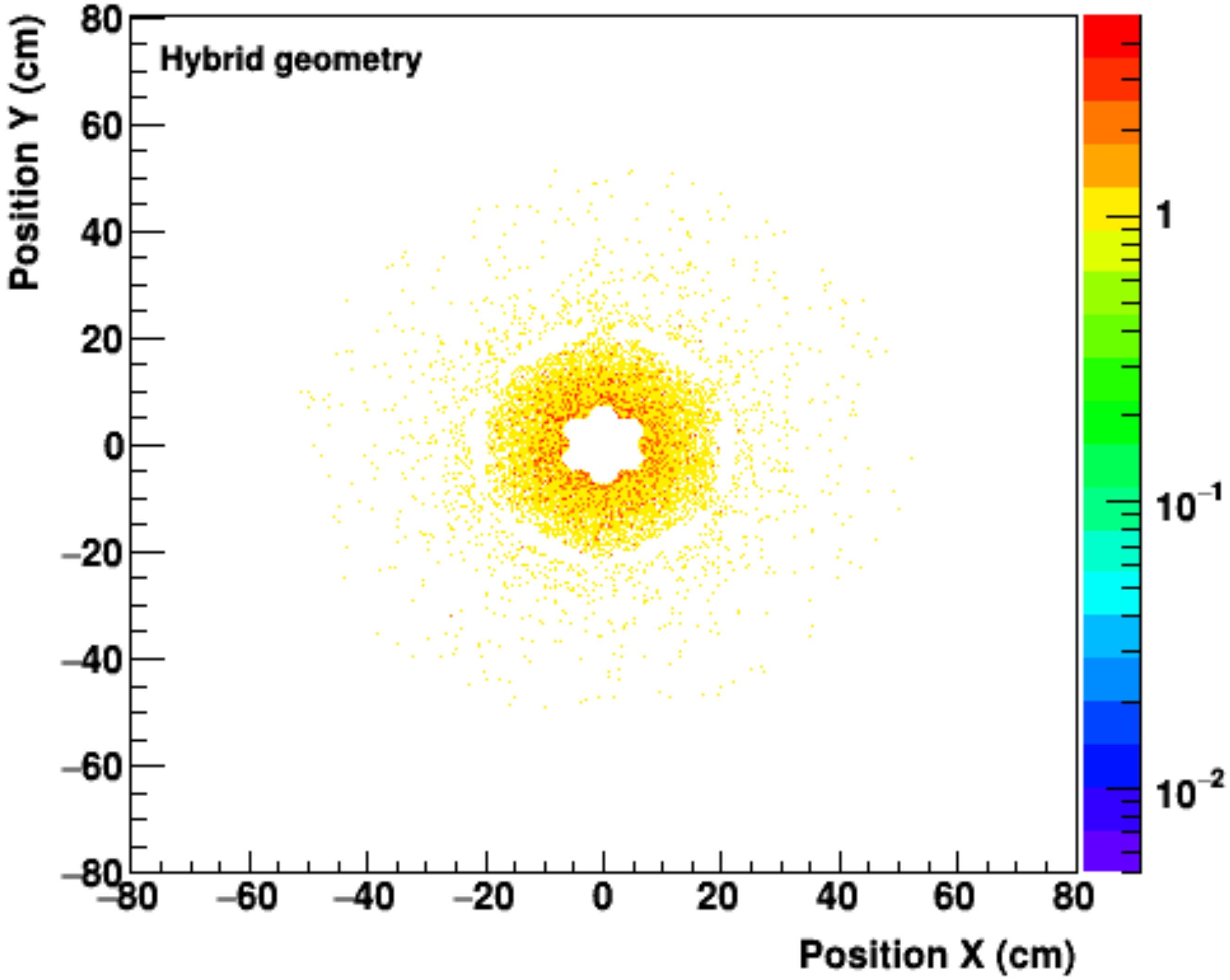
- **beam monitoring**
- **multiplicity:**
  - **centrality**
  - **event plane**

Hybrid (LHC-RHIC)

σ_{t3} = 0.5*σ_{t2} ps ?

Dead zones.

Beam-Beam monitoring detector geometry



The size of the hexagon cells was optimized according to the distribution of hits from the first particle reaching the detector. Most of these particles reach the inner part of BE-BE on either side for Au-Au Collisions. The figure shows that most of the first particles hitting BE-BE will be distributed along the innermost ring of small hexagons.

Simulation details
Number of generated events: 40 000, Minimum Bias
Enabled detectors: TPC, BE-BE
System: Au-Au
Energy in the center of mass: 11.5 GeV
Magnetic Field: 0.5 T

Beam-Beam monitoring detector geometry

Based on these results, we assume that the BE-BE trigger signal will be given by any hit on the inner part within the hexagonal cells for Au-Au collisions.

Region	Fraction (%)
Hex_{sideA} & Hex_{sideC}	81.1
Pie_{sideA} & Hex_{sideC}	4.7
Hex_{sideA} & Pie_{sideC}	5.0
Pie_{sideA} & Pie_{sideC}	1.1
Hex_{sideA} || Hex_{sideC}	95.8
Pie_{sideA} || Pie_{sideC}	13.1
Hex_{sideA} || Pie_{sideC}	90.5
Pie_{sideA} || Hex_{sideC}	90.7

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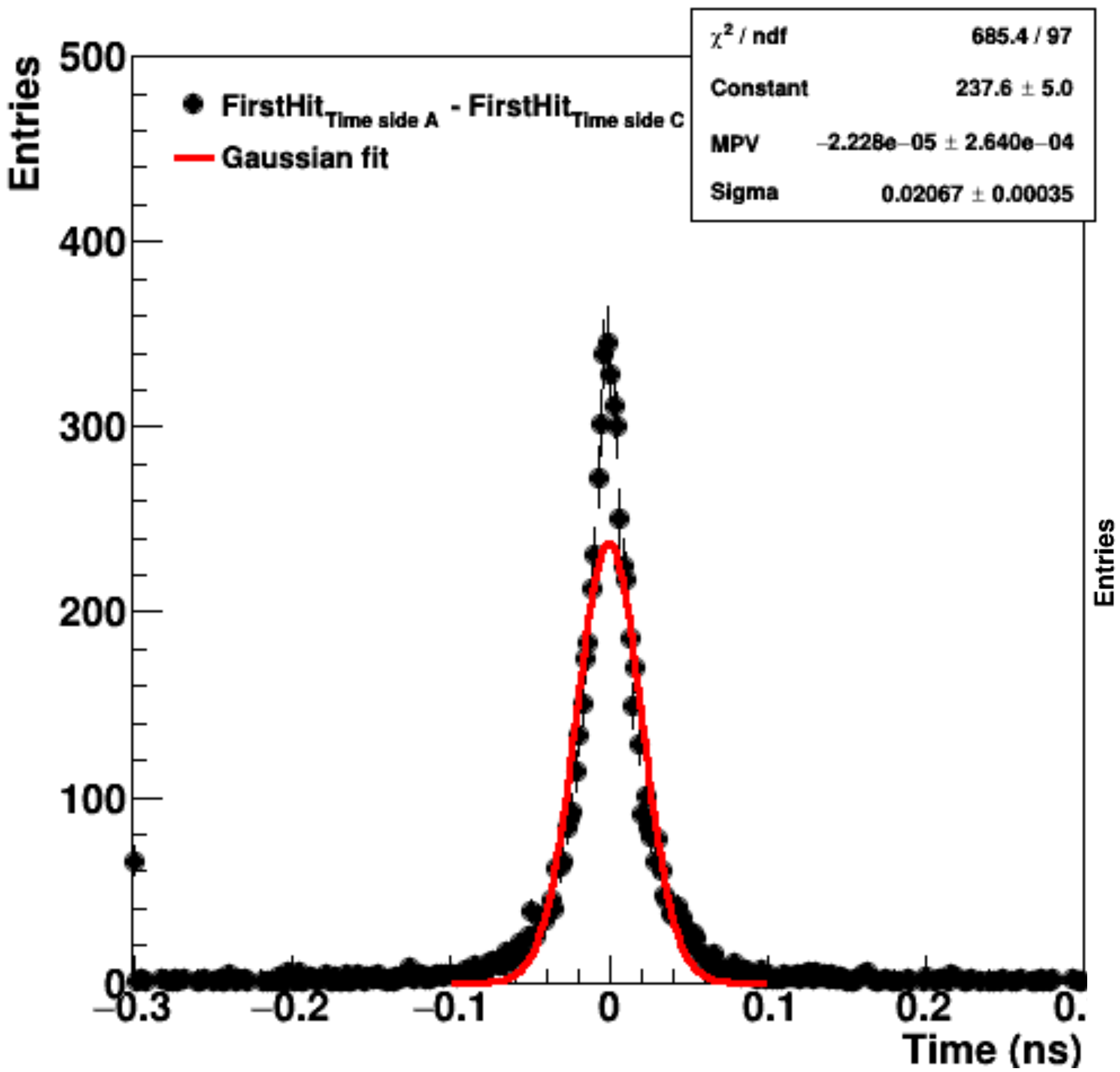

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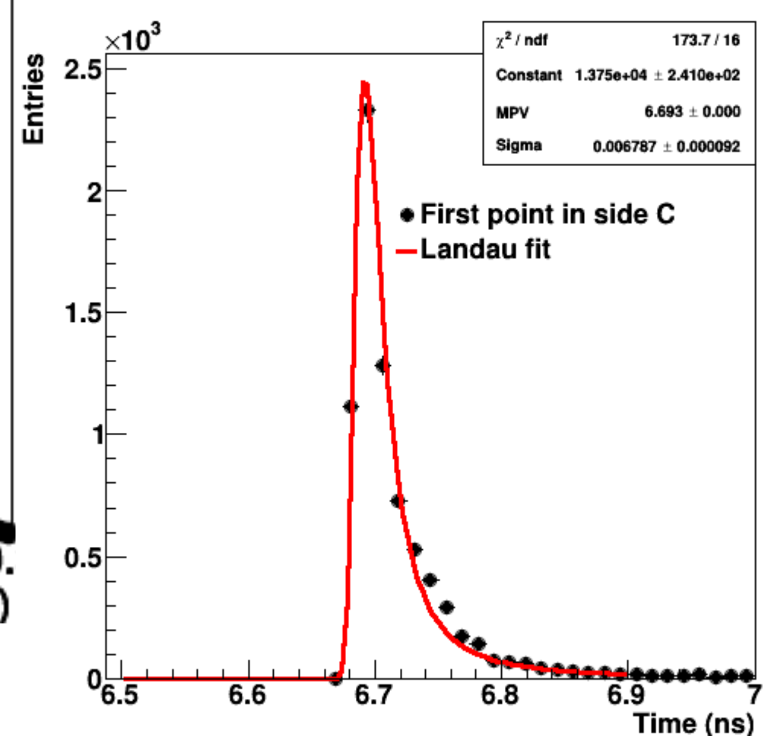

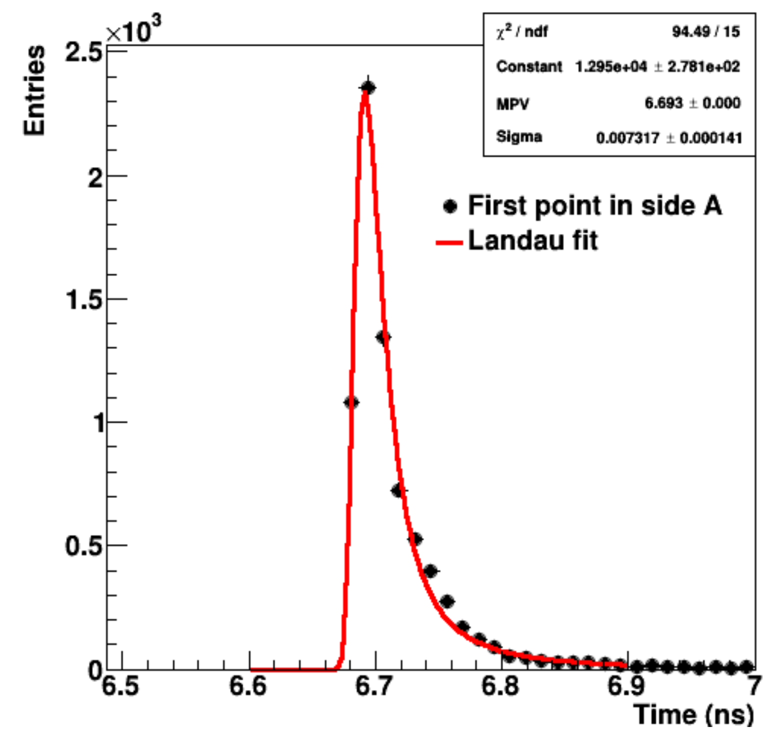

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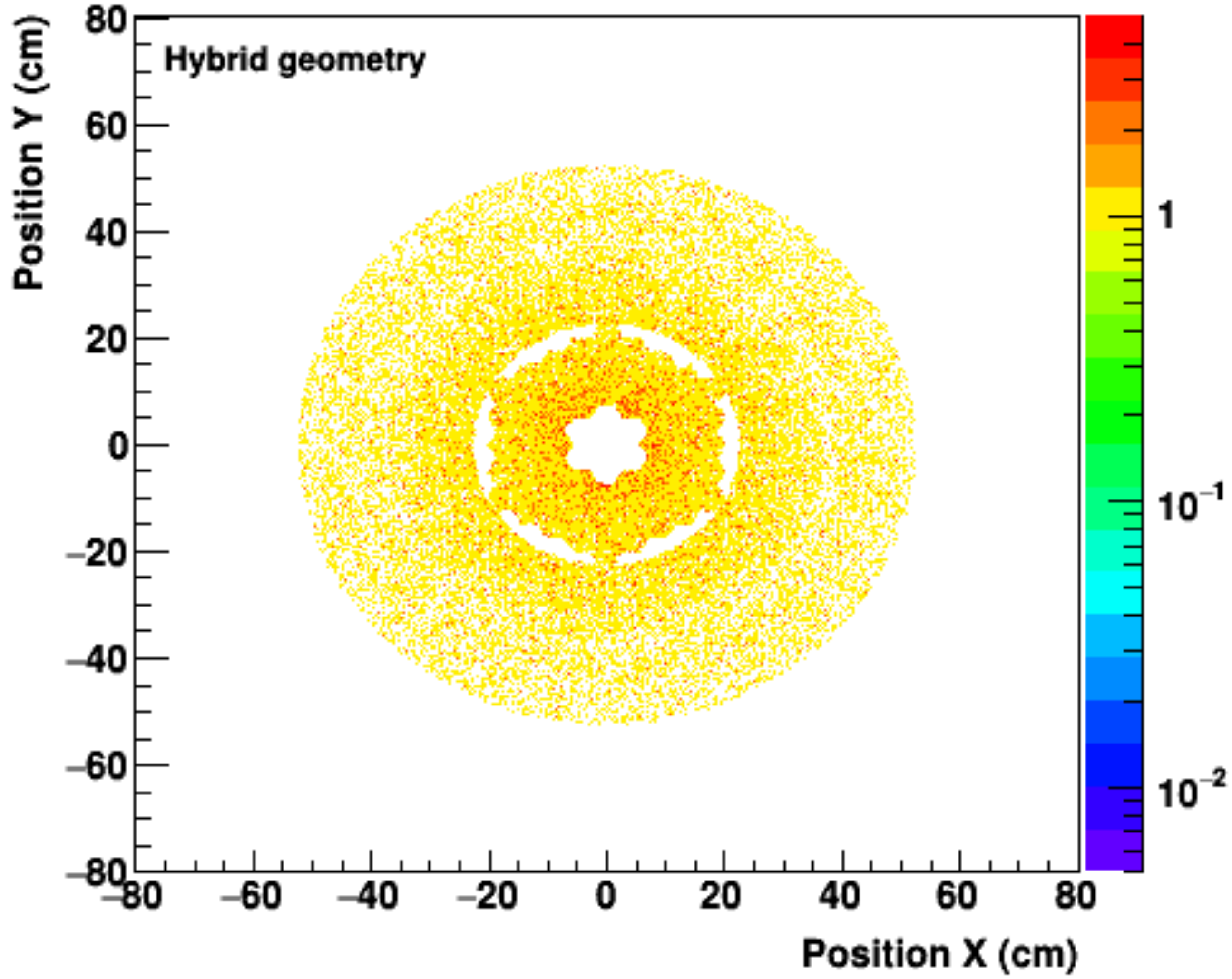
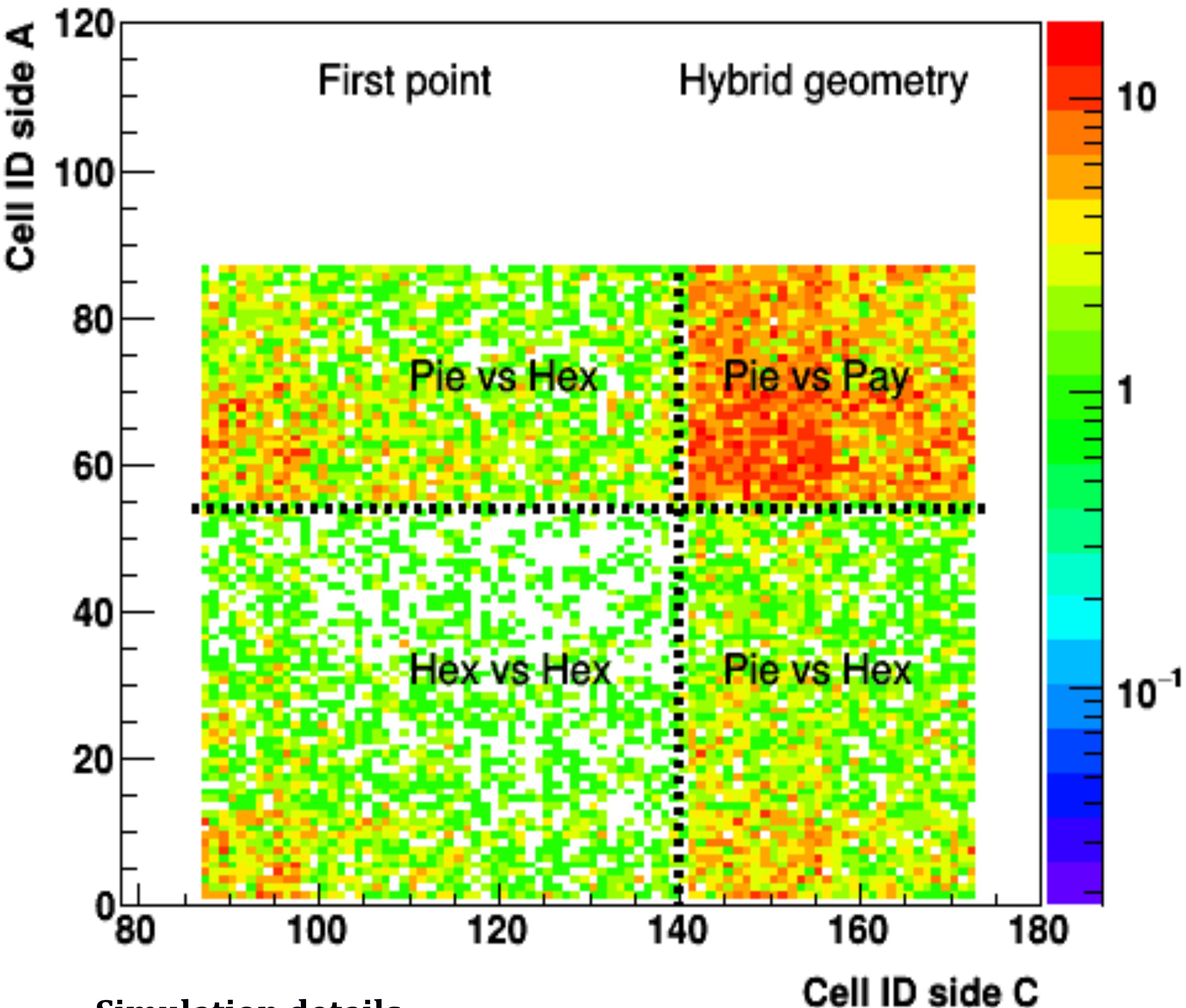


For proton-proton systems, we expect more hits in the two outer rings from the first particle reaching the detector.

Simulation details
Number of generated events: 50000, Minimum Bias
Enabled detectors: TPC, BE-BE
System: p-p
Energy in the center of mass: 22 GeV
Magnetic Field: 0.5 T
Generator: pythia 8

Beam-Beam monitoring detector geometry



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Number of generated events: 50000, Minimum Bias
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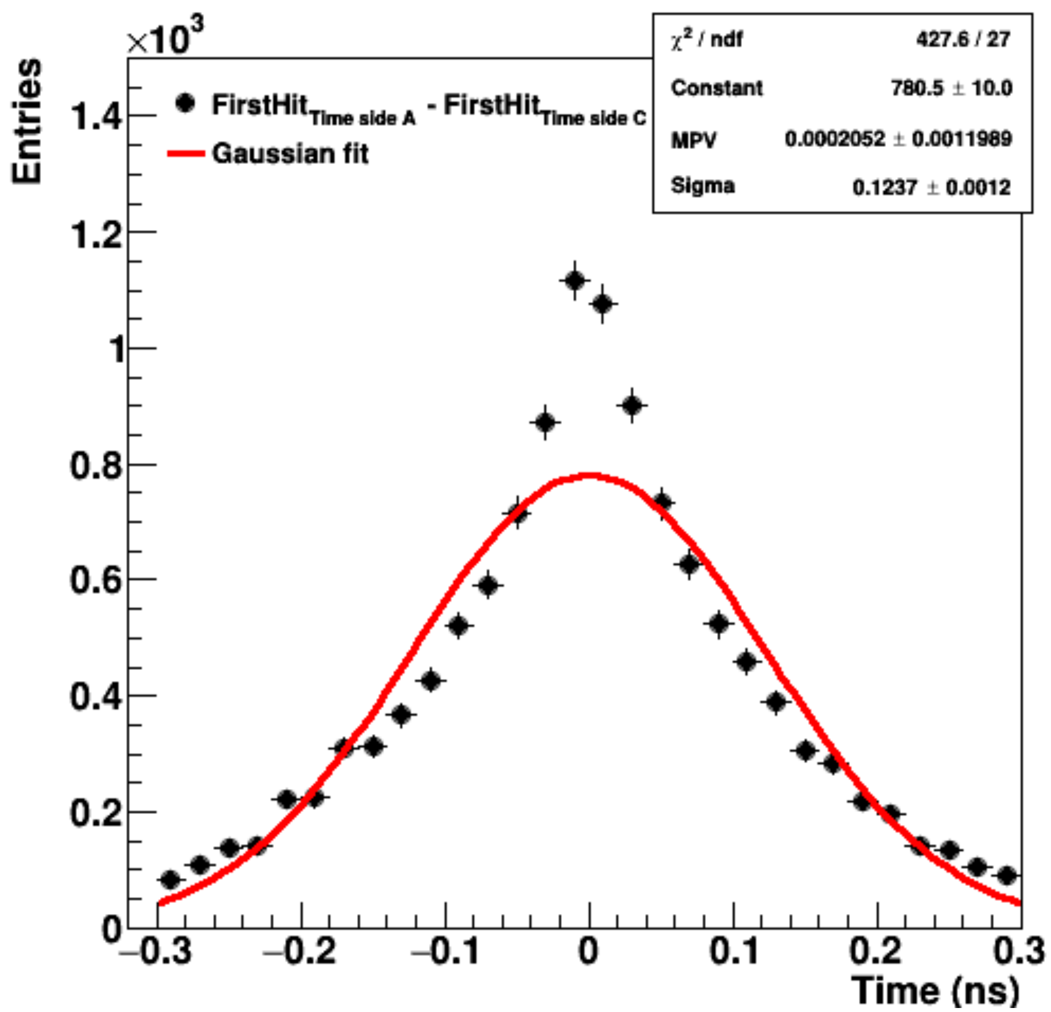
Generator: pythia 8

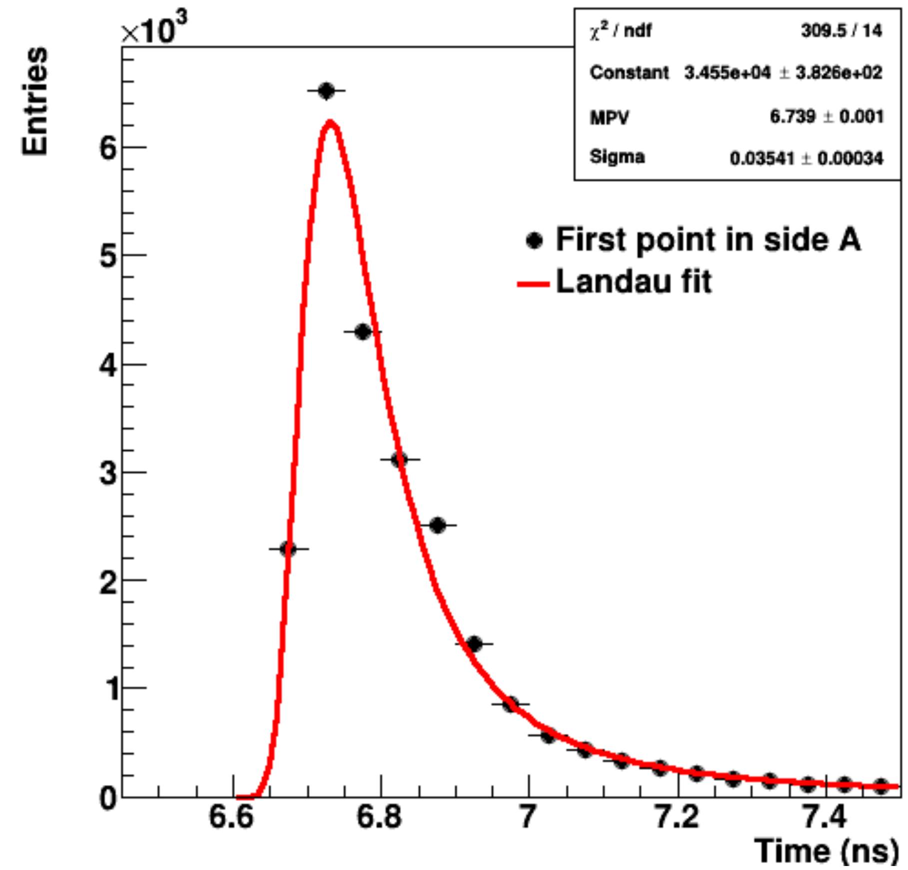
For pp collisions, simulations show that the first hit is distributed over the inner and outer parts of the detector with 46.6% and 61.6%, respectively.

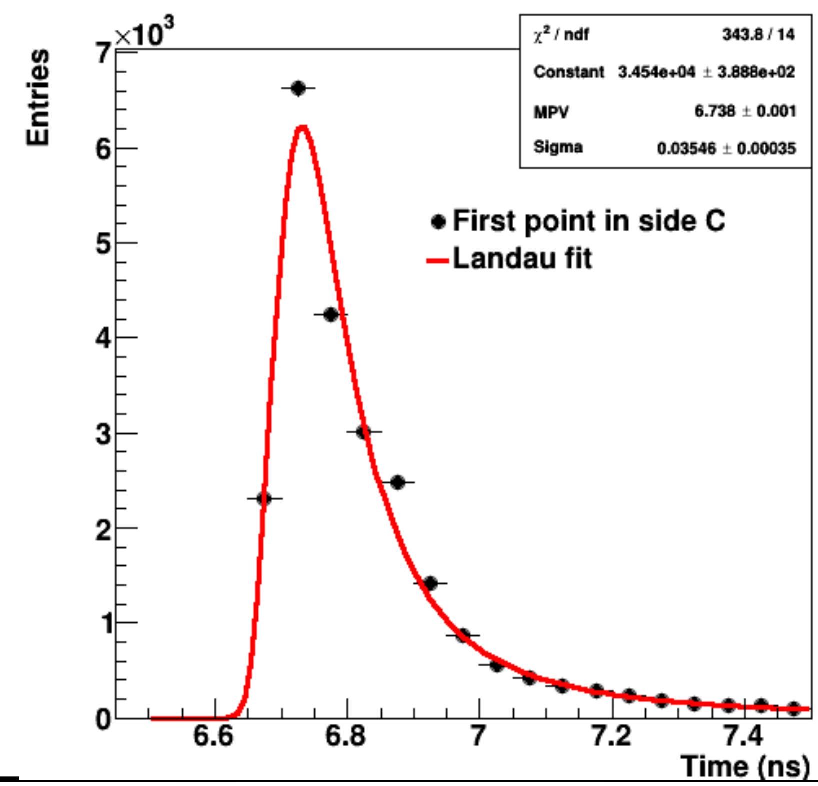
The two outer rings should be optimized for triggering.

Region	Fraction(%)
HexSideA&HexSideC	7.9
PaySideA&HexSideC	9.2
HexSideA&PaySideC	8.8
PaySideA&PaySideC	14.8
HexSideA||HexSideC	46.6
HexSideA||PaySideC	56.4
PaySideA||HexSideC	56.5
PaySideA||PaySideC	61.6

Beam-Beam monitoring detector geometry







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Beam-Beam monitoring detector geometry

System	sigma for time difference of BeBe-A and BeBe-B	sigma for time of the first particle in BeBe-A	sigma for time of the first particle in BeBe-C
Au-Au	0.020 ns	0.0067 ns	0.0073 ns
p-p	0.12 ns	0.035 ns	0.035 ns
Asimetric systems (x-X)	Work in progress	Work in progress	Work in progress

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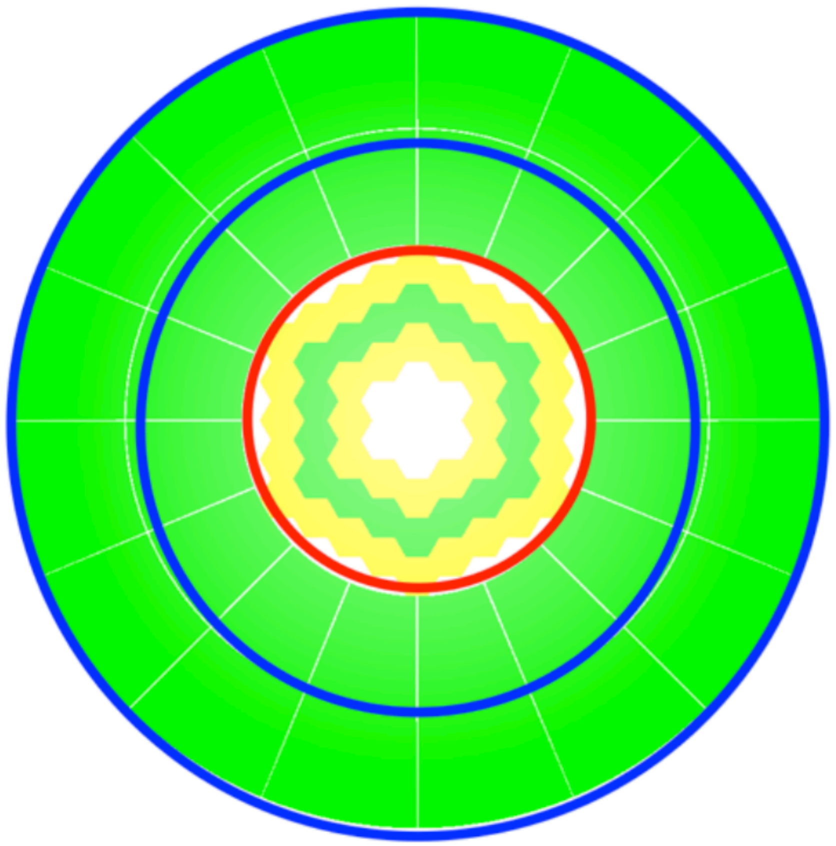
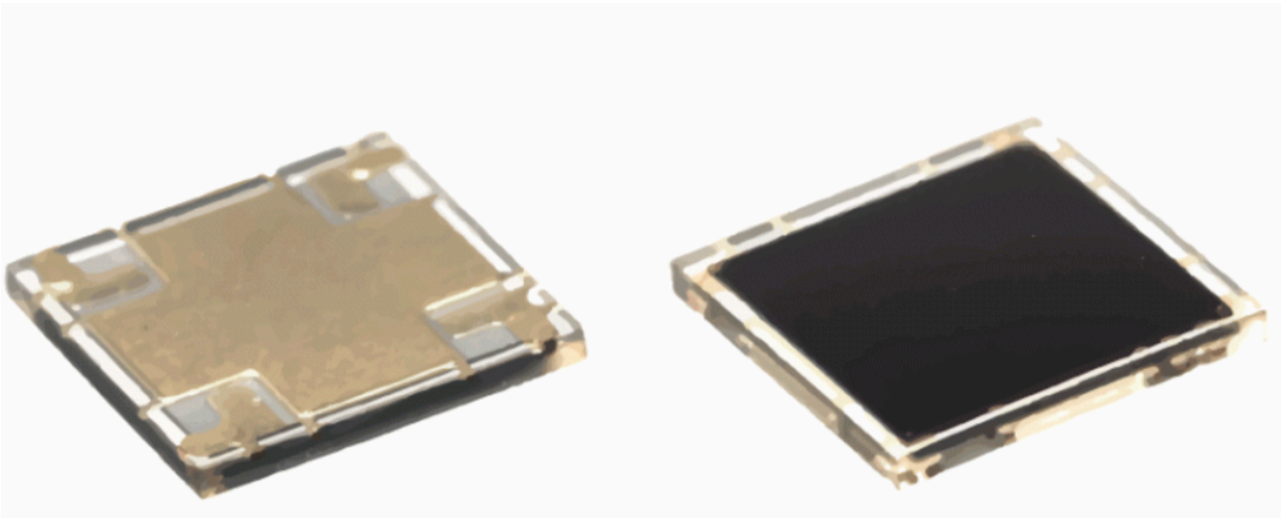


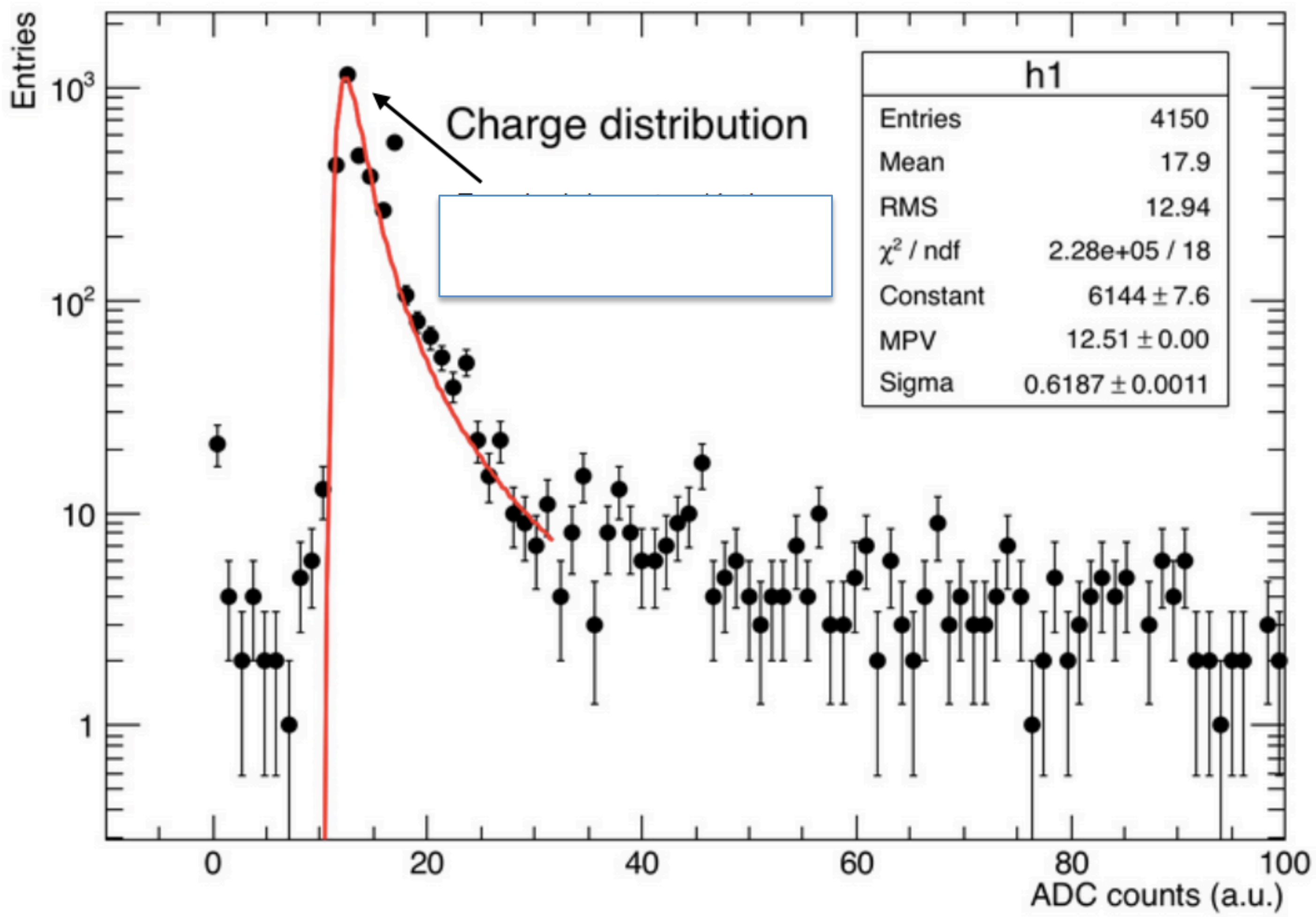
BeBe proposal

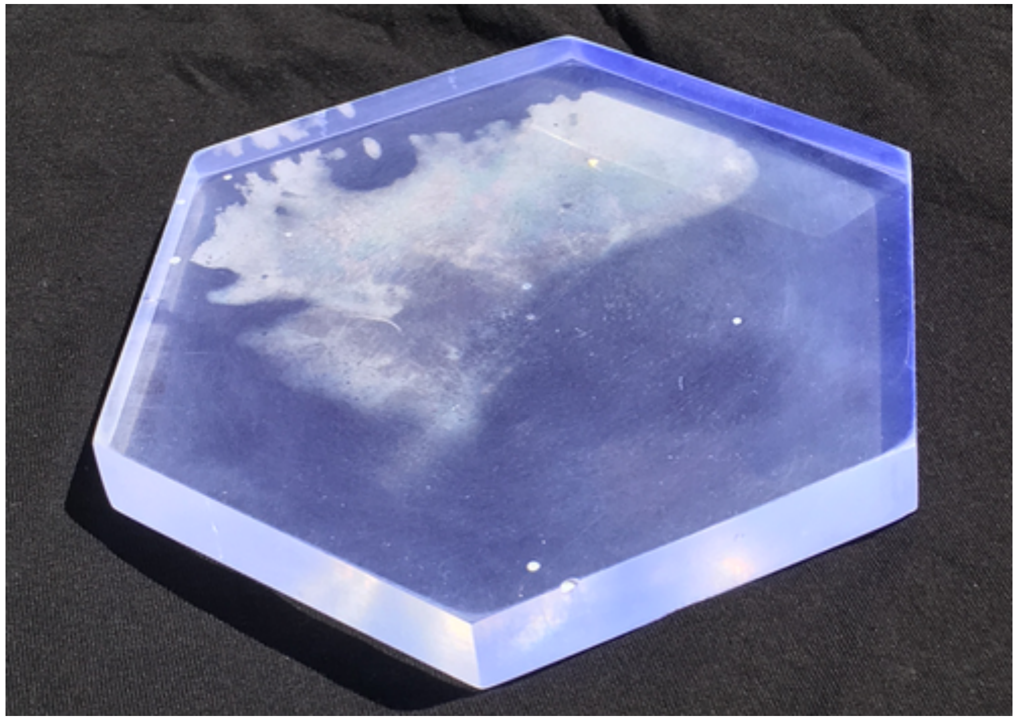
- plastic scintillator of 20 mm width (BC404). We have the option to use plastic scintillator developed in Mexico (see next slides)
- light collection with an SiPM light sensor (sensL, 6 x 6 mm^2)

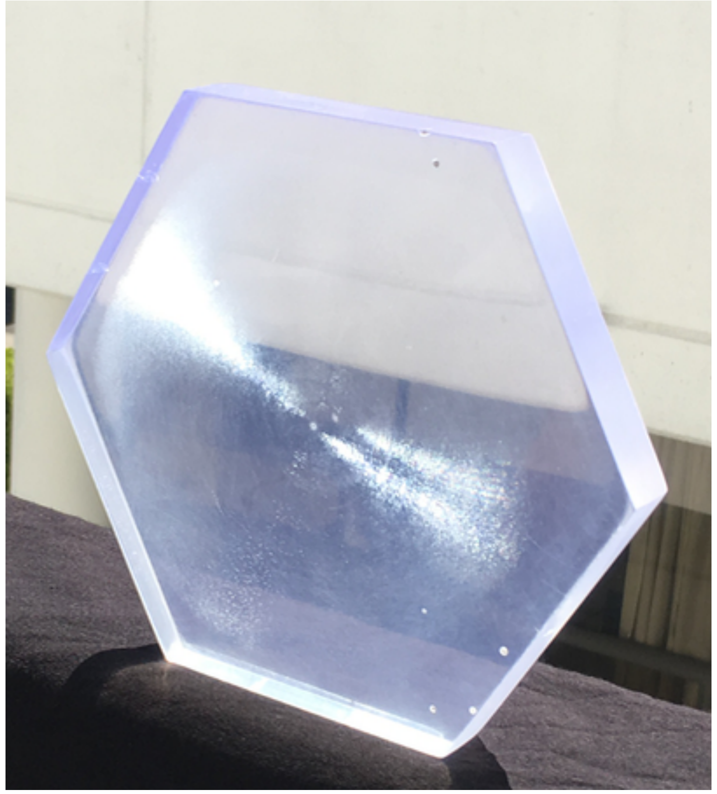


Possibility to use plastic scintillator produced in Mexico

PoS(ICRC2017)346





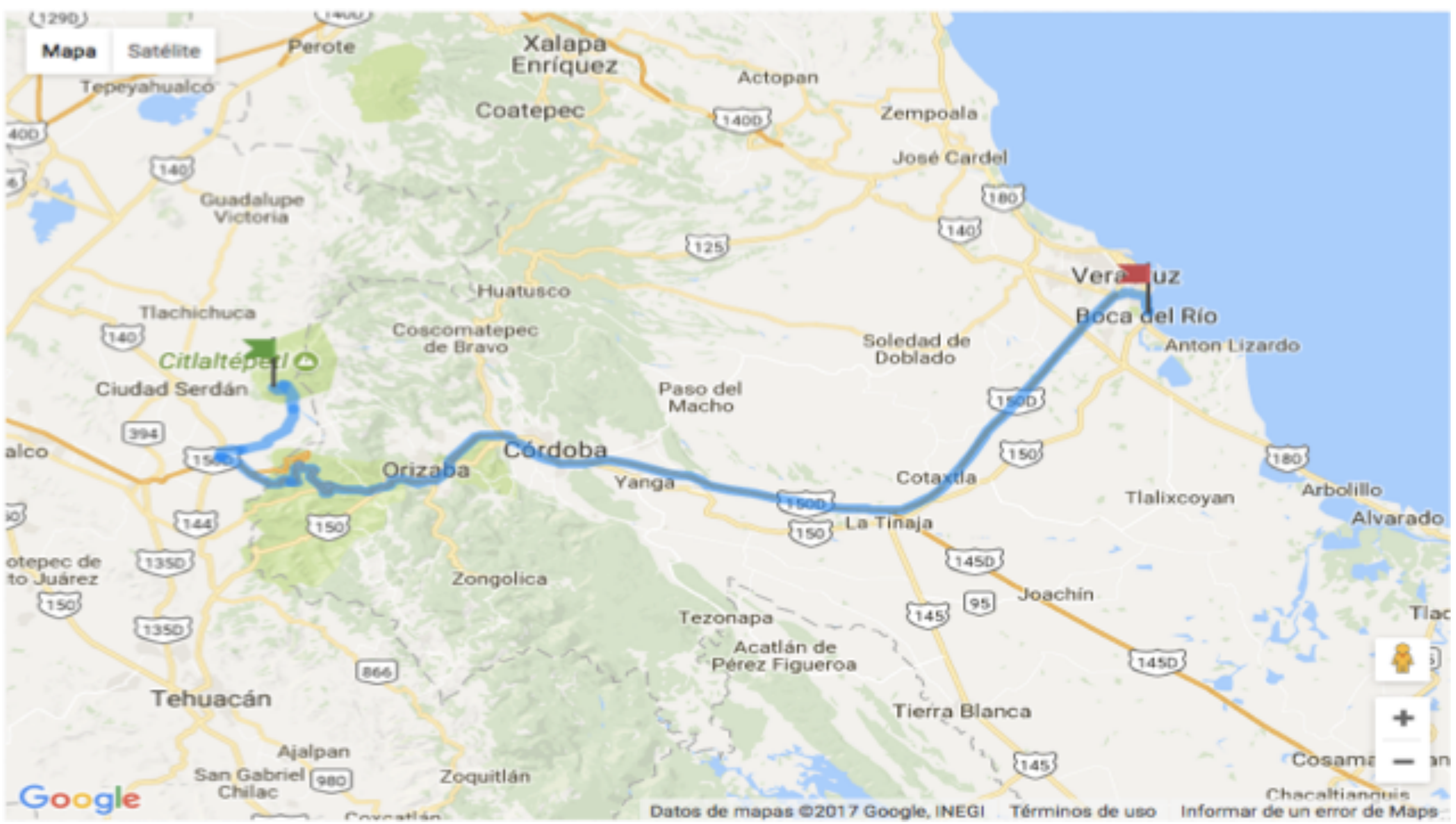


Is it possible to use plastic scintillator produced in Mexico?

We tested 3 plastic scintillators : 2 produced in Mexico and 1 BC404

More details in PoS(ICRC2017)346

We estimated the cosmic rate with respect to the altitude. From 4500 m.a.s.l. (HAWC site, Sierra Negra Puebla) to the sea level (Veracruz)



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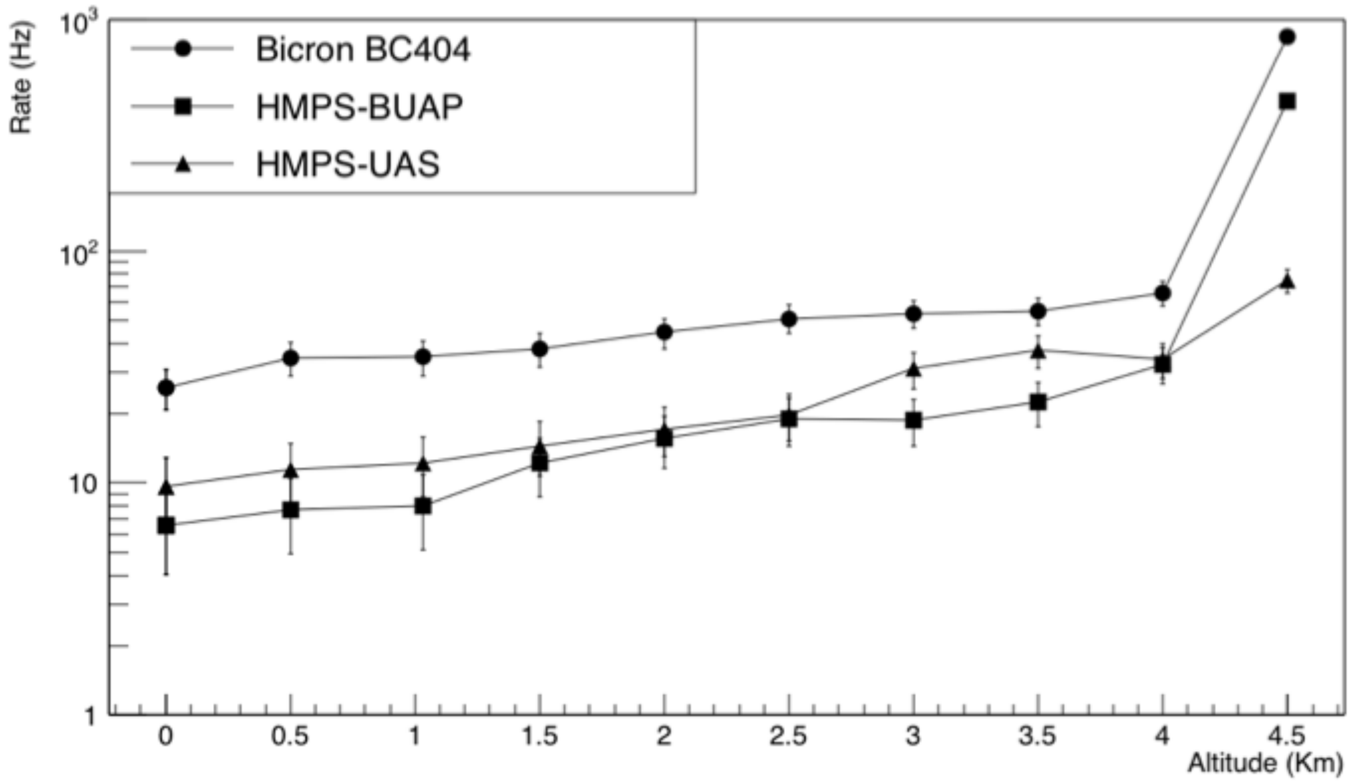
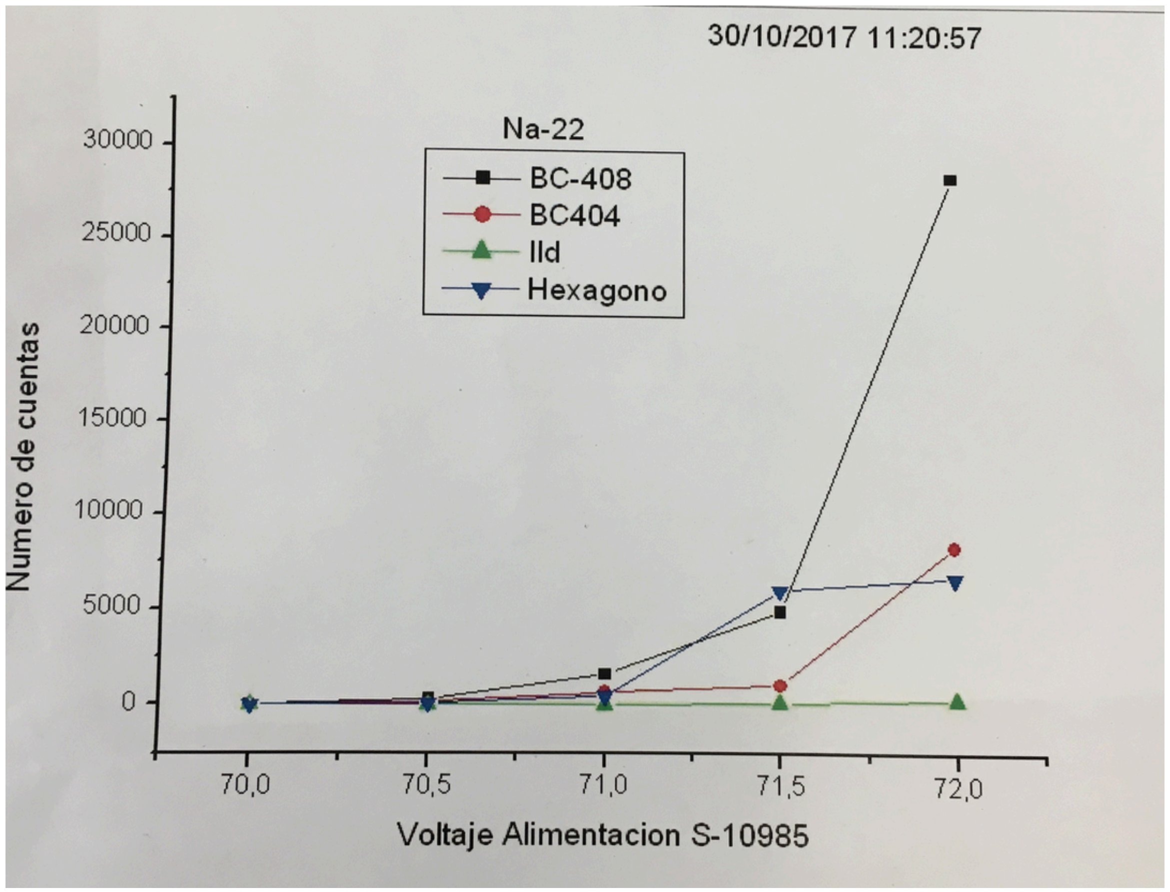
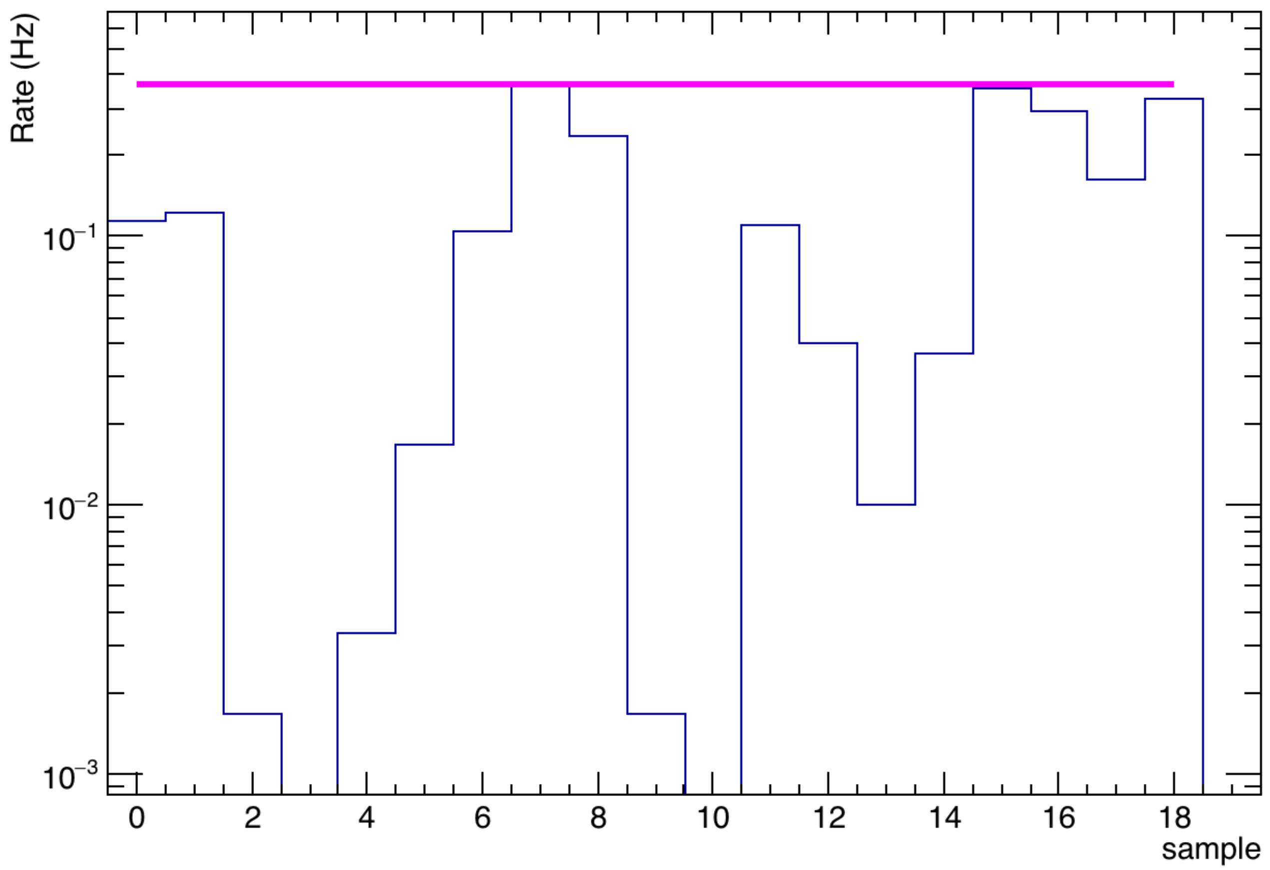


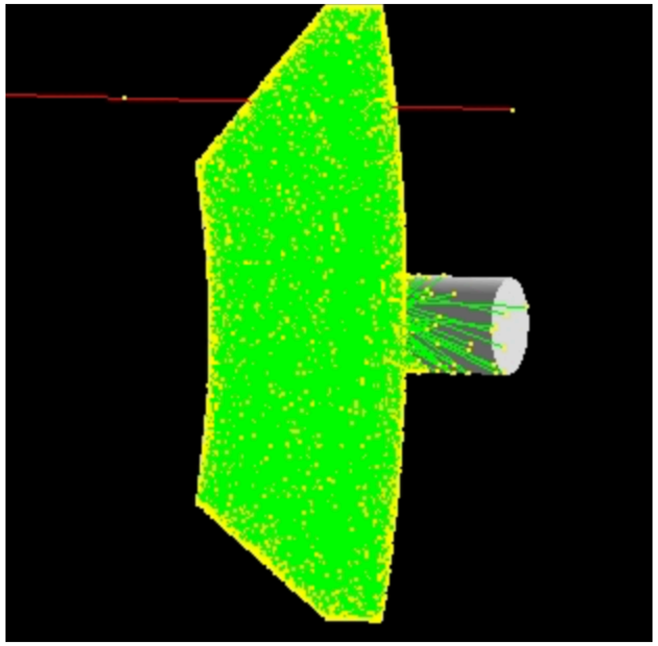


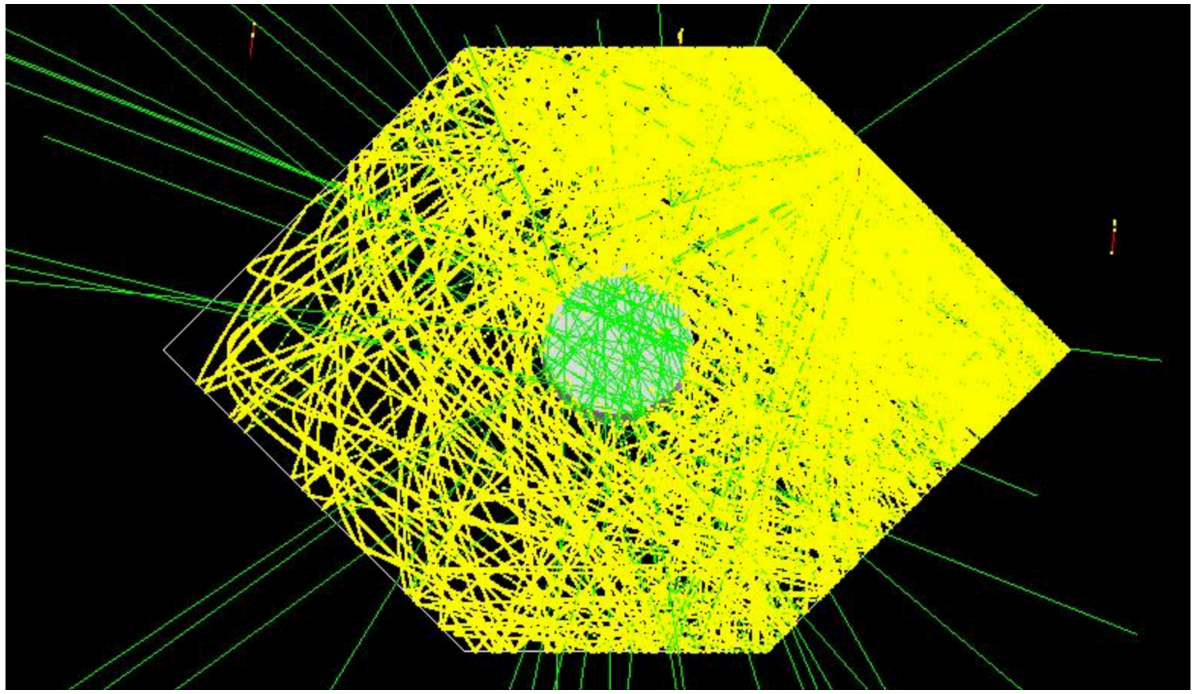
We produced 20 small samples of plastic scintillator to compare with BC404

It seems that we can achieve a good plastic scintillator. To be checked with further tests (again, light production, etc).



Further simulations are needed





Laboratory tests to find out light collection performance

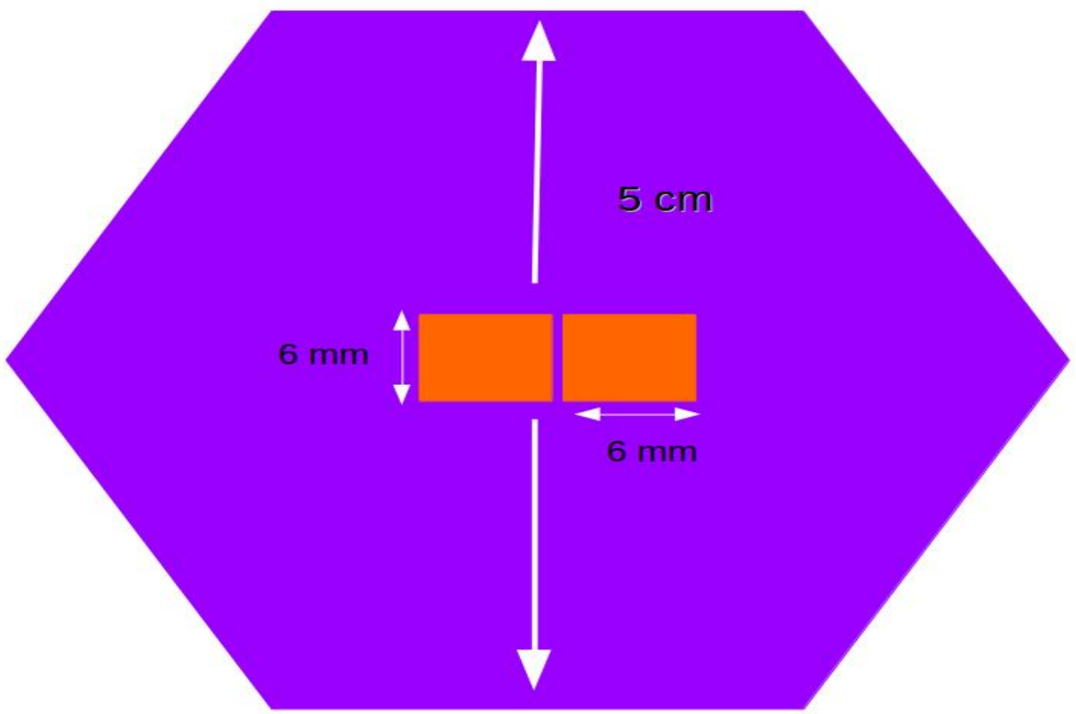
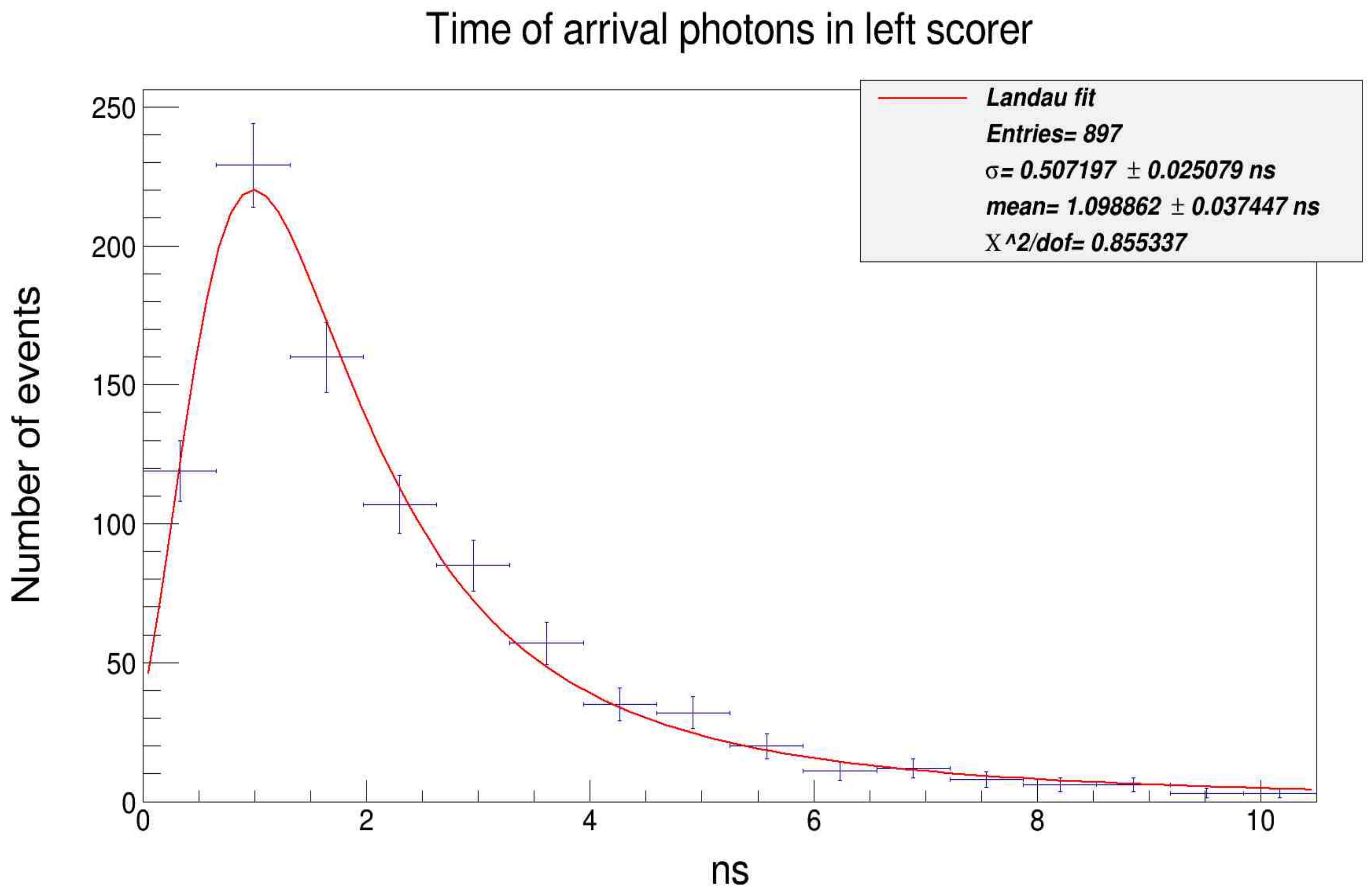


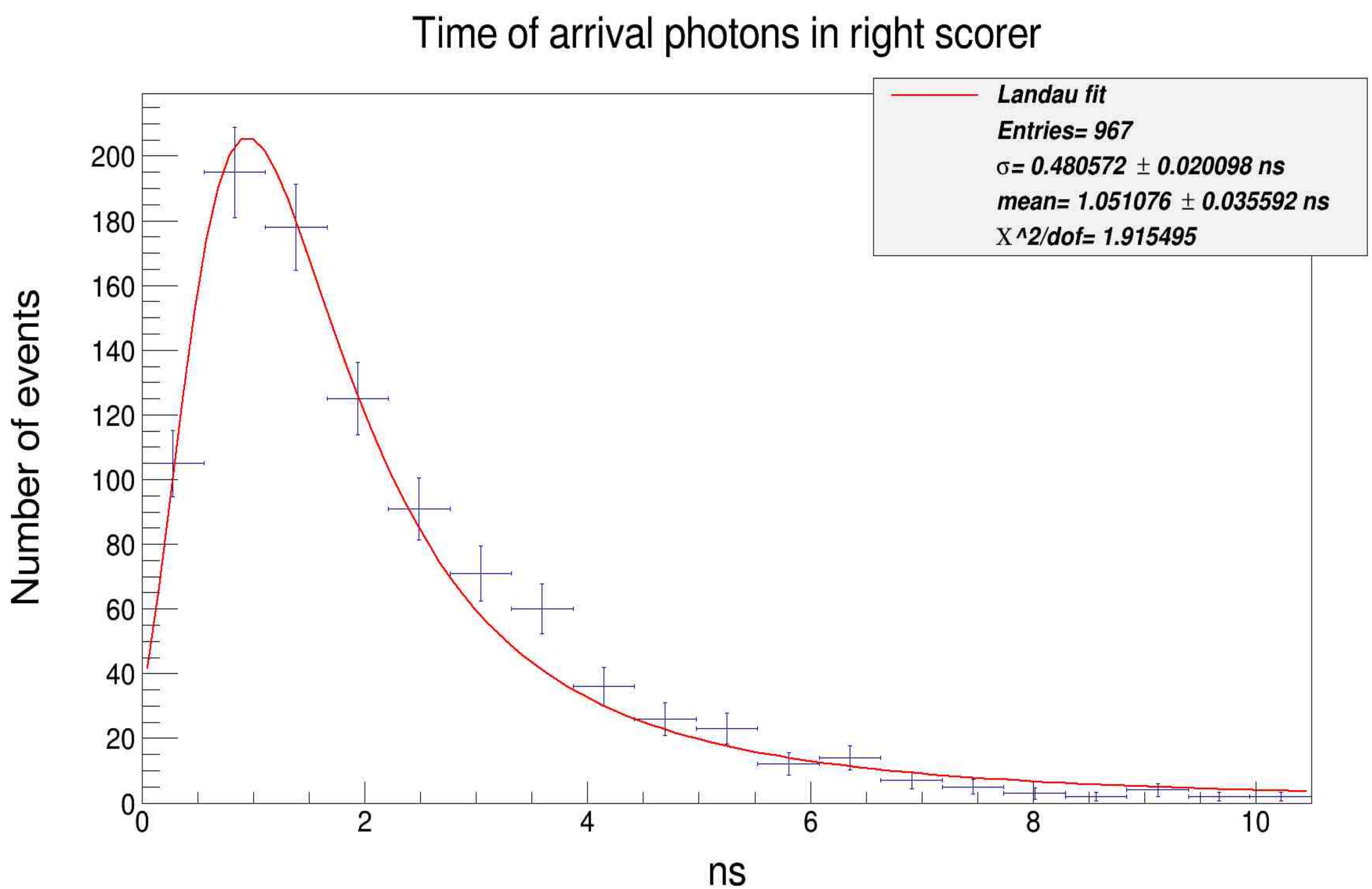
Illustration of the extent of the scintillator material (purple) and the two scorers (orange rectangles) that Represent the photodetectors

Left scorer

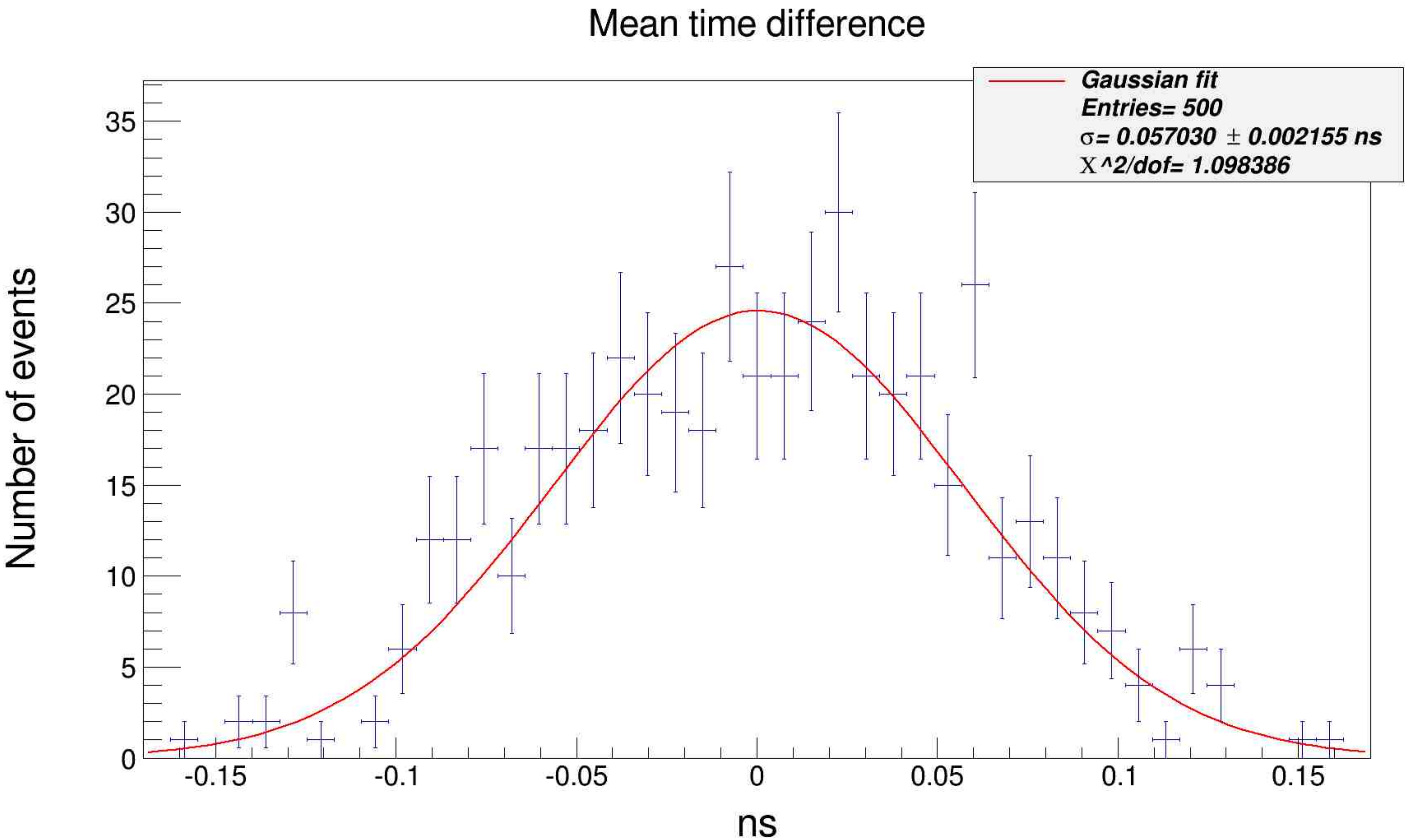


Time of arrival photons in left scorer
Landau fit
Entries= 897
σ= 0.507197 ± 0.025079 ns
mean= 1.098862 ± 0.037447 ns
X^2/dof= 0.855337
Number of events
ns
0
50
100
150
200
250
0
2
4
6
8
10

Right scorer

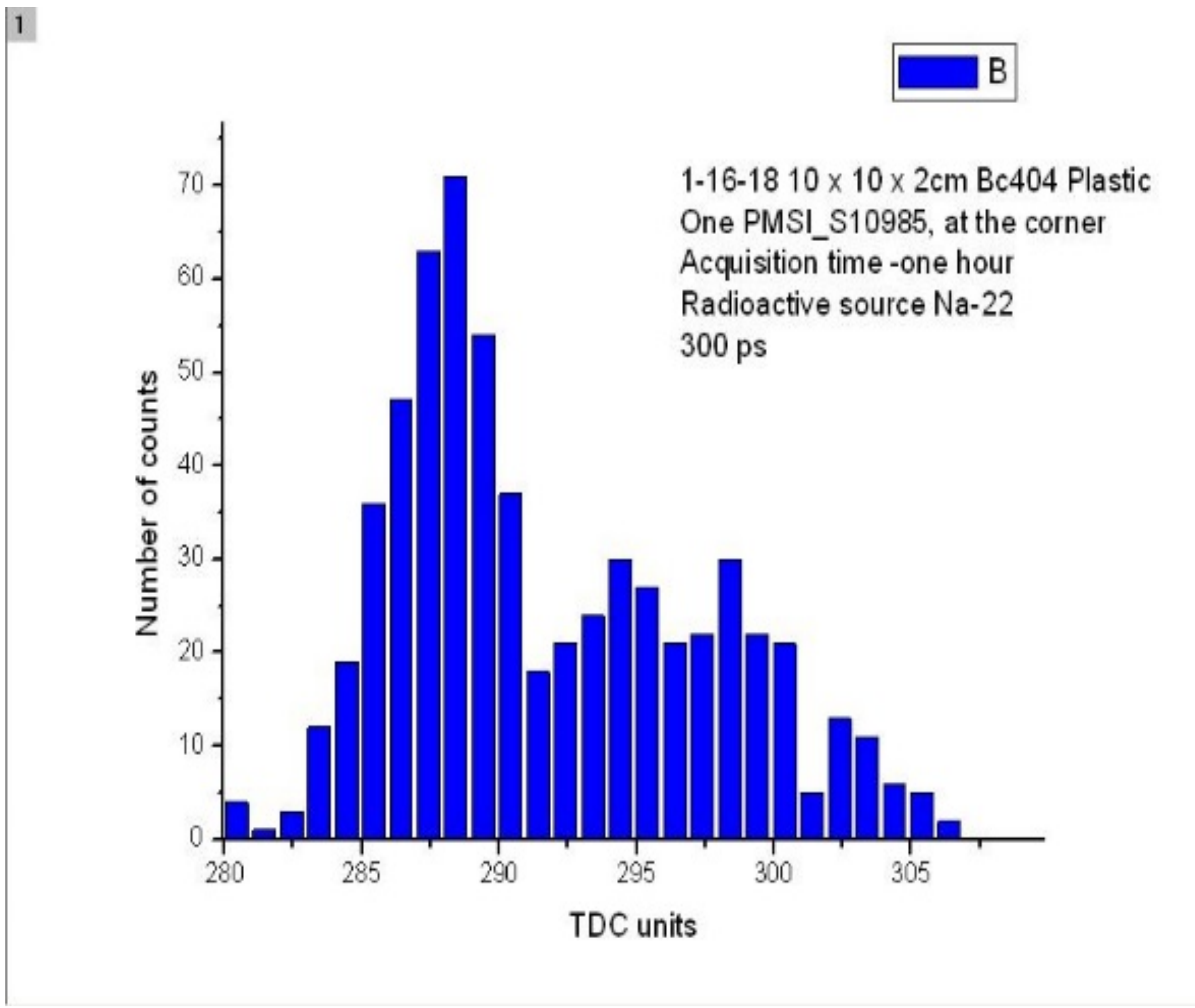


Difference in time of arrival

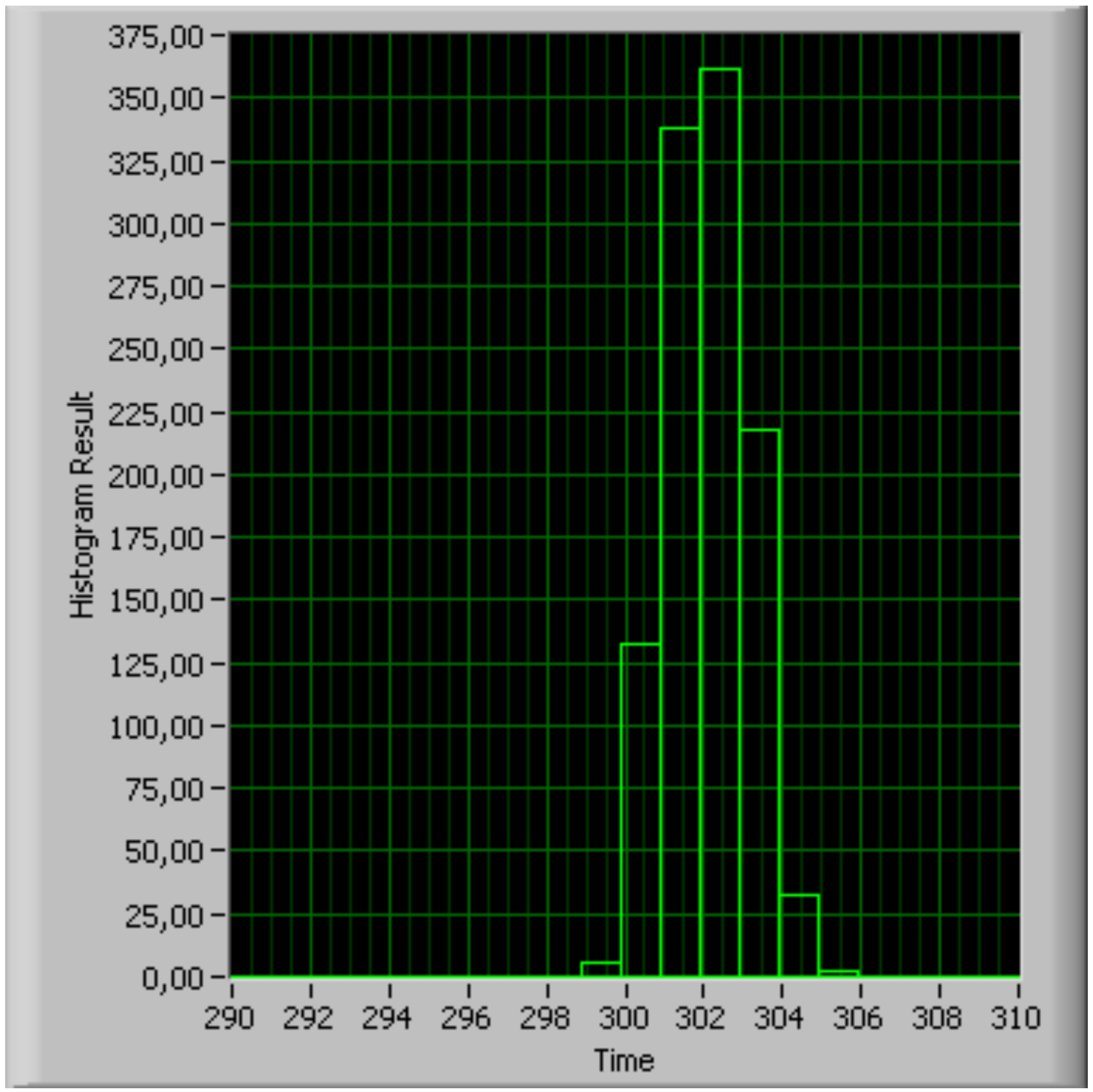


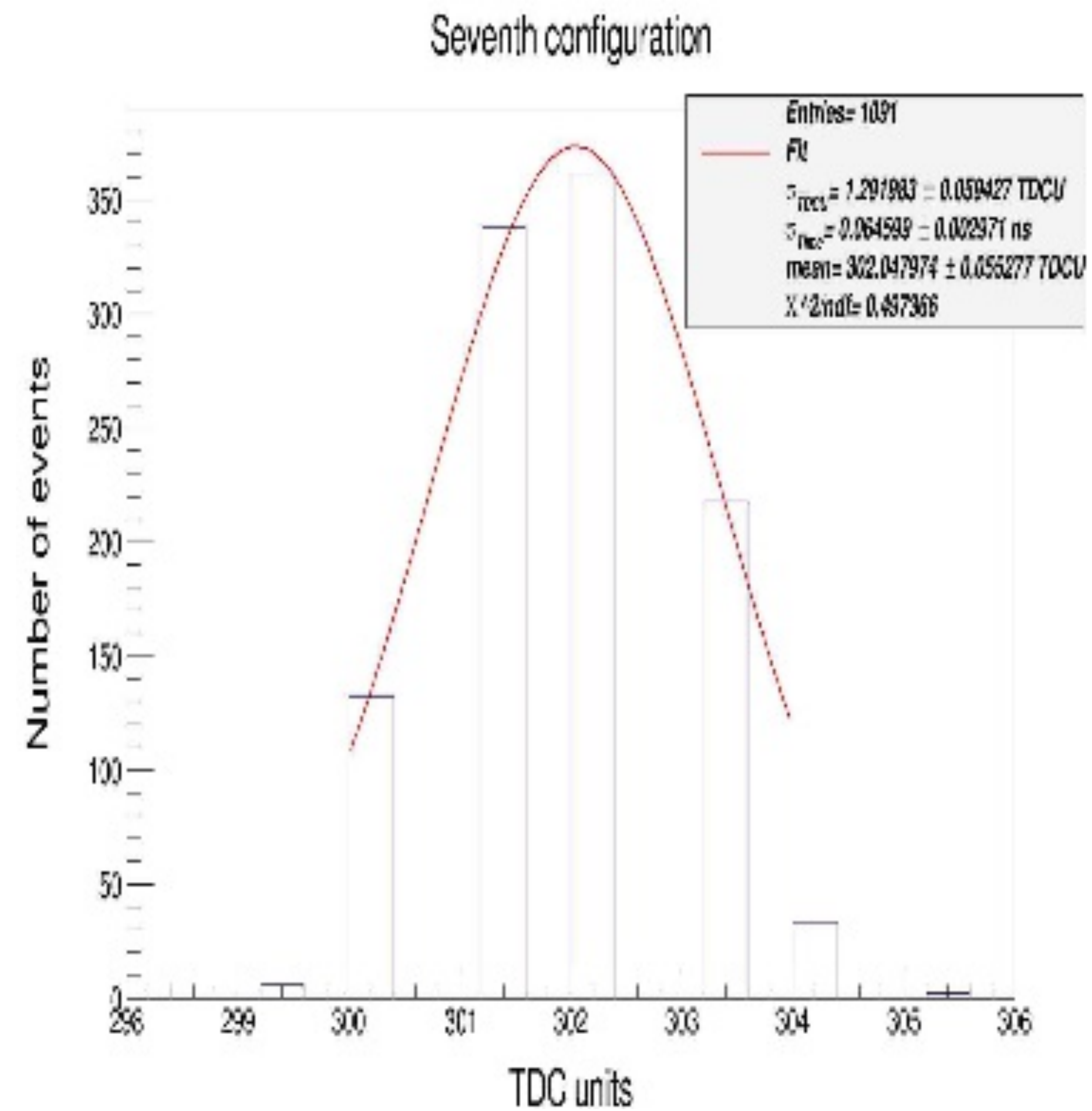
σ = 58.5 +/- 5.4 ps.

Time distribution for light collection S10985 light sensor



Time difference between the trigger light sensor and the delay of the light sensor signal





A fit to the histogram gives a standard deviation around 65 ps

Mid-term Time schedule for BeBe detector

2018

January

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

February

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28			

March

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

April

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

May

S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

June

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

July

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

August

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

September

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

October

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

November

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

December

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

detector development

cosmic runs

beam test

with plastic scintillator produced in Mexico

MExNICA Theory/Pheno Research Agenda

- √ to identify the critical behaviour through multiplicity fluctuations in collision systems at finite temperature and density
- √ to explore the strong interactions in relativistic heavy ion collisions as well as the mechanisms of energy and momentum interchange between hard probes and the QGP
- √ to investigate the pattern of chiral symmetry restoration in the scalar/pseudo-scalar as well as the vector/axial-vector channel
- √ to elaborate a new conjecture for the QCD phase diagram

Conjecture about the QCD Phase Diagram

Effective theory: 3d O(4) non-linear σ-model on the lattice

$$S[\vec{e}] = \beta \sum_{\langle xy \rangle} (1 - \vec{e}_x \cdot \vec{e}_y) \ , \qquad \vec{e}_x \in S^3$$

Global O(4) symmetry matches chiral symmetry of 2-flavor QCD

SSB with 3 Nambu-Goldstone bosons

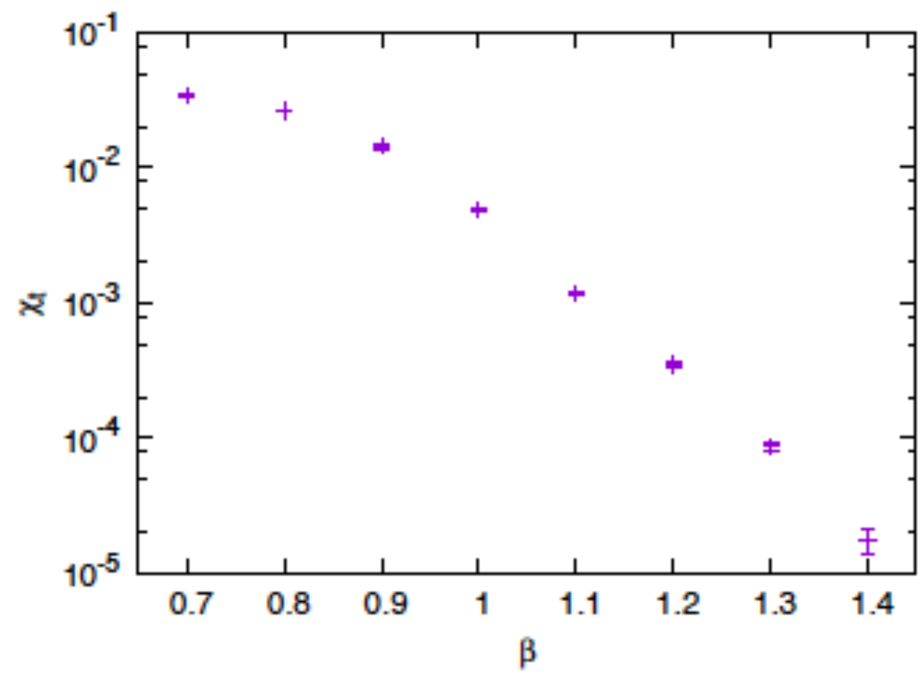
$$\begin{aligned} \mathrm{O}(4) \rightarrow \mathrm{O}(3) \quad &\Leftrightarrow \quad \mathrm{SU}(2)_L \otimes \mathrm{SU}(2)_R \rightarrow \mathrm{SU}(2)_{L=R} \\ \text{inv. coupling} \ \beta \quad &\Leftrightarrow \quad \frac{1}{2} F_\pi^2 \\ \text{topological charge} \ Q[\vec{e}] \quad &\Leftrightarrow \quad \textbf{baryon number} \end{aligned}$$

Skyrme '61, Alkins/Nappi/Witten '83, Zahed/Brown '86

Within the effective model, we have numerical access to high baryon density, without sign problem.

First results for the top. susceptibility $\chi_{\mathrm{t}} = (\langle Q^2 \rangle - \langle Q \rangle^2)/V \quad (V = 8^3)$

($\beta_{\mathrm{critical}} \simeq 0.936$, Engels/Fromme/Seniuch '03)



$\beta > \beta_{\mathrm{crtical}}$: χ_{t} exp. suppressed $\sim$ dilute instanton gas (Bietenholz/Fernández/Nava '18)

Later: anisotropic volumes $L \times L \times L_t$, $L \gg L_t = 1/\mathrm{temperature}$,

plus imaginary θ-term $\Leftrightarrow$ chemical potential

Conclusions

- The optimal devices for the construction of prototypes are so far the plastic scintillator BC404 coupled with Hamamatsu S10985 light sensor using up-to-date improved read out electronics.
- We plan to simulate and carry out laboratory tests with homemade (Puebla) scintillator prototypes of different sizes, and to include two or three light sensors in each scintillator in order to further refine the time resolution.

Conclusions

- Out of the three BE-BE geometries that were implemented in the MPD-ROOT environment, the hybrid geometry could satisfy the resolution time requirement.
- The trigger will be given by the hits on the inner part (hexagonal cells). In this sense, it is crucial to manufacture and test a prototype made out of one of the three innermost rings.
- The information from the two outer rings could be used for centrality and multiplicity studies.

Conclusions

- The “honeycomb” and hybrid geometries have similar performances. However, the number of cells in the hybrid geometry is significantly lower, which makes this a better design to avoid having a large number of read out channels.
- A similar study was carried out with p-p collisions. However the time-of-flight distribution of the first particle that reaches the BE-BE detector behaves differently than in Au-Au collisions, which might be due to the fragmentation implemented in the MC event generator.

Conclusions

- Theory/phenomenological efforts are also being carried out: LQCD models to explore phase diagram; studies to explore the approach to chiral symmetry restoration.
- Use of BeBe to determine event plane and perform flow analysis.