Local proton polarimetry for SPD

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SPD/NICA Collaboration

Status report
8 June 2020

Major goals of local polarimetry

1. Permanent monitoring of the beam polarization during data taking to reduce the systematic error coming from the beam polarization variation.

2. Independent from the major polarimeters (CNI and absolute) monitoring of the beam polarization and possible usage of this tool to tune the beam polarization axis.

Local polarimetry is just additional tools to the absolute pp- and pC- polarimeters in the collider!

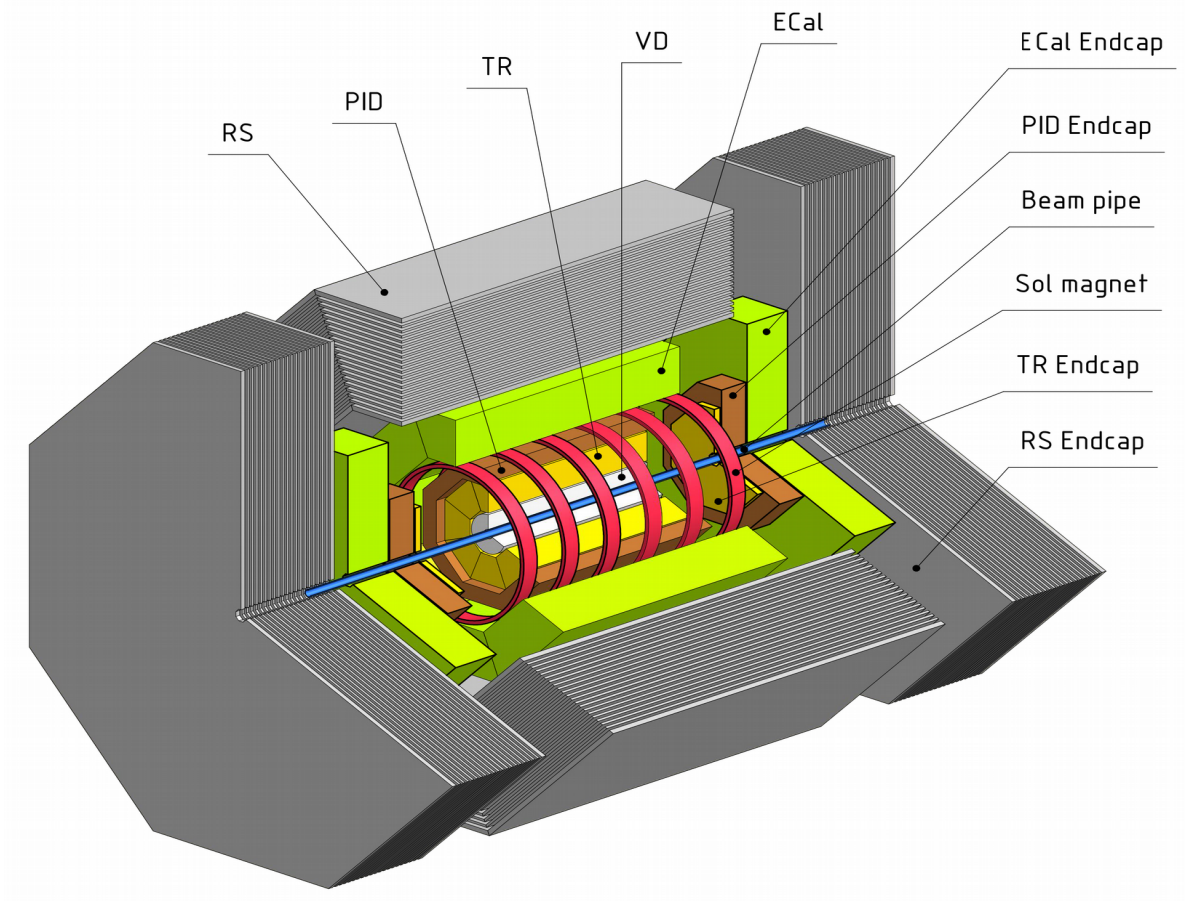
Reactions for local proton polarimetry

1. Asymmetry in inclusive production of charged particles in forward direction.

2. Single transverse spin asymmetry for very forward neutron production.

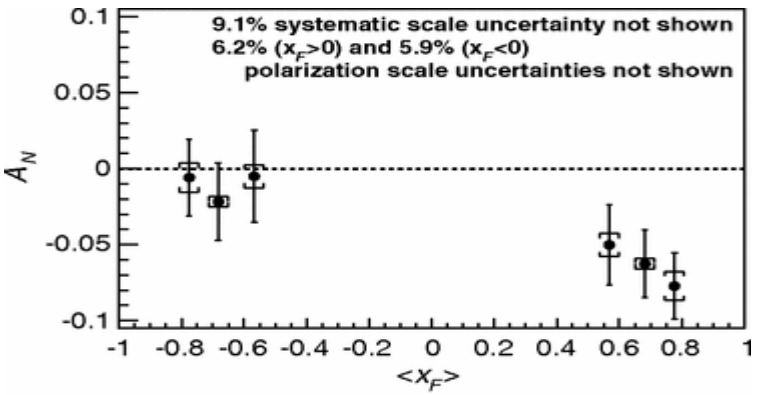
3. Inclusive $pp \rightarrow \pi^{o}X$ reaction at large x_F

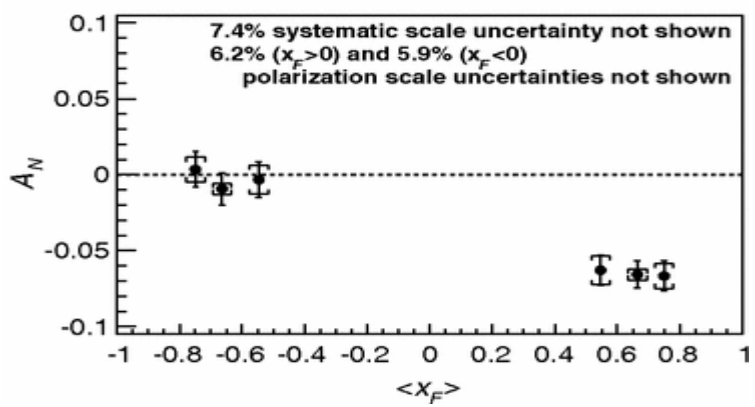
Detectors for local polarimetry

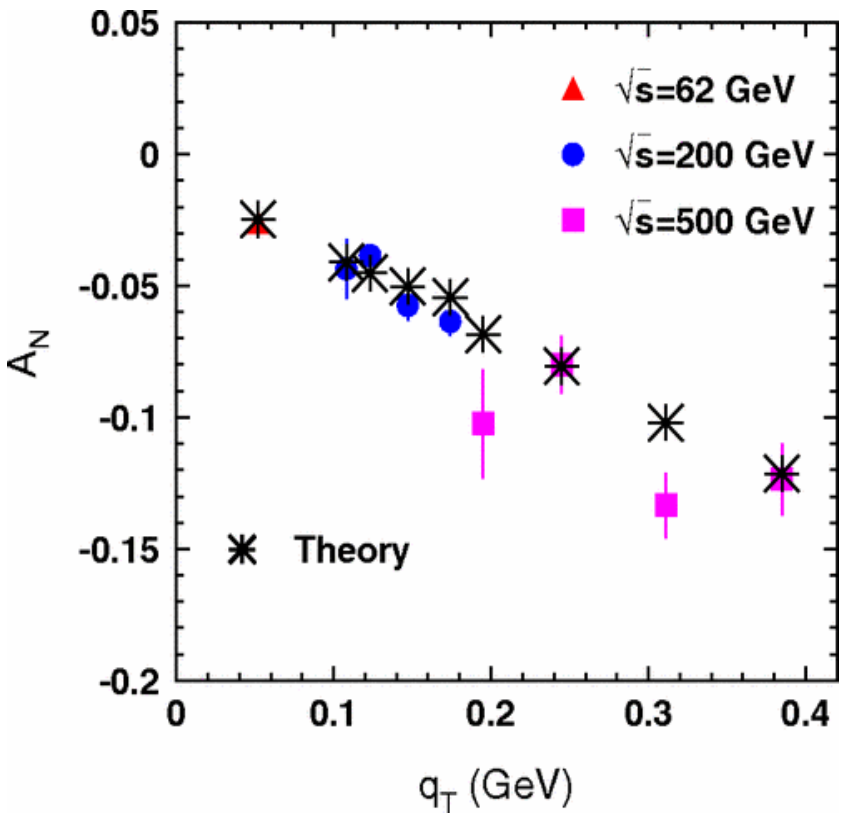


BBC, Endcap ECAL, ZDC(?)

Very forward neutron production



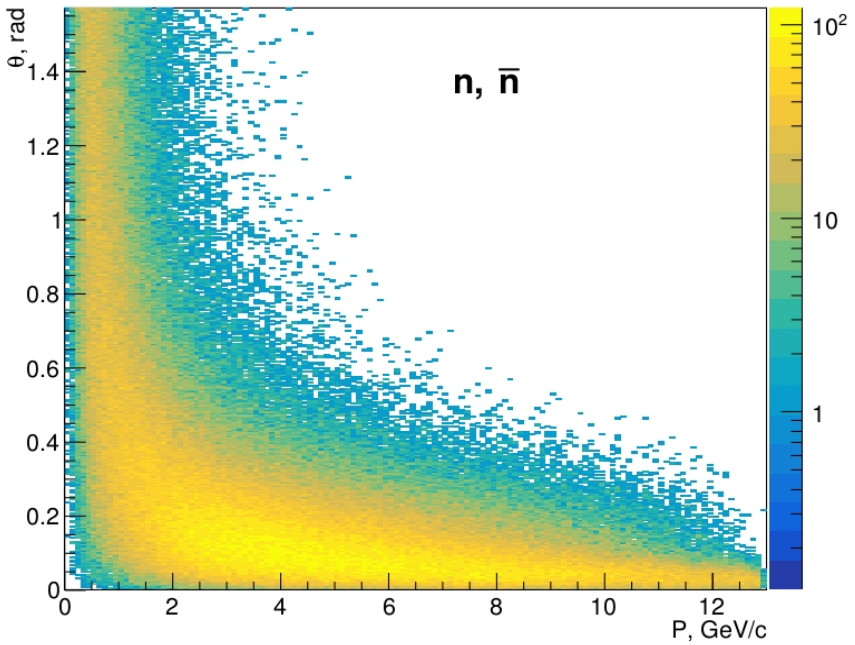




B.Kopeliovich calculations are in good agreement with the PHENIX results.

One can expect $A_N \approx -0.02$ in very forward neutron production at the highest SPD energies.

Forward neutrons: SPD energy range



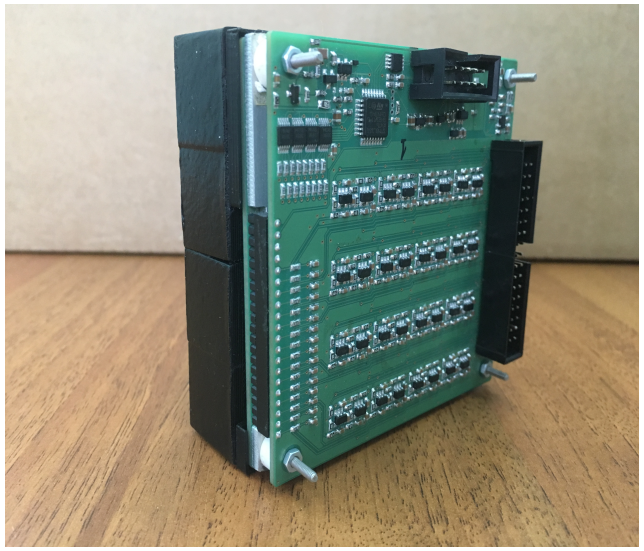
Data provided by A.Guskov

Quite large amount of neutrons in forward direction at large x_F at SPD energies.

However, seems, that due to quite small value of the effective analyzing power such method will work only at the energies close to the maximal one at SPD.

ZDC for forward neutrons polarimetry

PHENIX: quartz fibers+ W -absorber

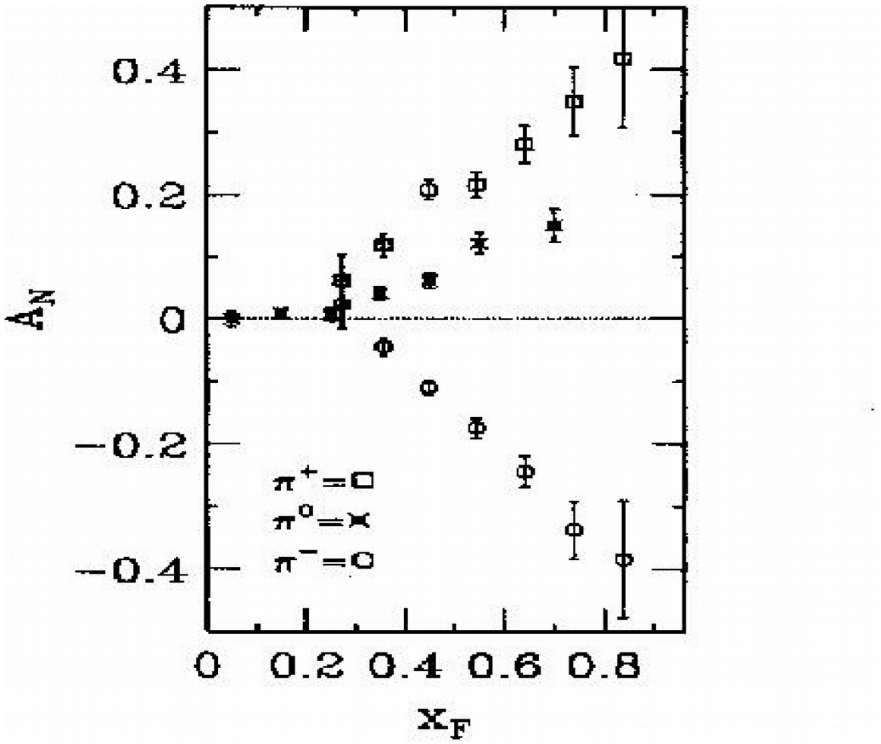


16-channel scintillation detector 2x2x2 cm^3 coupled with 16-channels Hamamatsu S12572-010P SiPM board.

No own resources+problems with the space: postponed

1. **Possible participation in R&D using 16-channel SiPM board.**
2. **Participation in R&D for $BaO\text{-}2SiO_2\text{-}0.34Gd_2O_3$ calorimeter.**

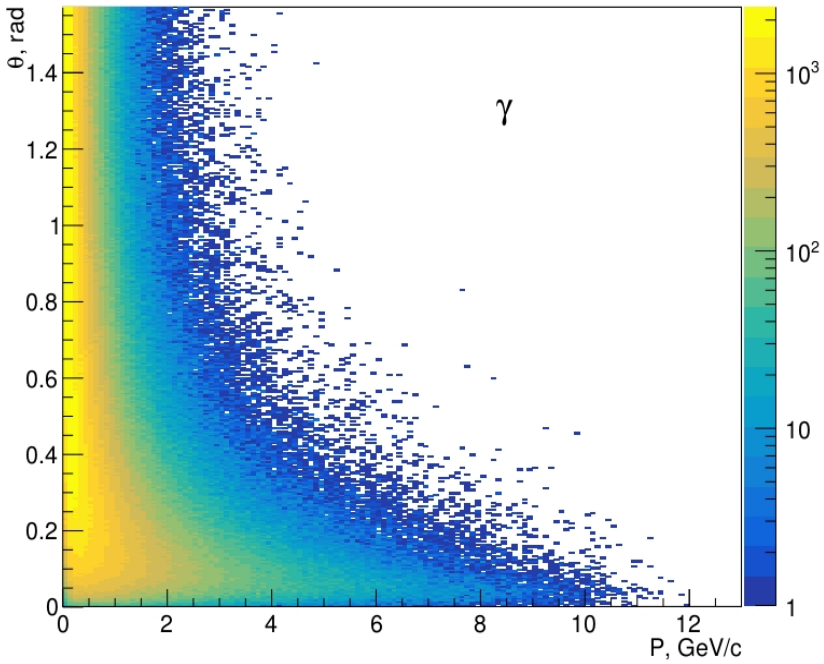
Inclusive pp → π°X reaction



D.L.Adams et al., Phys.Lett.B 261, 201 (1991); Phys.Lett.B 264, 462 (1991).
C.E.Allgower et al., Phys.Rev.D 65, 092008 (2002).

Method should work in the whole SPD energy range. However, analyzing power increases at high x_F , therefore, measurements can be performed with the ECAL Endcaps only.

Gammas at SPD energies



Data provided by A.Guskov

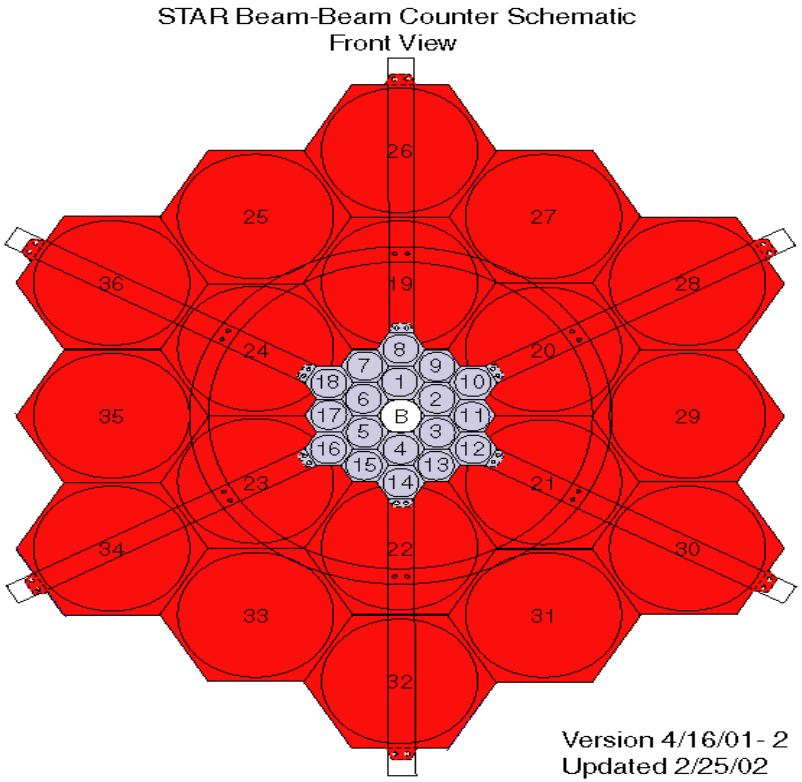
Gammas at the energies up to 11-12 GeV for the reconstruction of the invariant mass of 2 of them.

ECAL Endcap for local polarimetry

-No special detector development is needed.
- ECAL endcap information will be used.
-The local polarimetry can be realized at the level of free-streaming DAQ via dedicated FPGA settings.
-Fast online π^0 selection algorithms should be developed.

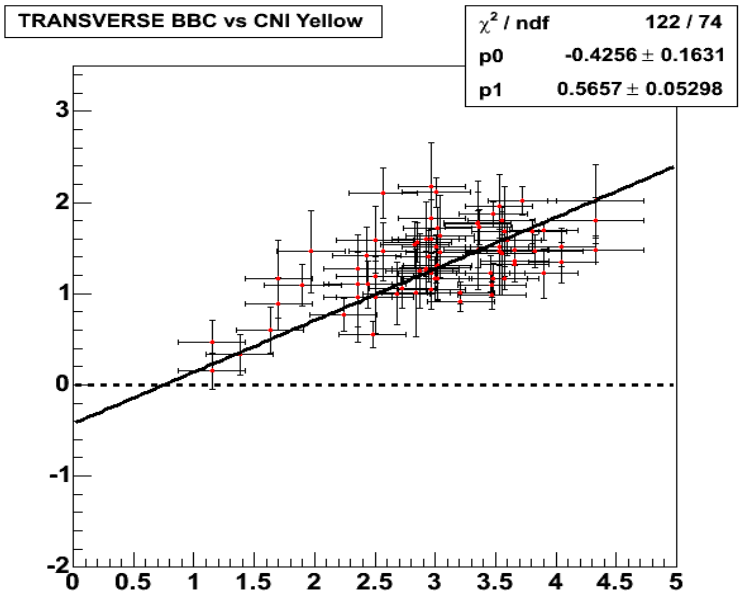
Of course, physics data at different energies first, local polarimetry in parallel.

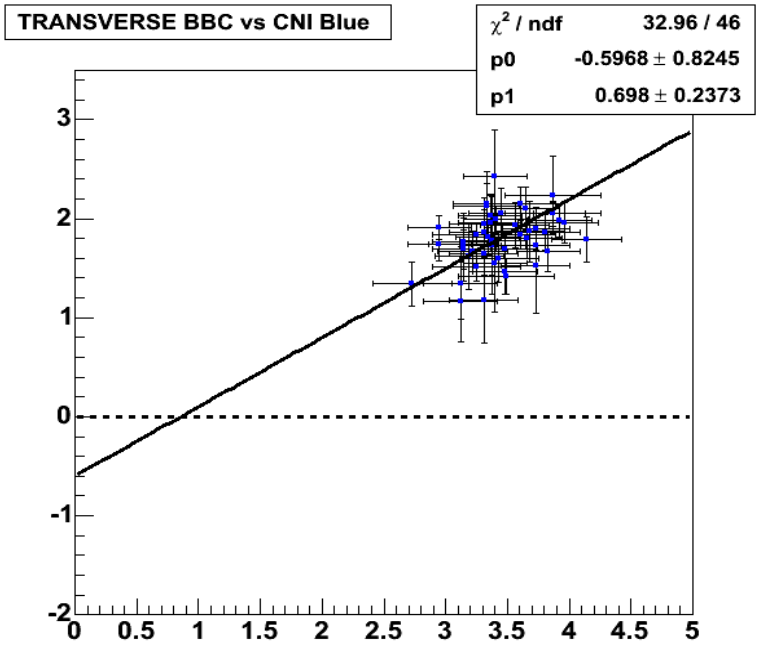
STAR BBC for local polarimetry



1. Inner zone – for luminosity estimation
2. Outer zone – for local polarimetry
3. Trigger and T0

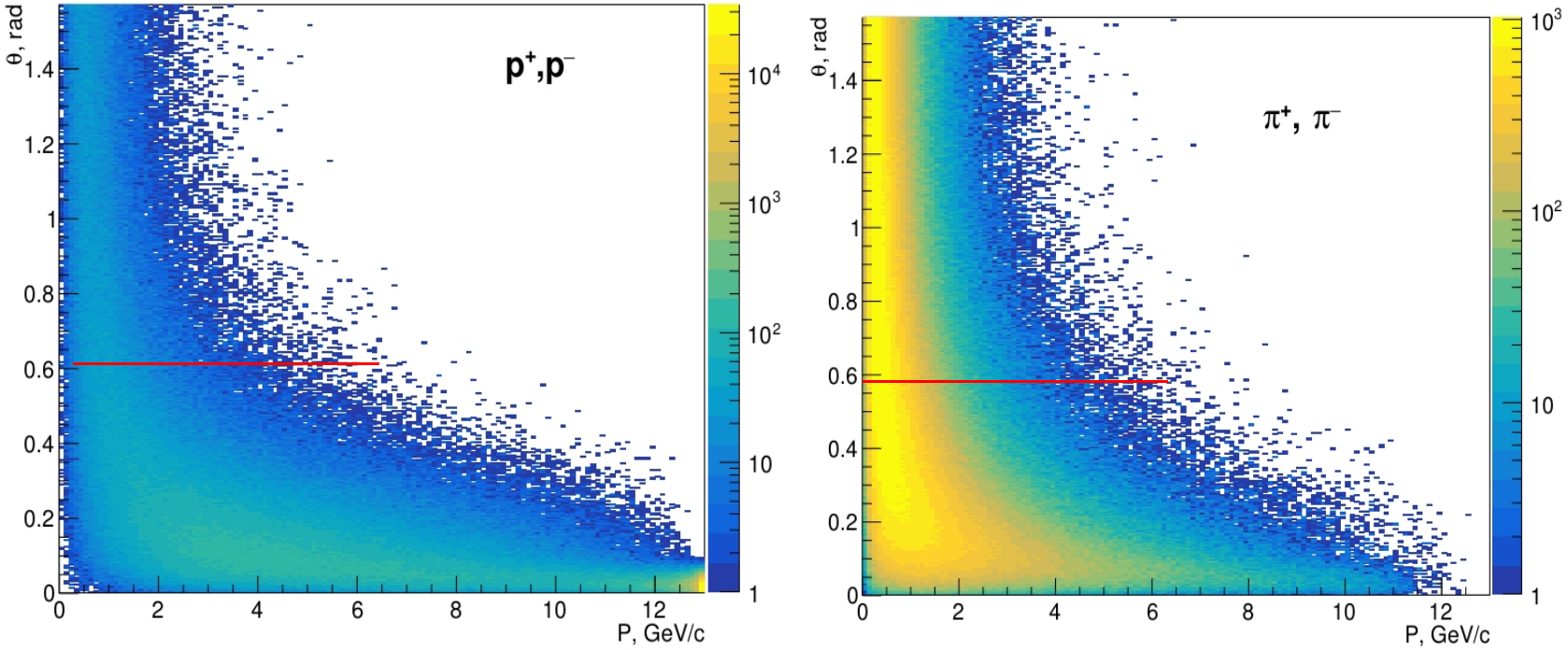
BBC: STAR experience





Correlation between CNI polarimeter and STAR BBC asymmetries.

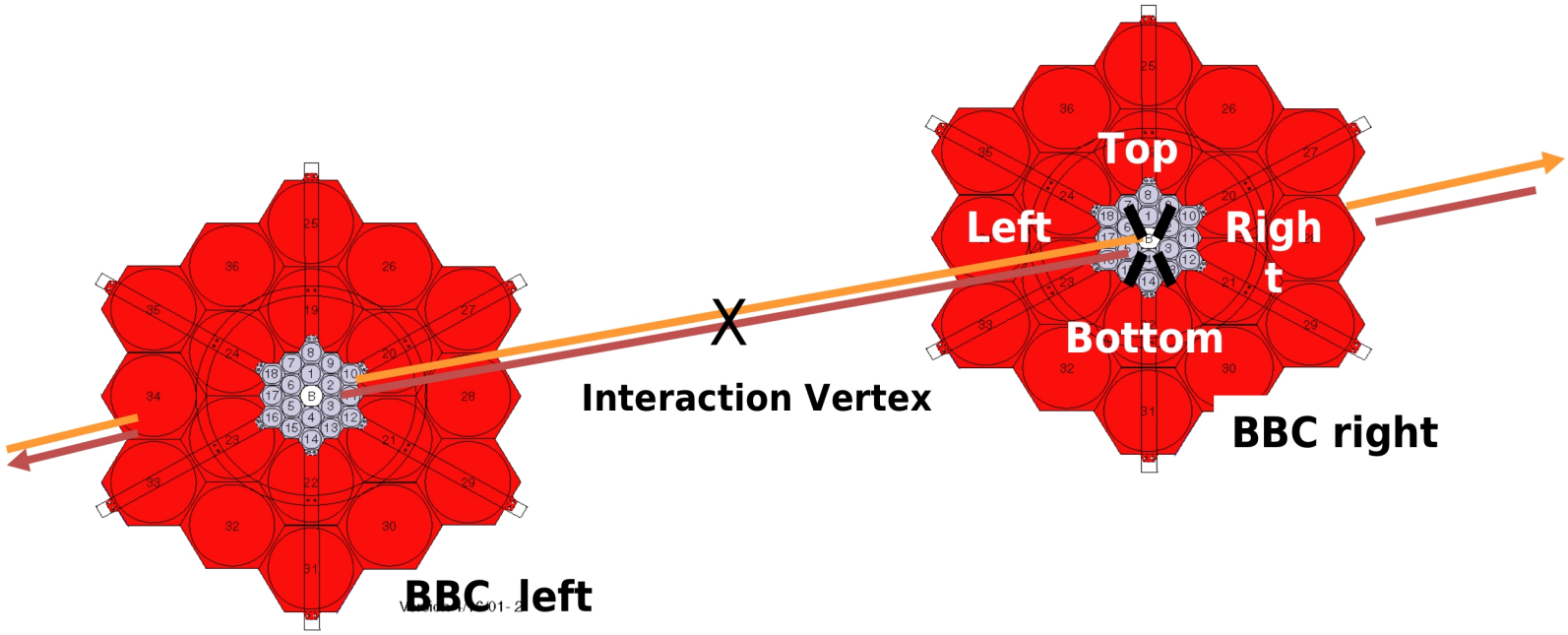
BBC: SPD energy range



Data provided by A.Guskov

Most of charged particles in forward direction at SPD energies are protons and pions.
We expect that the value of the effective analyzing power at SPD will be larger than at STAR energies.

BBC for L0-trigger and T0



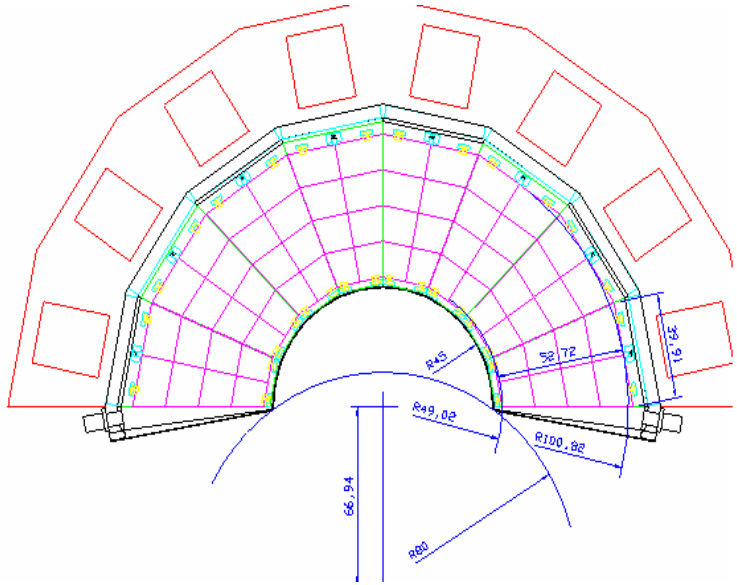
-Coincidence Left-Right corresponds to the beam-beam interaction, while signals from the left or right correspond to the interaction of the beam on the residual gas. Simulation is required for SPD case.

-Possible solution for T0 signal?

Beam-Beam Counter (BBC) for SPD

Concept: inner part – microchannel plates (MCP) based detectors

outer part - high granularity scintillator tiles with SIPM readout



1. full BBC – for the L0 trigger.

2. BBC inner part detectors have few tens ps time resolution → can be applied for T0 purpose (in HI mode).

3. BBC outer part – scintillation counters with SiPM readout with 80-120 ps resolution for local polarimetry.

Purpose is the permanent monitoring of the beam polarization using the azimutal asymmetry of the inclusive charged particles yield.

Current option for BBC

1. 2 BBCs: Left and Right
2. Inner part covers 30-60 mrad

– 4 layers *32 sectors = 96 channels MCP

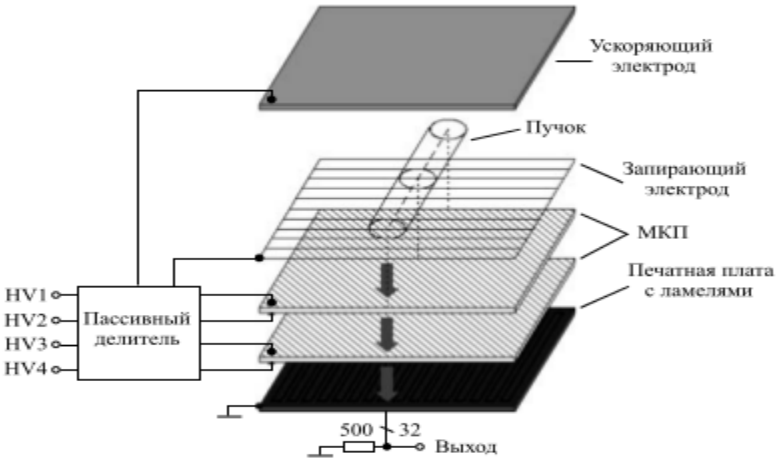
3. Outer part covers 60-500 mrad

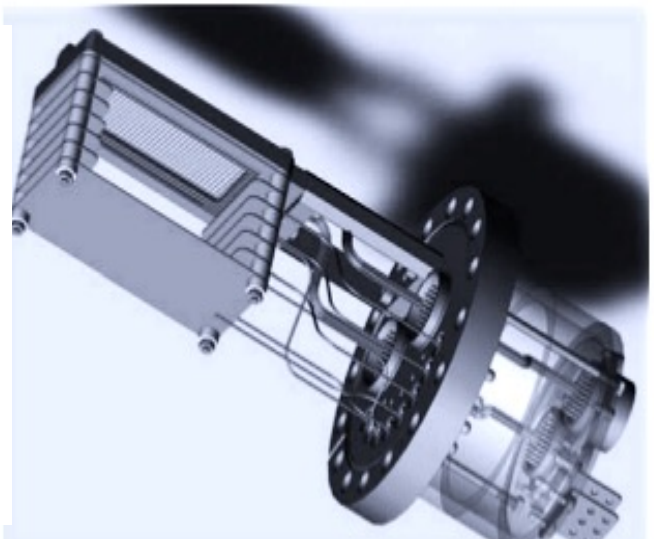
– 5-6 layers *16 sectors* 2 SiPM = up to 192 channels

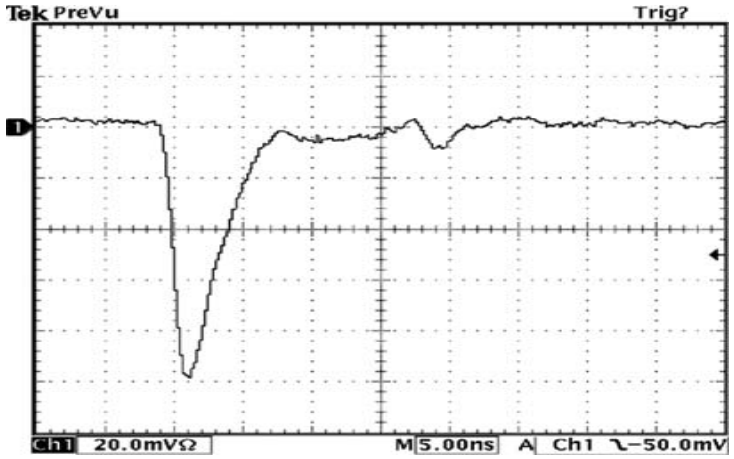
Simulation for polar angle granularity is required!

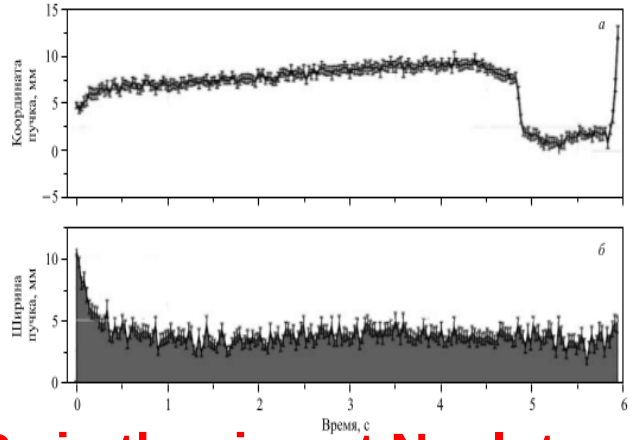
4. FEE – less than 20 W/channel
5. TDC – 25ps/channel or better (HPTDC)
6. Holding -carbon plastic
7. Needed place – about 5 cm in front of TOF
8. Weight – 50-80 kg

Inner part of BBC -MCP technology



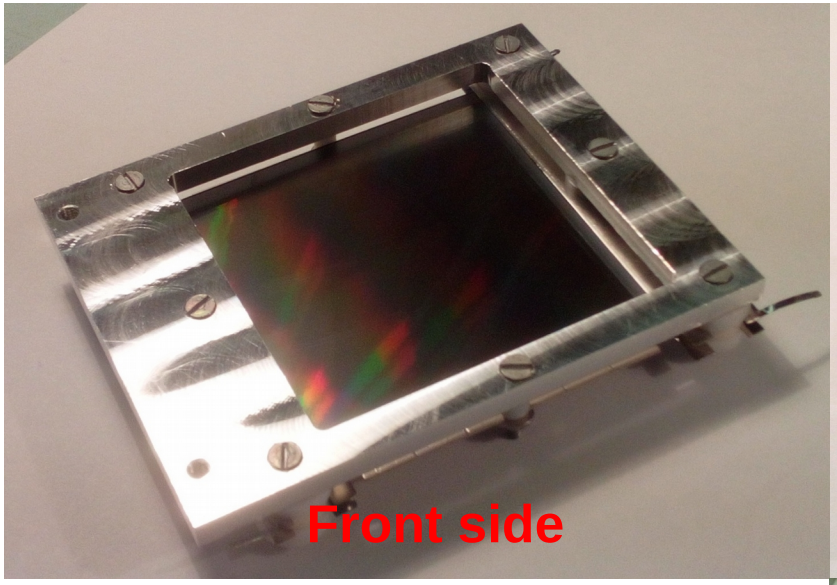


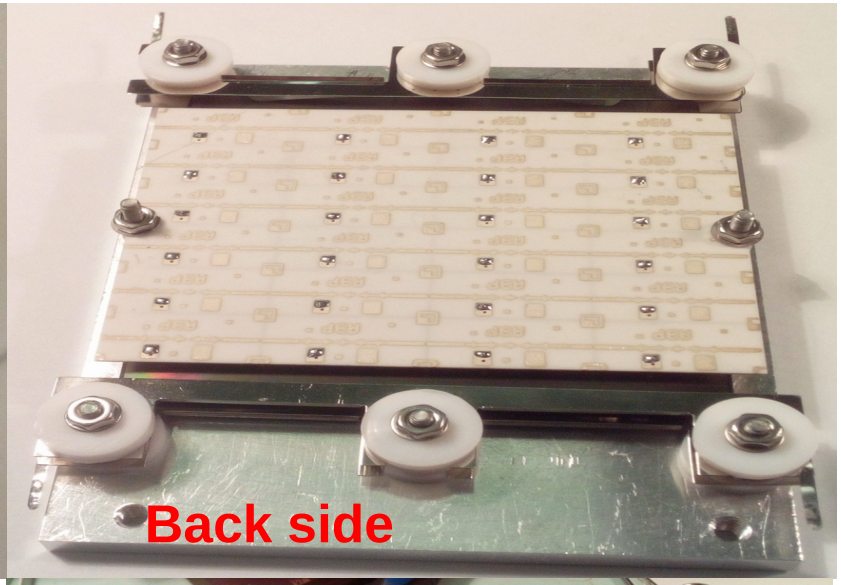




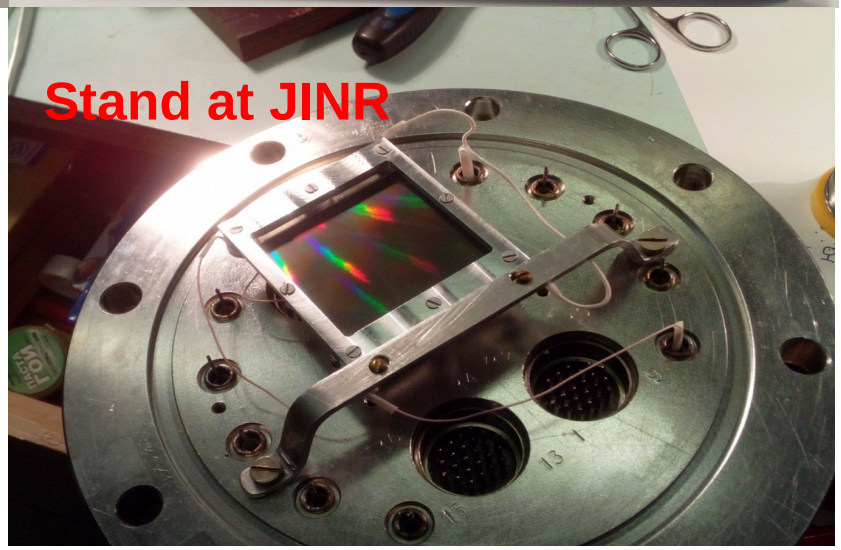
A.Baldin team -SEM based on MCPs in the ring at Nuclotron

Prototypes for inner part of BBC

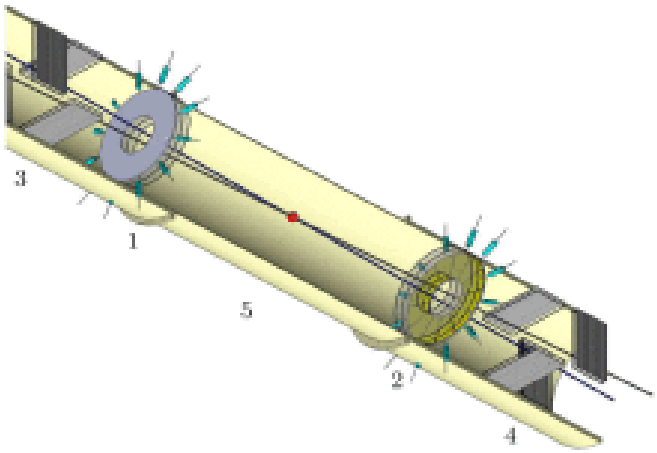




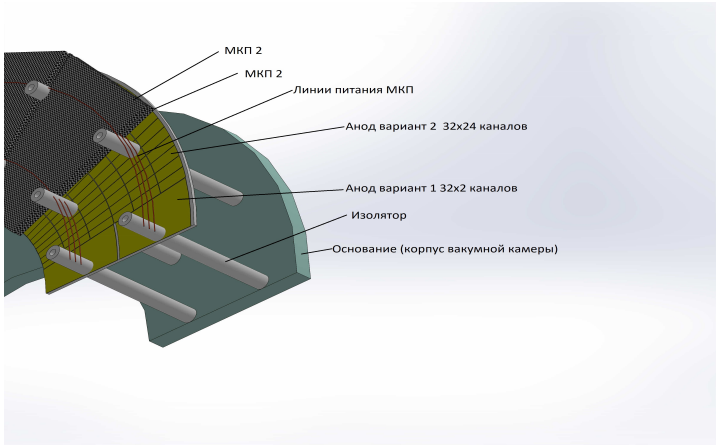
In collaboration with G.Feofilov et al. - experience at ALICE (supported by RFBR)



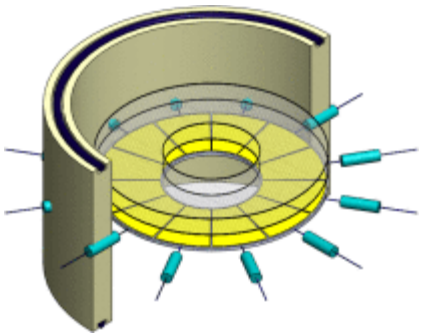
Option “inside beampipe”



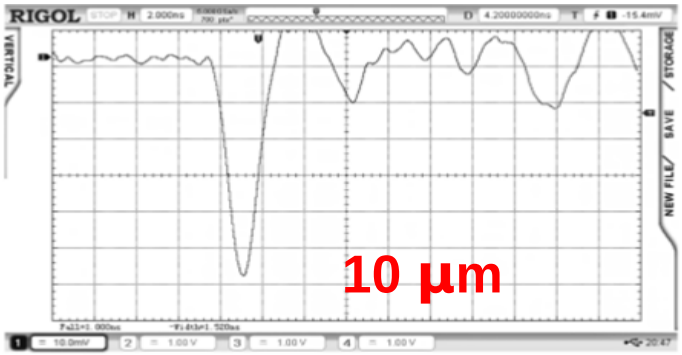
BBC positions inside beampipe



Design of MCP detector



SPD BBC inner part



MCP signal for SPD prototype
50-55 ps time resolution expected

Results and nearest plans

-Testbench for MCP detectors has been equipped (using 1065 and 1087 sources).

-Several prototypes of the shevron assembles have been tested. The expected time resolution is 50-55 ps.

-2 different designs (inside and outside of the beampipe) is under work.

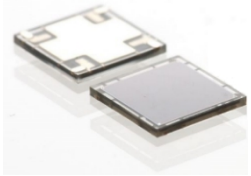
The "outside" option requires 2 separate vacuum boxes with total weight 10 kg each.

-We plan to design the FEE board based on the 32-channels ASIC Petiroc-2A which includes 10bits ADC and 40 ps/ch TDC.

-We plan to prepare several prototypes of the MCP part of BBC (for SPD testbeam zone, SPD zone at collider etc.).

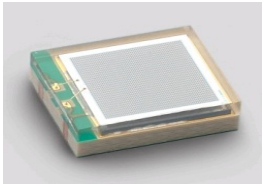
Outer part of BBC -SiPM technology

Main option is the scintillation detectors with SiPM readout at several points to improve the time and space resolutions.



SENSL

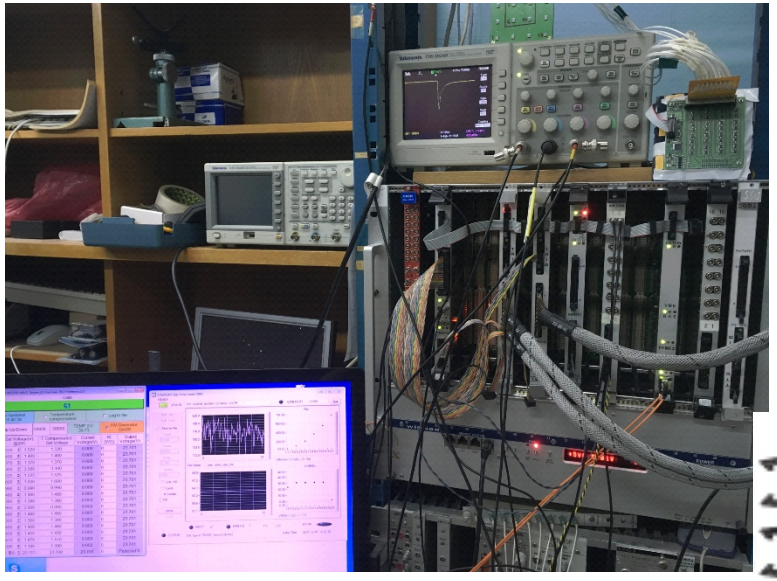
KETEK PM3350

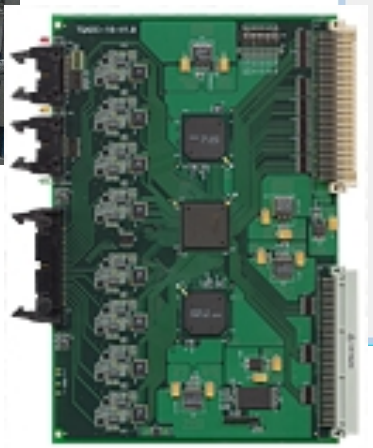


Hamamatsu S12572-010P

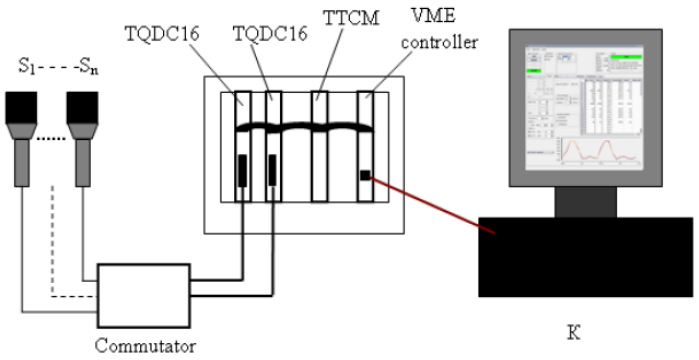
16 channels SiPM readout board has been developed and used for the tests.

Outer part of BBC: testbench





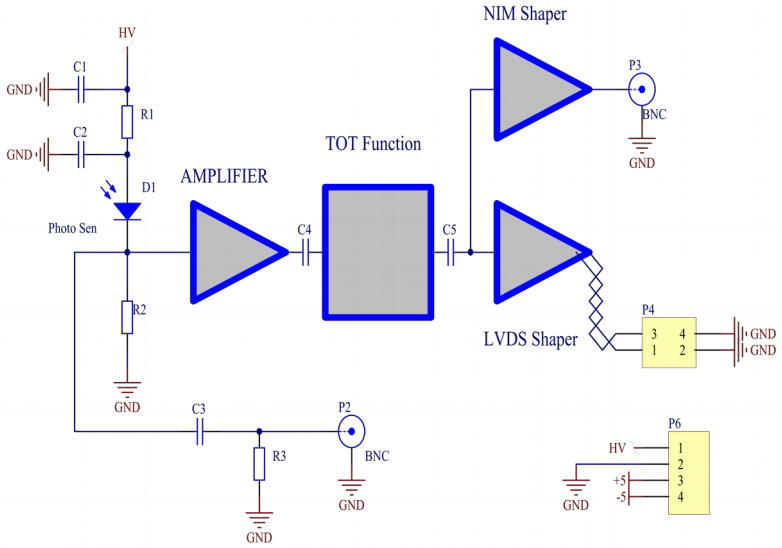
Ch.	Set Voltage(V) @20C		T Compensated Set Voltage	Current Voltage(V)	Kt (V/C)	Output Voltage(V)
0	1.356	1.356	1.356	1.356	0	73.646
1	1.239	1.239	1.239	1.239	0	73.763
2	1.247	1.247	1.247	1.247	0	73.755
3	1.648	1.648	1.648	1.648	0	73.354
4	1.351	1.351	1.351	1.351	0	73.651
5	1.125	1.125	1.125	1.125	0	73.877
6	1.399	1.399	1.399	1.399	0	73.603
7	1.323	1.323	1.323	1.323	0	73.679
8	1.341	1.341	1.341	1.341	0	73.661
9	1.224	1.224	1.224	1.224	0	73.778
10	1.297	1.297	1.297	1.297	0	73.705
11	1.348	1.348	1.348	1.348	0	73.654
12	1.608	1.608	1.608	1.608	0	73.394
13	1.315	1.315	1.315	1.315	0	73.687
14	1.225	1.225	1.225	1.225	0	73.777
15	1.299	1.299	1.299	1.299	0	73.703
Ped	75.000	75.002	74.998	75.002	0	Pedestal V



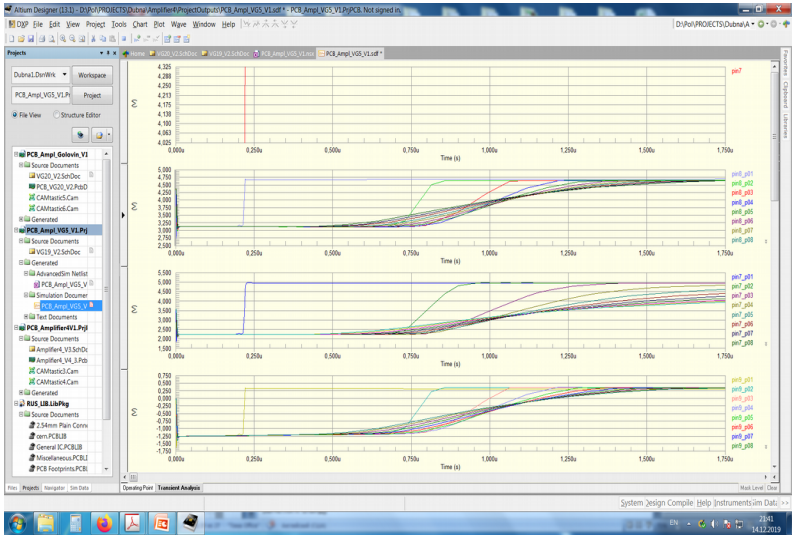
TQDC16 or TDC32(64)

The VME based data acquisition system was developed and used for the data taking from scintillation detectors.

FEE for scintillator part of BBC



Scheme of the TOT amplifier (ITEP)



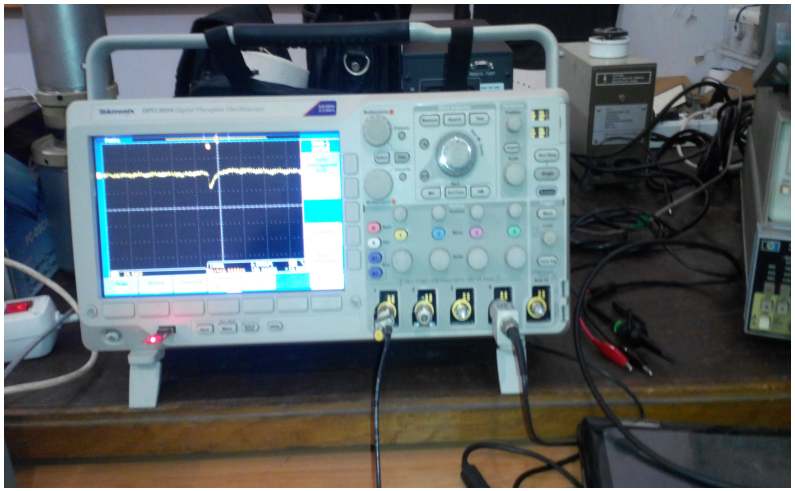
Simulation of the amplifier for large signal amplitudes

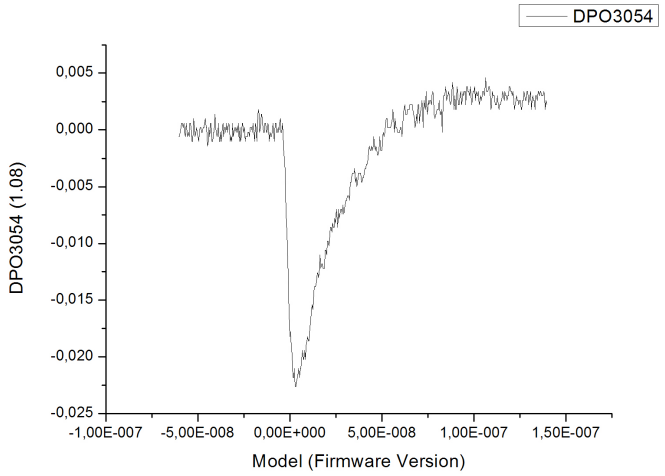
-Prototype of the front-end electronics with TOT function for Hamamatsu S12572-010P SiPM has been developed.

-Prototype of the bias voltage system has been developed.

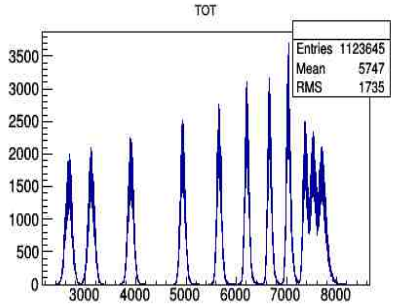
FEE with TOT function allows to use standard TDC (with leading and trailing edges).

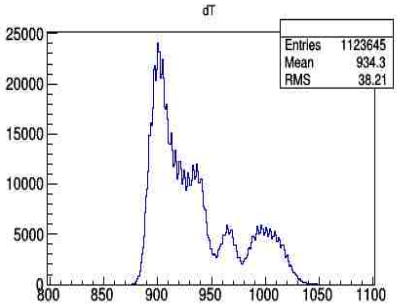
Status of the amplifier with ToT

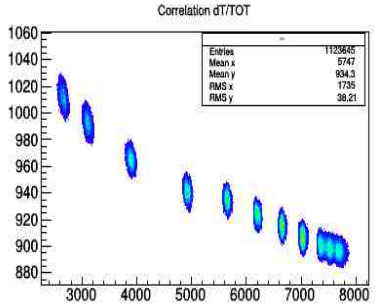


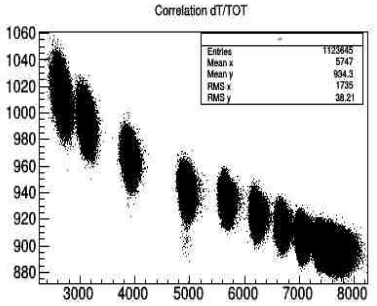


FEE for scintillator part of BBC









-Prototype of the FEE with TOT function for Hamamatsu S12572-010P SiPM has been tested using LED at the testbench equipped at LHEP.

-TOT function (signal width vs amplitude) can be parameterized by the polinomians.

Studies were stopped due to COVID-19.

Results and nearest plans

-Testbench for the scintillation detectors with SIPM readout has been equipped (using 1065, 1097, 1106 sources).

-Prototype of the FEE with TOT function for Hamamatsu S12572-010P SiPM has been tested using LED.

-Different size and types scintillators (BICRON) are prepared for prototypes.

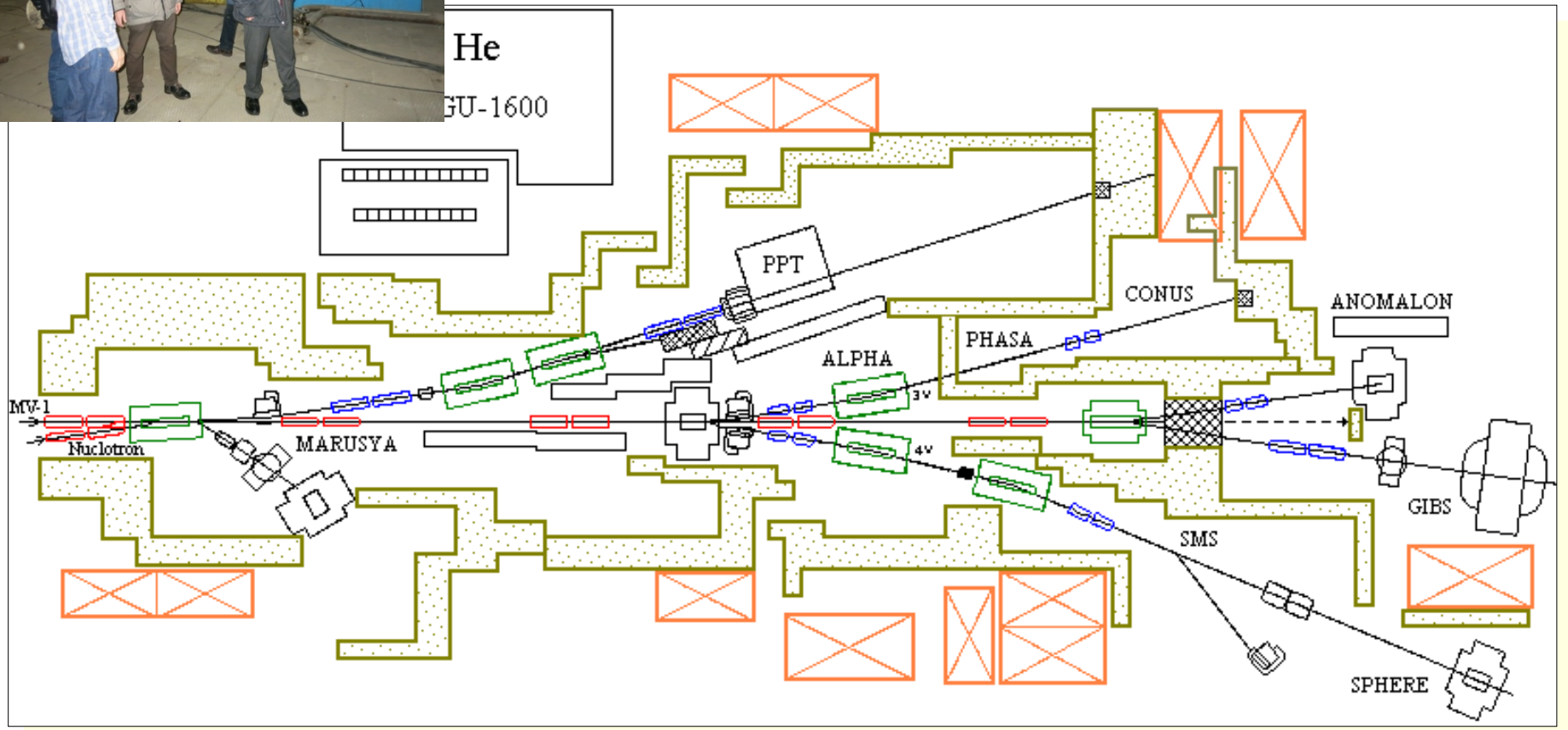
-We are expecting up to 24 FEE cells to make the tests with the scintillators.

-We signed a contract with ITEP on the development of the FEE for Hamamatsu S14160-XX (32 cells) with the bias voltage system.

-We plan to prepare several prototypes of the scintillator part of BBC (for SPD testbeam zone, ITS at Nuclotron and SPD collider zone).

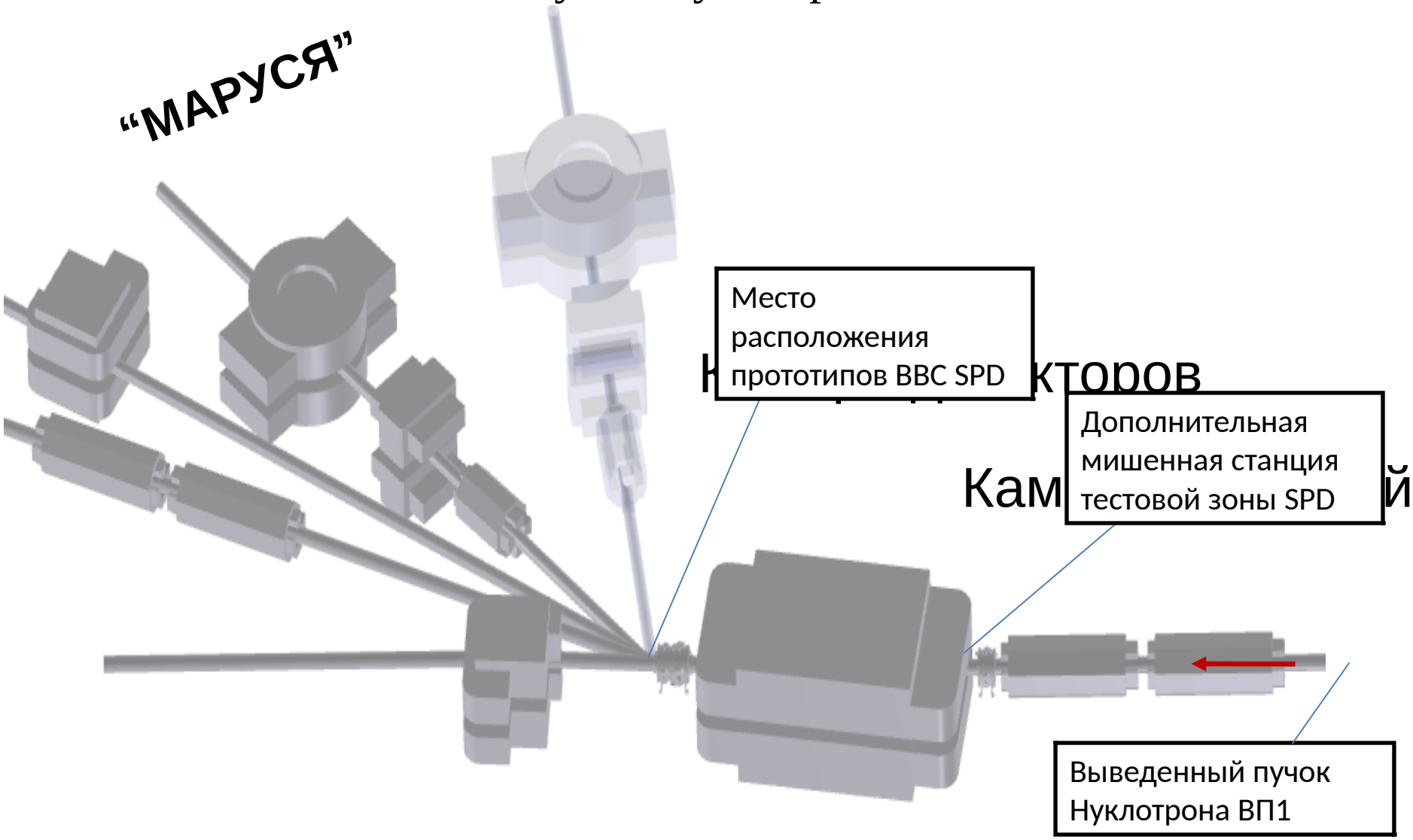
The PANDA option (S13360-3050PE+ TOFPET ASIC) for the BBC scintillator part should be investigated if the requirements to the time resolution will be erased.

SPD test zone:
“MARUSYA”+”Polarimeter” setups

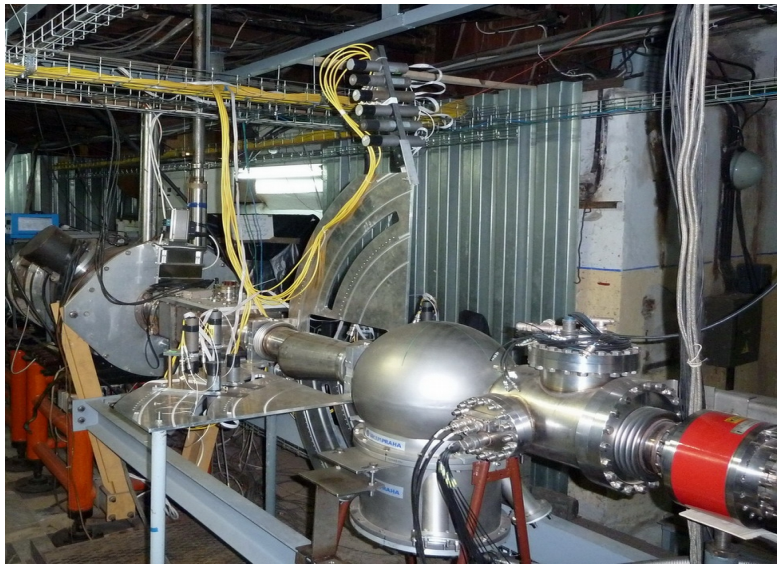


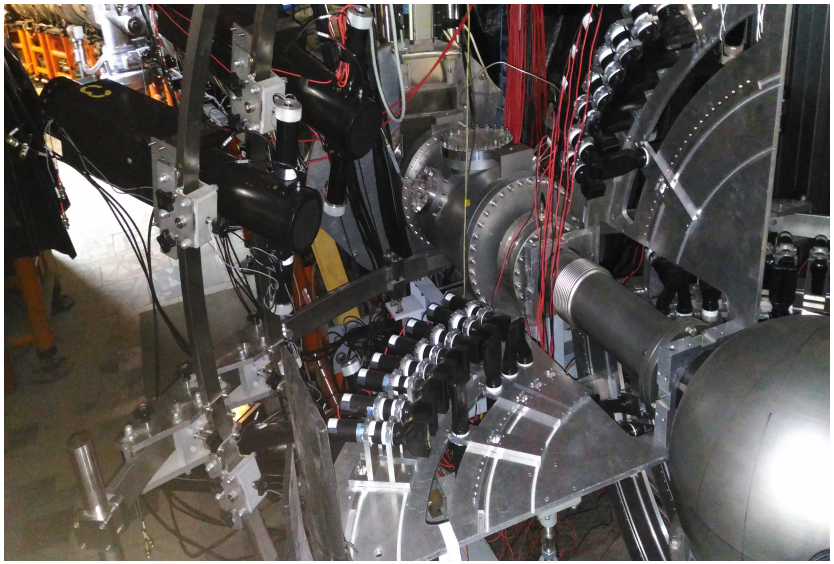
Test of the prototypes of the BBC, including both inner and outer parts - 2021.

Ионопровод тестовой зоны SPD на выведенном пучке Нуклотрона



Internal target at Nuclotron

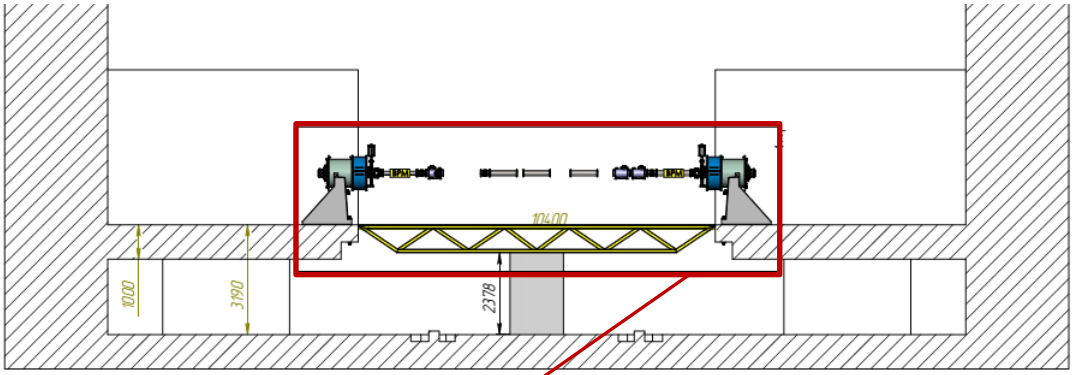


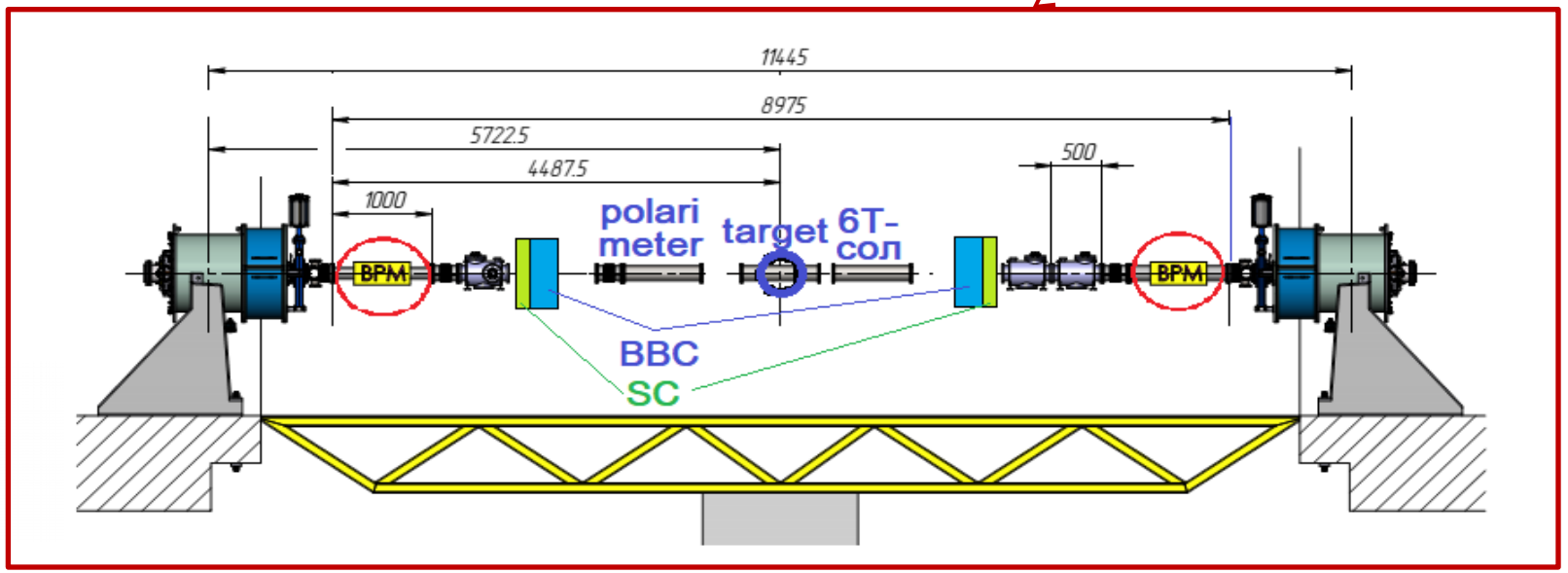


1. MCP part of BBC – different options of FEE
2. Scintillation part of BBC – together with proton/deuteron ITS polarimeter.
3. Part of the tests free (almost)!

BBC prototypes tests at SPD collider zone

From report of A.D.Kovalenko 5.05.2020 at SPD Interim SC.





-Prototypes of BBC can be tested during first beams at NICA.

Plans

1. Tests of the prototypes in the laboratory — 2 stands are fully equipped.
2. Development of the detector model for the SPDRoot and simulation- urgent help is needed.
3. Development of the BBC system prototype for the SPD test zone at Nuclotron. Parts of outer BBC can be tested at internal target at Nuclotron.
4. Preparation of the prototypes for SPD zone at collider.
5. Tests for cells prototypes at LNP LINAC (possibly in 2020)

6. Preparation of the contribution for CDR.

Manpower request

Missed: 0.5 FTE - designer

1.0 FTE = 2 Master students for SPDRoot

1.0 FTE = 2 Master students for detectors

Conclusions

1. Local polarimetry for protons at the first stage (low luminosity and non-maximal energy) can be provided using BBC.

2. ECAL endcups can be also used for the proton local polarimetry. Possible participation in the fast online neutral pions reconstruction for ECAL endcups.

3. ZDC at the first stage seems to be useless for the proton local polarimetry. Participation in the R&D an tests. We can help in the development of the neutron spectator detector.

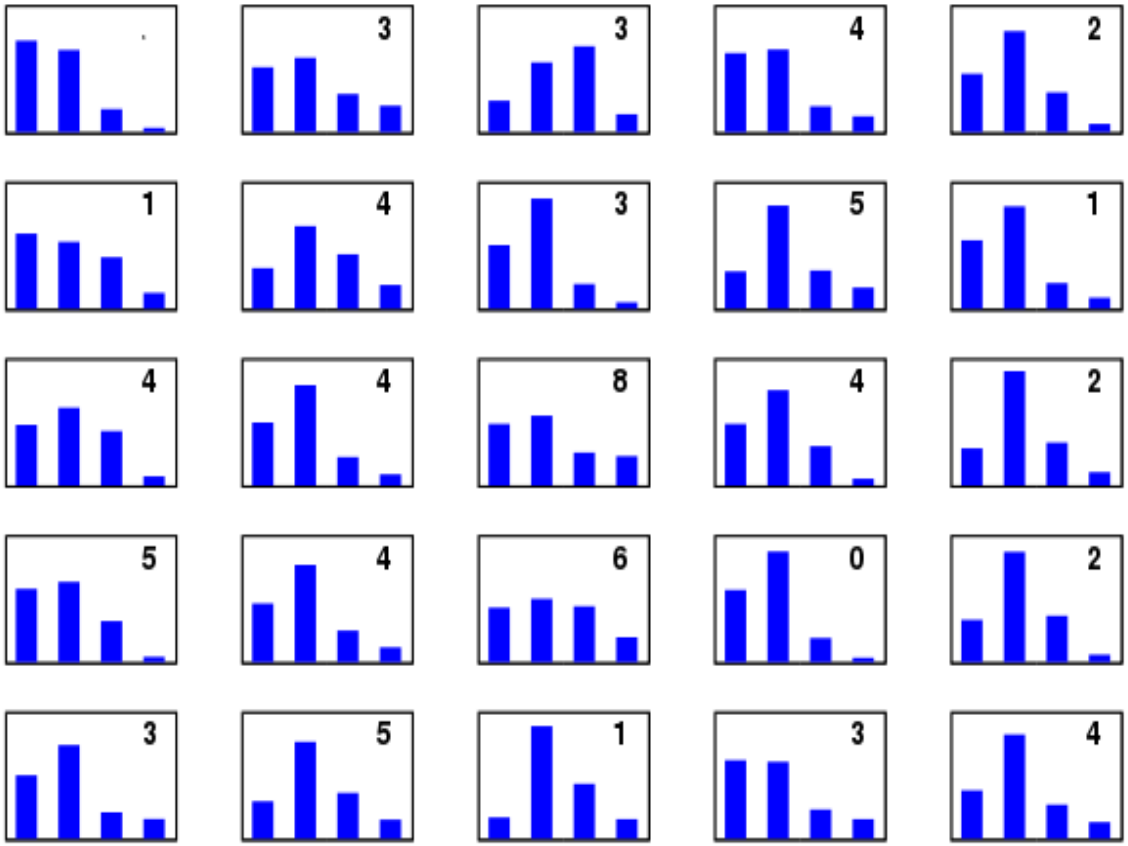
4. The BBC project is going quite smooth. Delay, especially, with the ToT FEE development exists. Manpower, especially for the simulation is needed.
Clean rooms are needed for the work with the full azimuthal angle prototypes.

5. Several prototypes will be prepared in 2021 for the tests at Nuclotron and SPD.

6. No evident solution for deuteron local polarimetry both for tensor and vector components!

Thank you !

1 GeV electrons “by quarters”

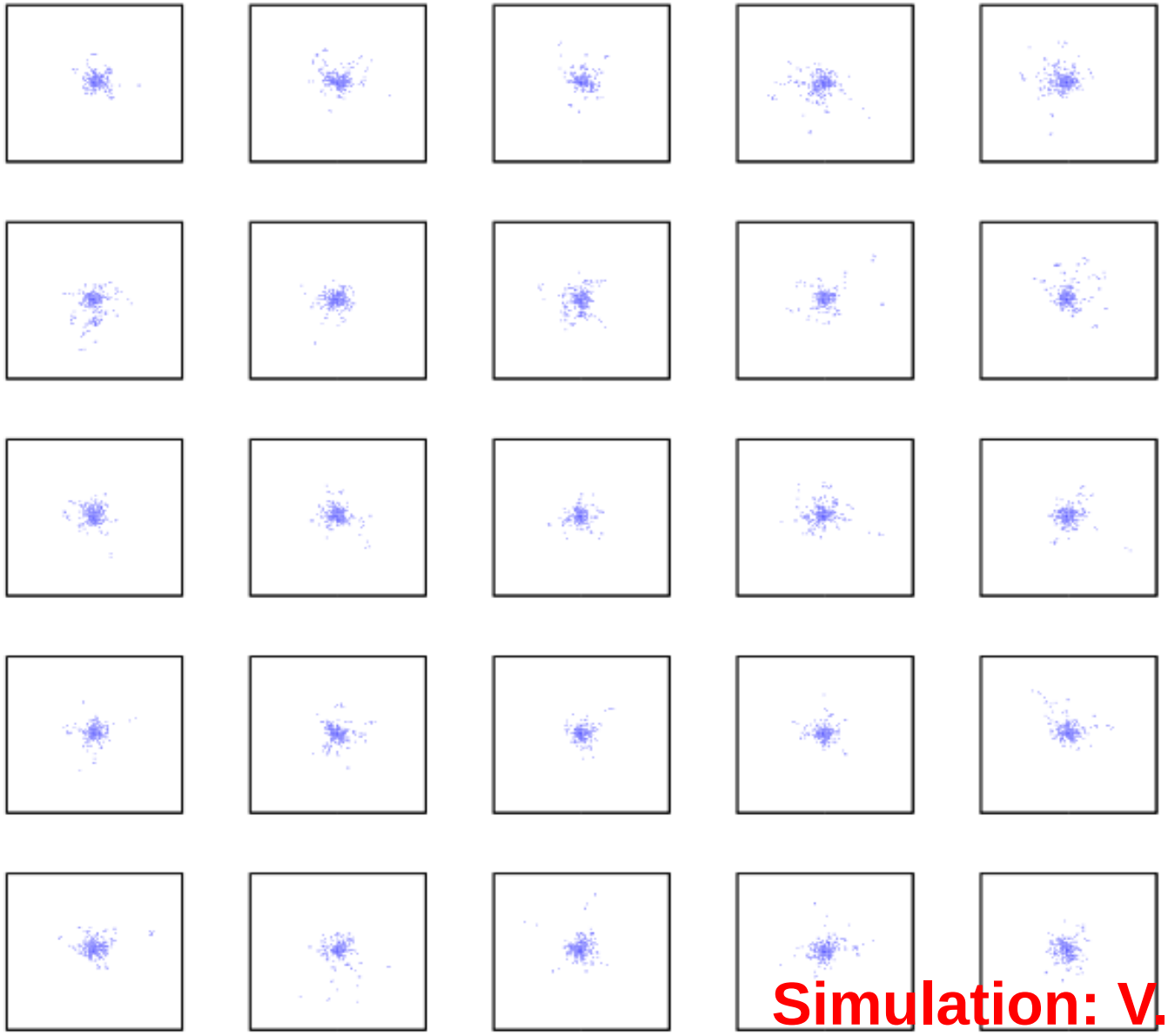


- Y-scale 0-600 MeV
- Black numbers: loss in percents. Pass through, albedo, hadronics

Idea: O.Gavrichtchouk

Simulation: V.Popov

1 GeV electrons, XY projection



Simulation: V.Popov

Inner part of BBC

A compact setup of two detectors with high timing capabilities based on the MCP applications - the Fast Beam-Beam Collision counters (FBBC) and the Beam Position Monitor (BPM), is proposed to meet the wide set of requirements of the future physics program with the polarized beams in the SPD at NICA.
The feasibility of the event-by-event monitoring of the beam-beam interactions at NICA is confirmed both by the previous developments of the UHF-UHV technology and by the beam tests at JINR and CERN of the prototype detectors and electronics, as well as by the in-lab tests of new 8μ-channels MCPs with the improved characteristics.
The new R&D efforts will be focused on the development and the in-beam tests of the next generation of compact fast MCP-based FBBC prototypes using the beam-test facility at JINR.