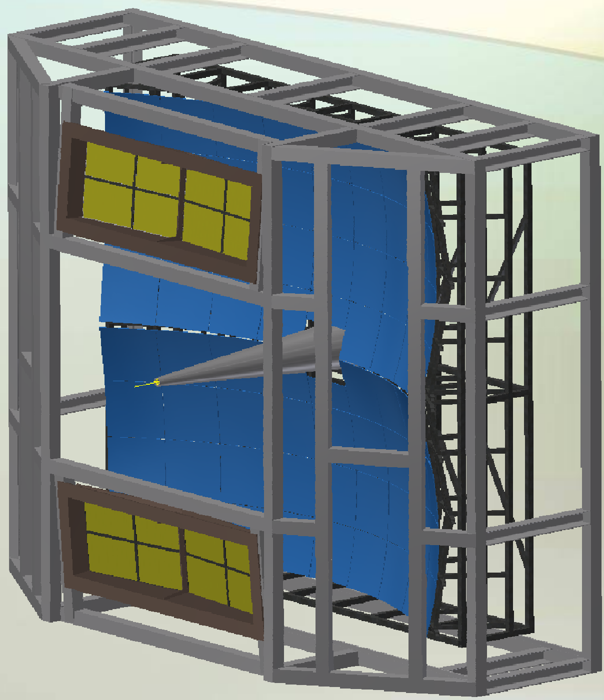
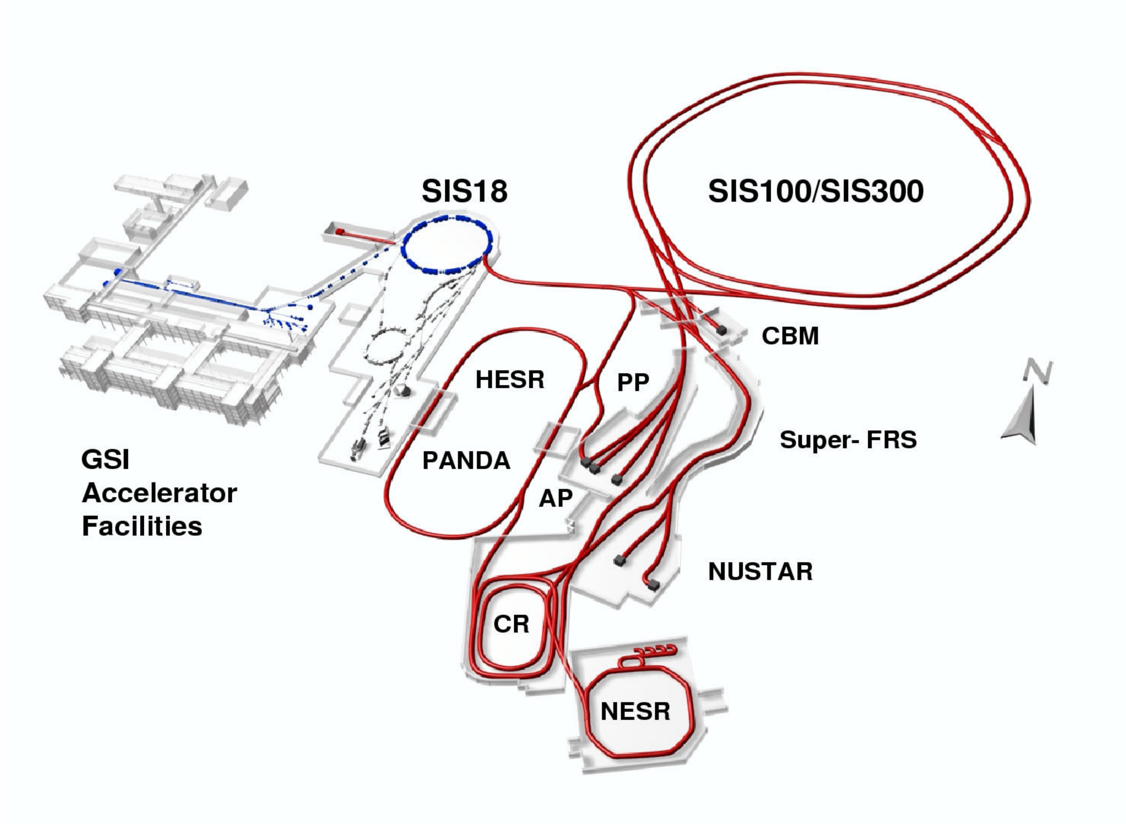
Детектор RICH для эксперимента СВМ.



Ю. Рябов, ЛРЯФ ОФВЭ

FAIR. Стартовая версия



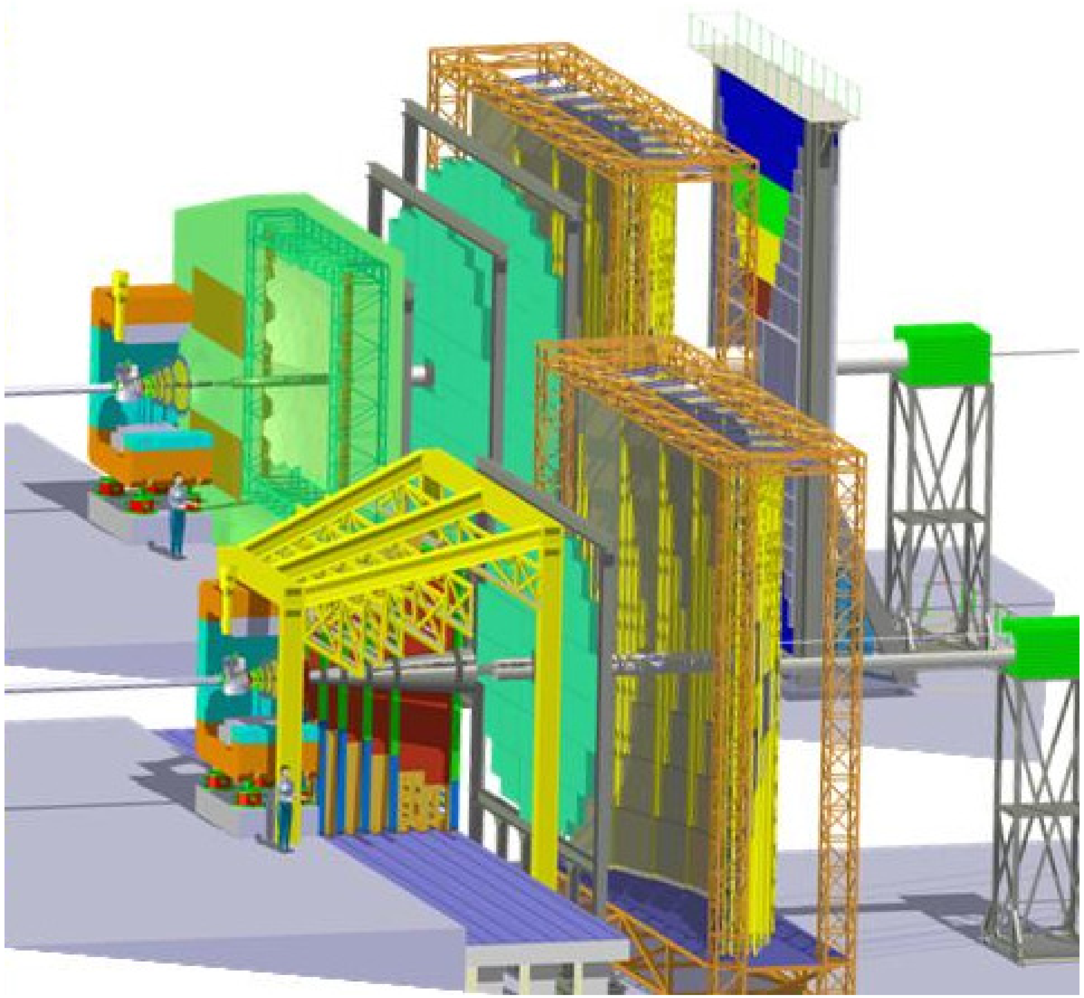
SIS100 в расположение **CBM** будет поставлять пучки **Au(Ca)** с энергией до **11(14) АГэВ** и **протонов** до **29 ГэВ**

SIS300 – ядра вплоть до урана с энергией **8-40АГэВ** и протоны до **90 ГэВ**

CBM (**C**ompressed **B**aryonic **M**atter) – эксперимент по ядро - ядерному и протон - ядерному взаимодействию на выведенном пучке.

Начало эксперимента планируется на **2018 г.** с запуском **SIS100**.

Эксперимент CBM.



- Концепция эксперимента – магнит и трековая система (силиконовые станции), затем PID.
- Идентификация электронов необходима для выполнения программы эксперимента (л.в.м (ω,ρ,φ), (J/Ψ, Ψ'), ди-электронный континуум, электроны от распадов тяжелых ароматов и т.д.).
- Необходимо подавление пионов > 1/5000 (сейчас по проекту 1/10000) (RICH (>1/100 до 7-10 ГэВ/c) + TRD).

RICH

Н. Болдырева, Е. Взнуздаев, М. Взнуздаев, А. Воинов, В. Добырн, В. Евсеев, Л. Коченда, П. Кравцов, Е. Леонова, Н. Мифтахов, Е. Рощин, Ю. Рябов, Г. Рыбаков, В. Самсонов, О. Тарасенкова, В. Толчин

Принцип работы.

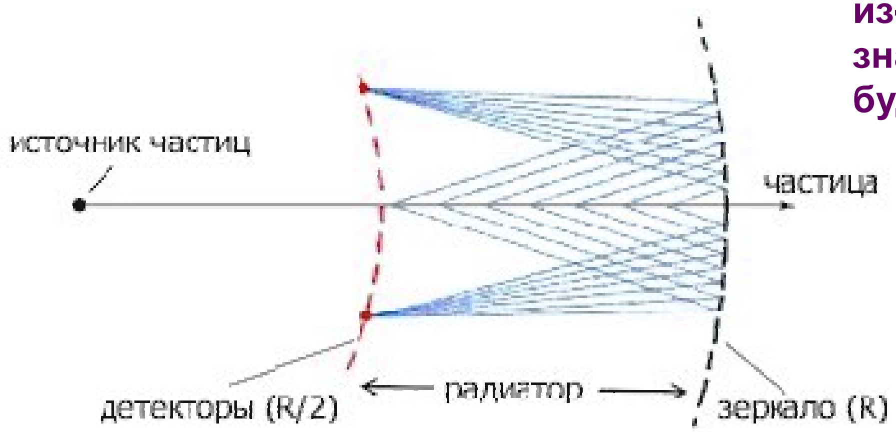
Регистрация черенковского излучения – возникает при движении заряженной частицы в прозрачной среде со скоростью большей скорости света в этой среде.

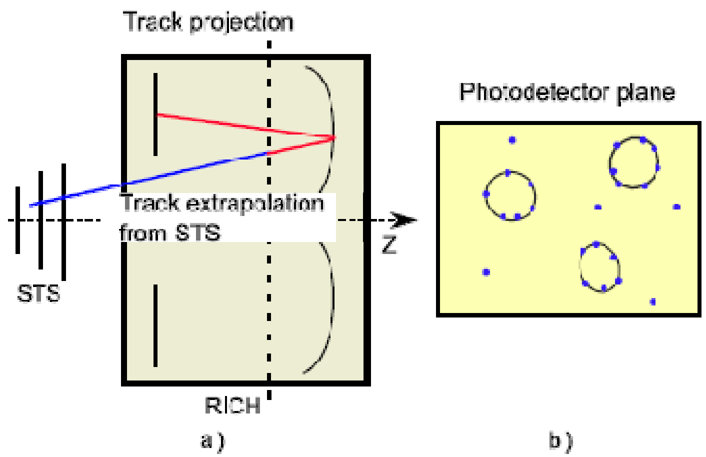
$$\beta = \frac{v}{c} > \frac{1}{n}$$ Условие возникновения черенковского излучения

$$\cos\theta = \frac{1}{\beta n}$$ Излучение идет вдоль поверхности конуса (изотропн. среда)

n – коэф. преломления радиатора $\beta = \frac{v}{c}$ $m = p\sqrt{1-\beta^2}/\beta c$

электроны начинают излучать черенковский свет, имея импульсы, гораздо меньшие, чем даже пионы из-за разницы в массах. Поэтому до определенных значений импульсов заряженных частиц электроны будут выдавать "круги", а остальные частицы нет.





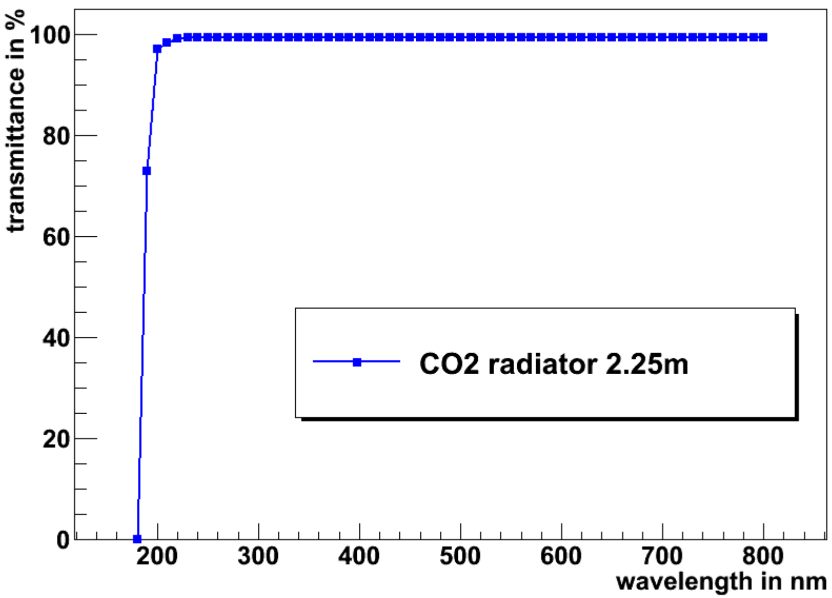
Радиатор.

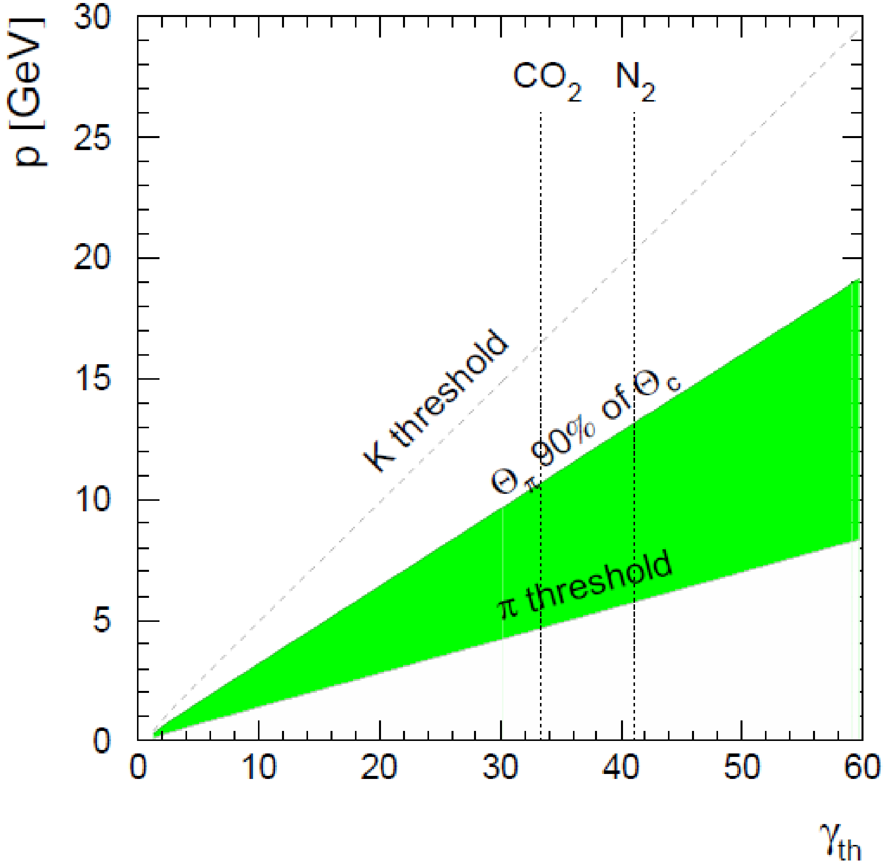
Классическая схема. В качестве радиатора – CO_2

n=1.00045, γ_{th}=33.3 $\gamma_{\rm th} = 1/\sqrt{1-1/n^2}$

p_{th}(пион)=4.65 GeV/c

1.7 m – средняя длина пути в радиаторе
(Nhits ≥ 20 (electron rings))

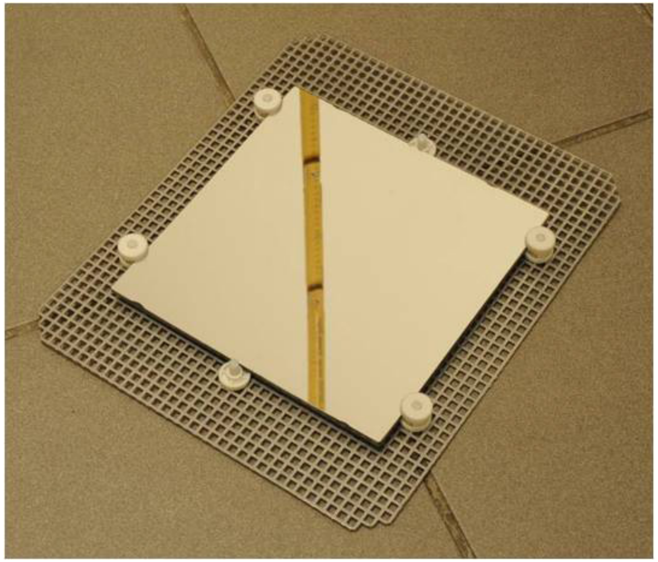


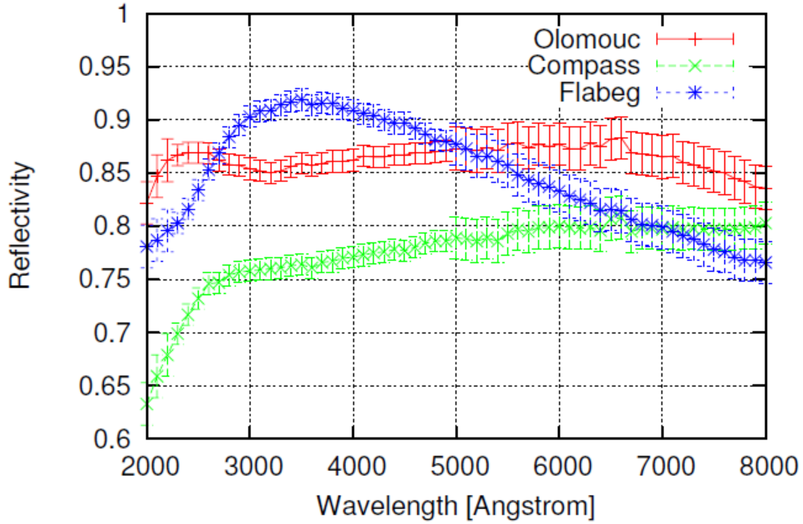


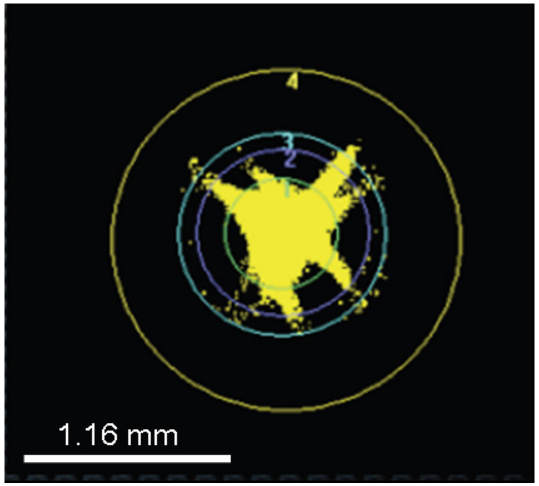
Зеркала.

Стеклянное зеркало. Отражающее покрытие – тонкий слой Al

Дополнительная защита (от коррозии) – MnF_2.



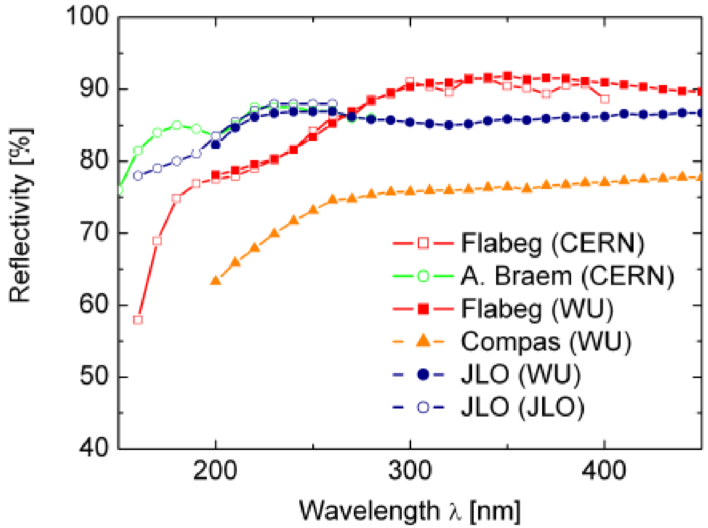




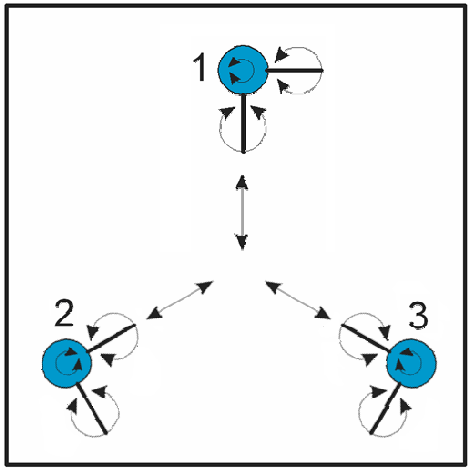
D_0<3 mm.

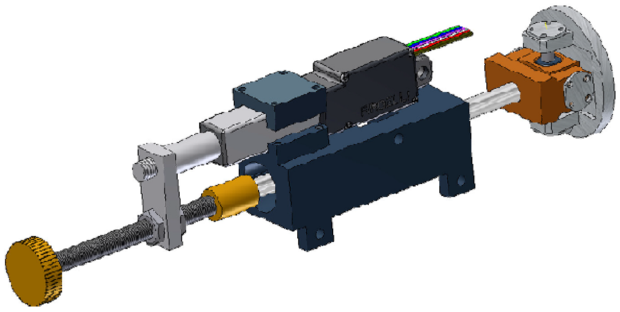
Толщина – 6мм.

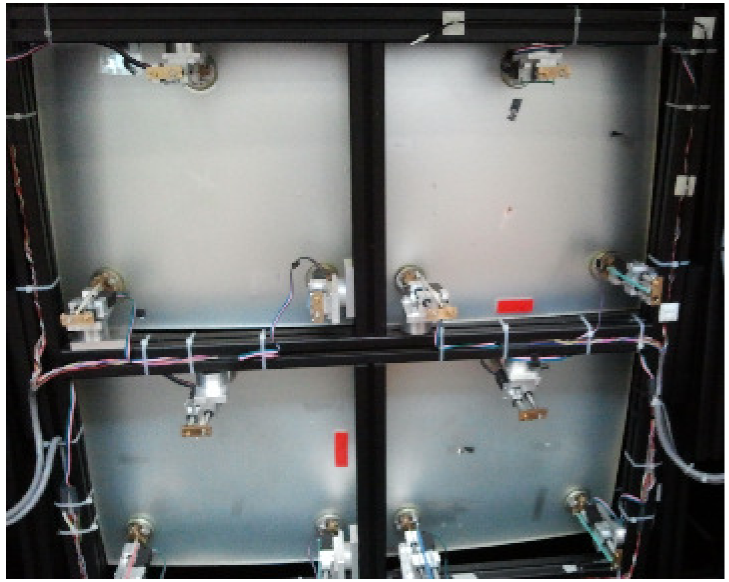
Размер 40x40 см

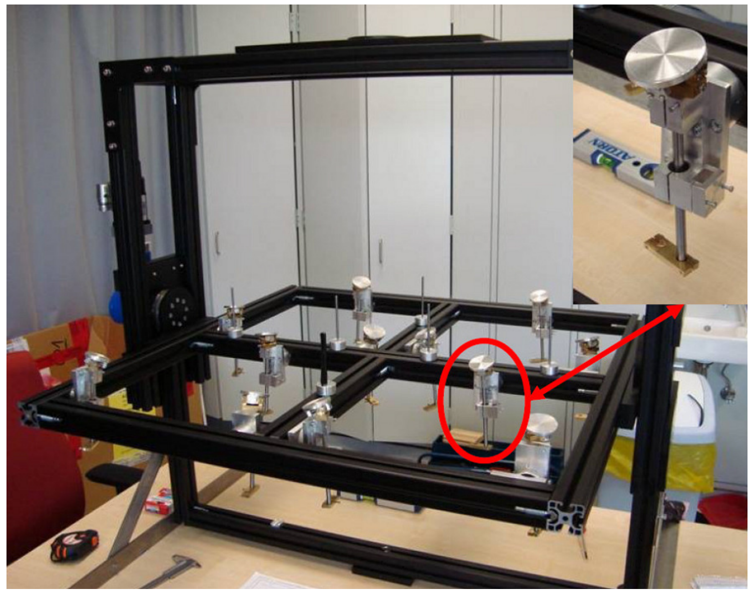


Подвесы.



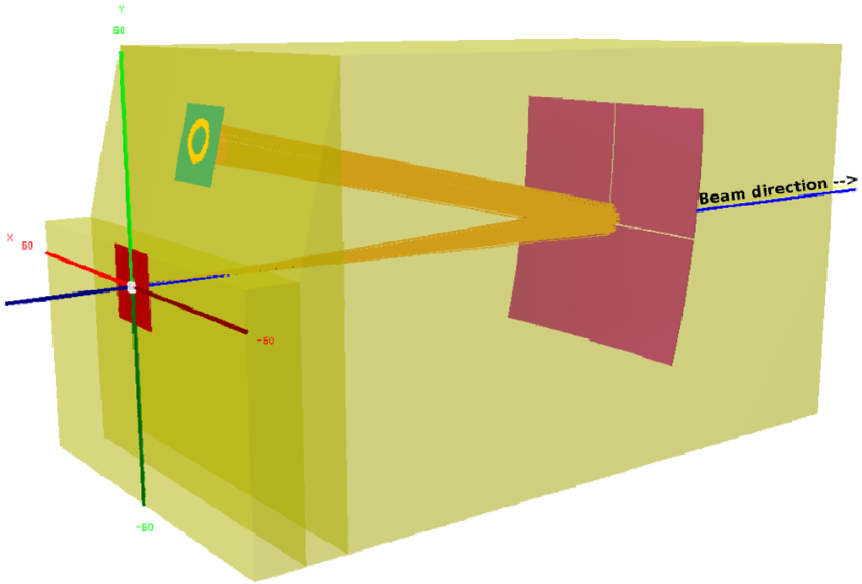


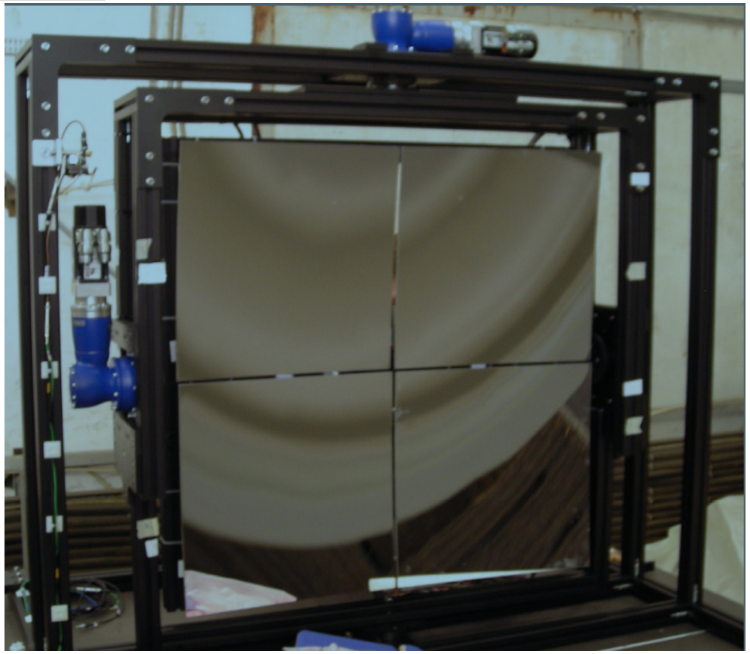


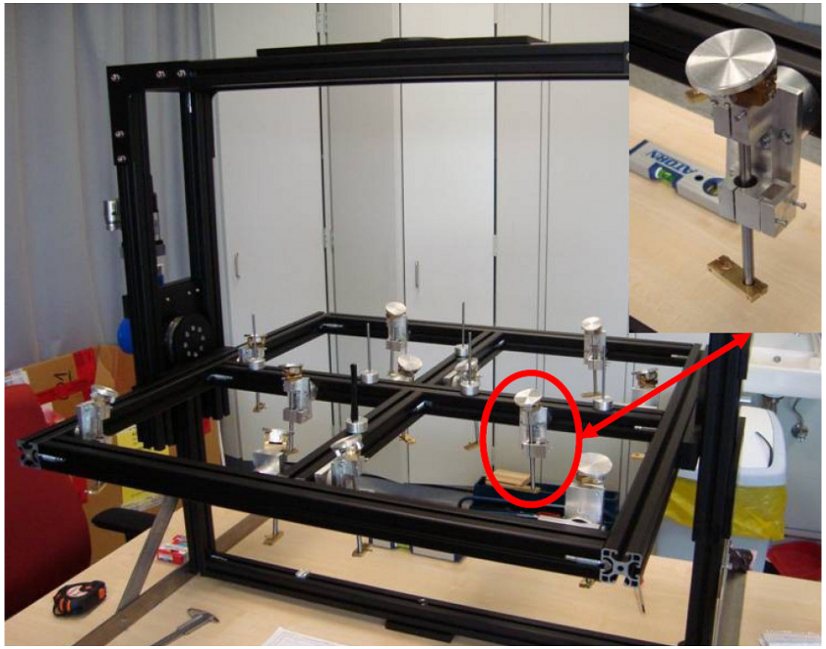


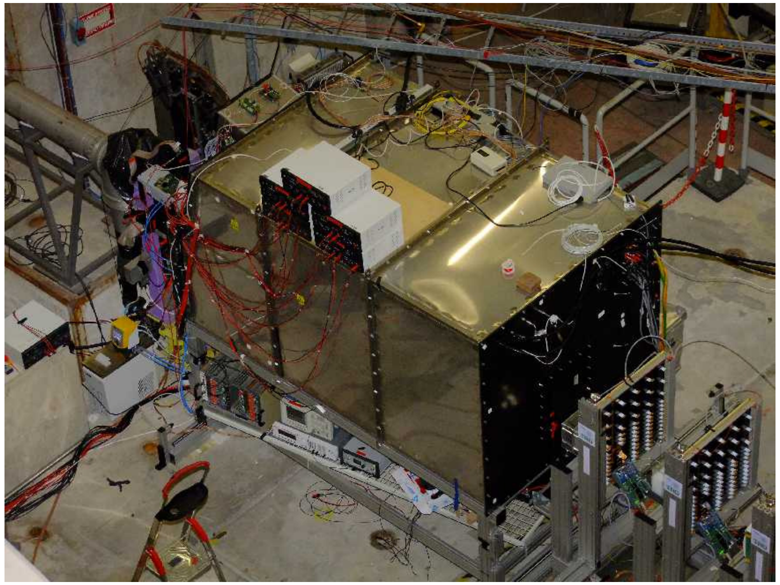
- Выбрана трех точечная концепция подвеса. Позволяет компенсировать гравитационные деформации зеркала (< 5 μm);
- Позволяет вращать зеркало (плитку) и перемещать вдоль z.
- Успешно протестировано на прототипе;
- В настоящий момент предусмотрено ручное и удаленное управление;

Прототип.



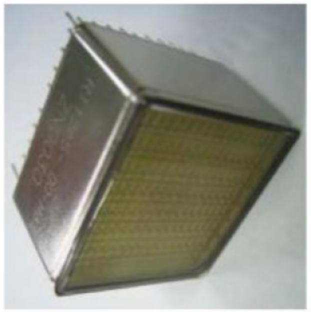




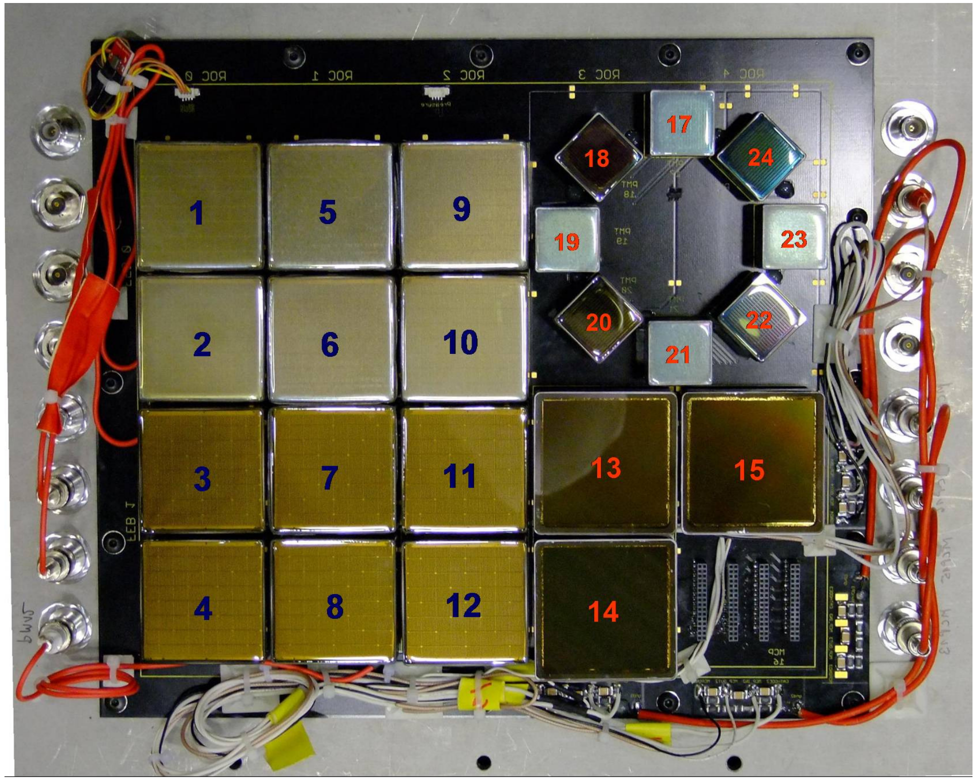


Прототип (фотосенсор).

H8500 C/D
64ch, 52x52mm²

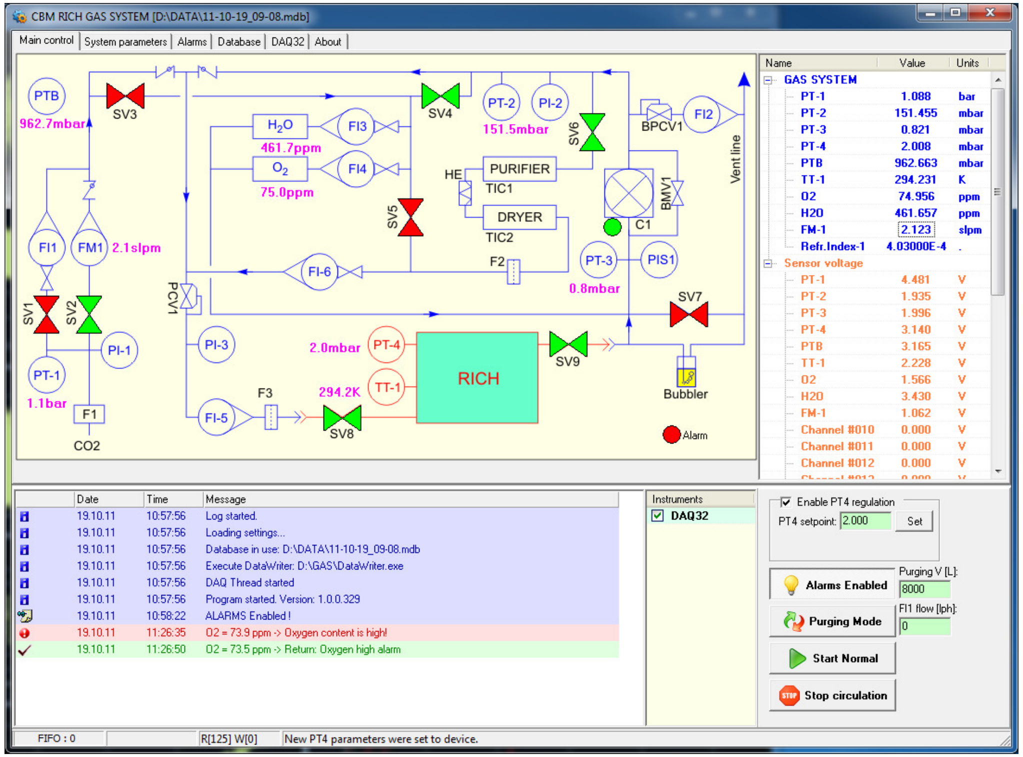


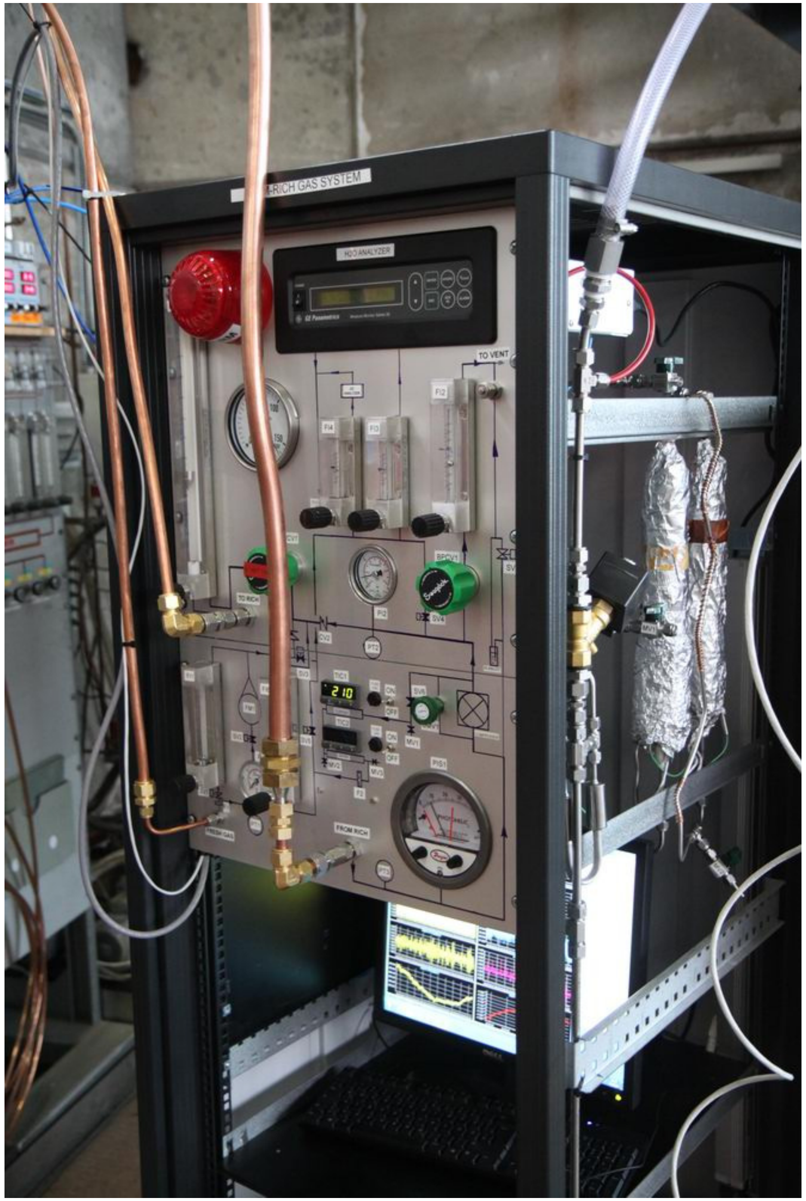
R11265-103-M16
16ch, 26x26mm²

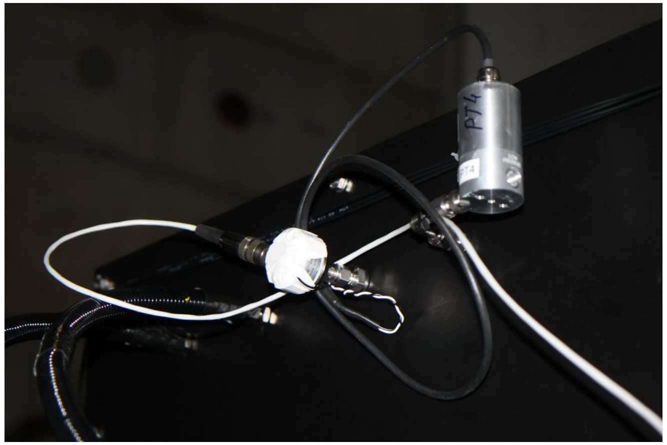


- XP89012 MCP: Multi-anode Mico-Channel-Plate from Photonis, can stand up to 1T magnetic field, very good timing very expensive

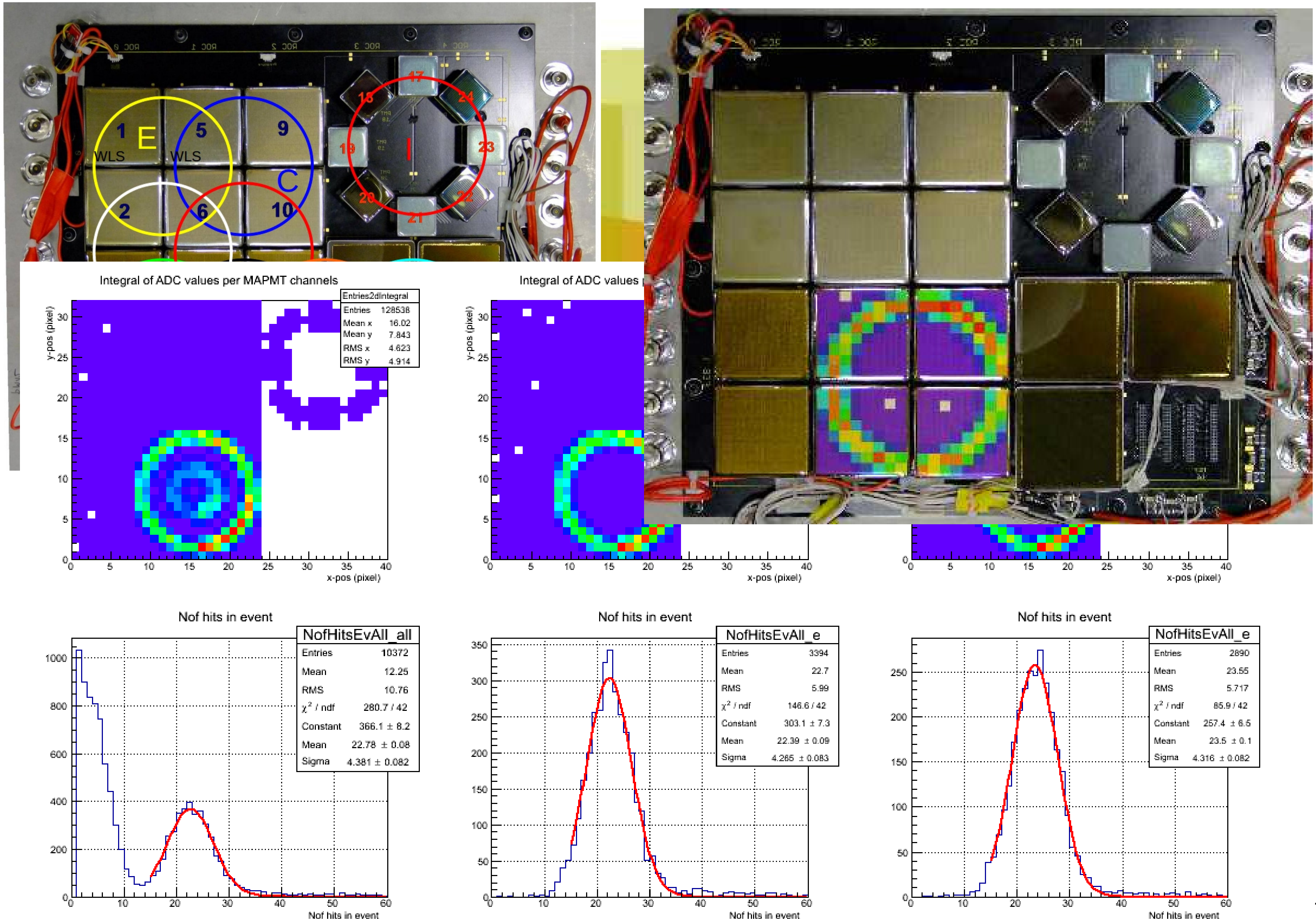
Тестовый пучок



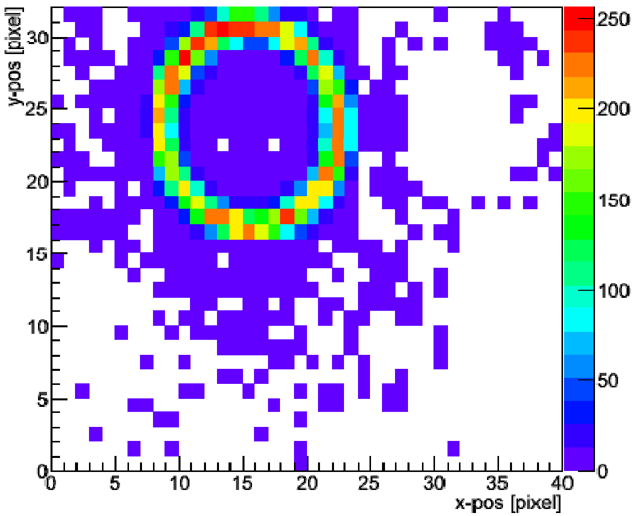


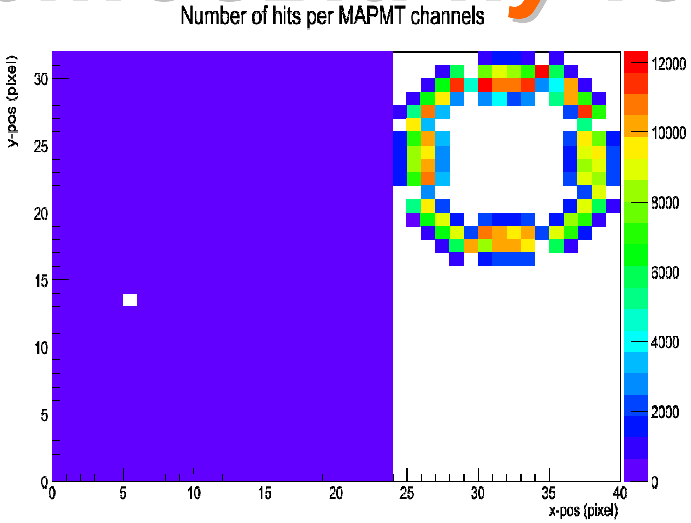


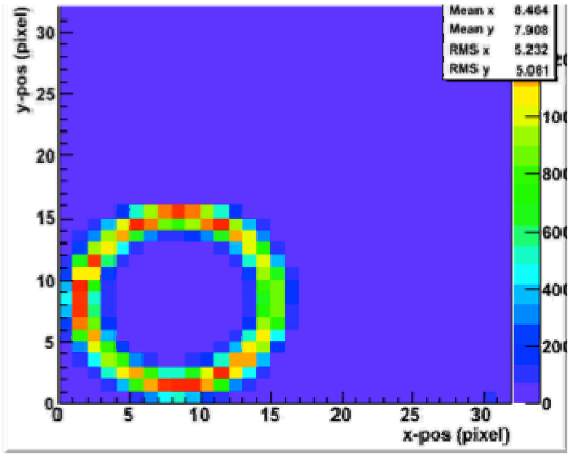
Тестовый пучок

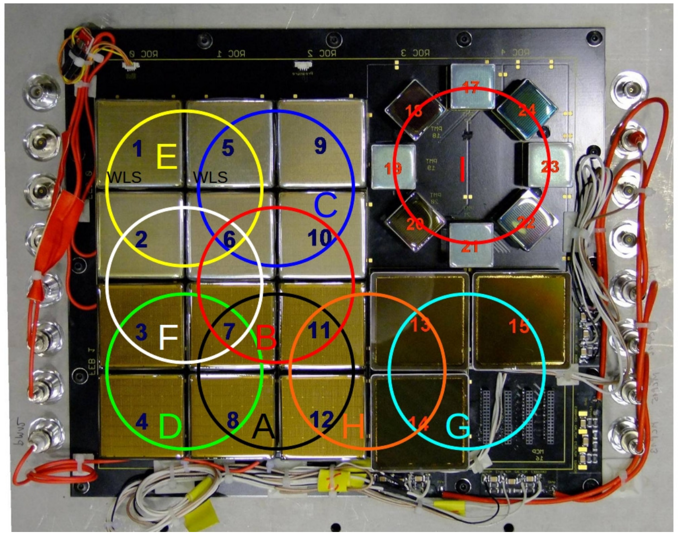


Тестовый пучок



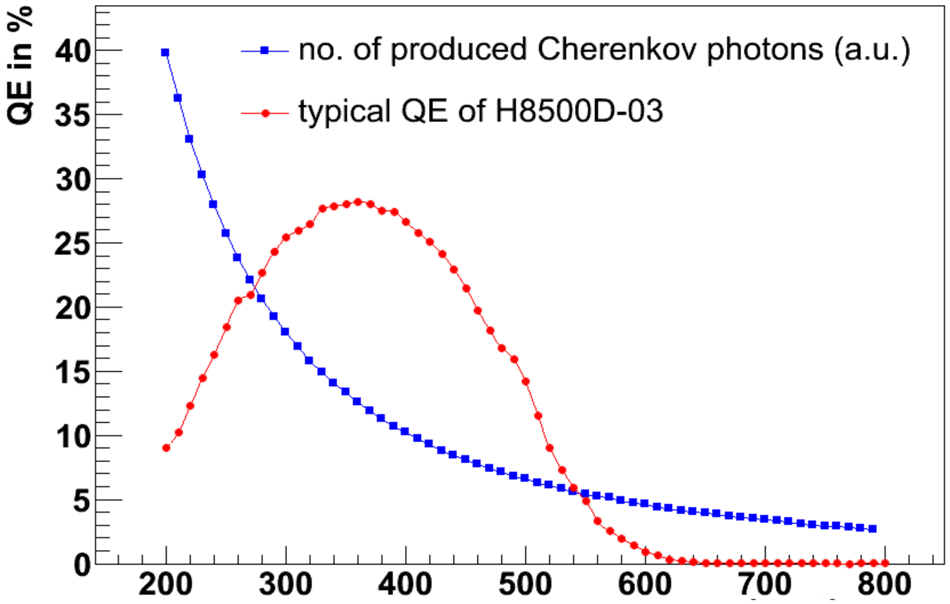




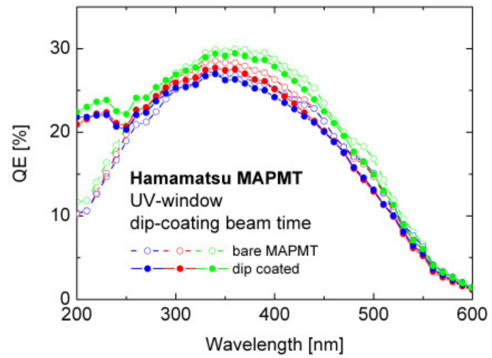


- **Скан по позициям. С пленками и без пленок**
- **Скан по HV (для каждой поз.).**
- **Скан по порогам.**
- **С 2 типами FEE.**
- **Скан по содержанию O2 и воды.**
- **Скан по импульсам**

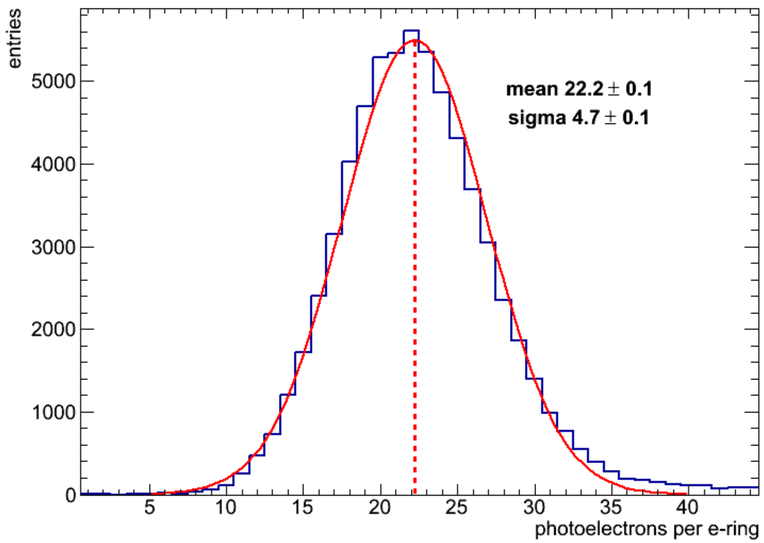
Тестовый пучок

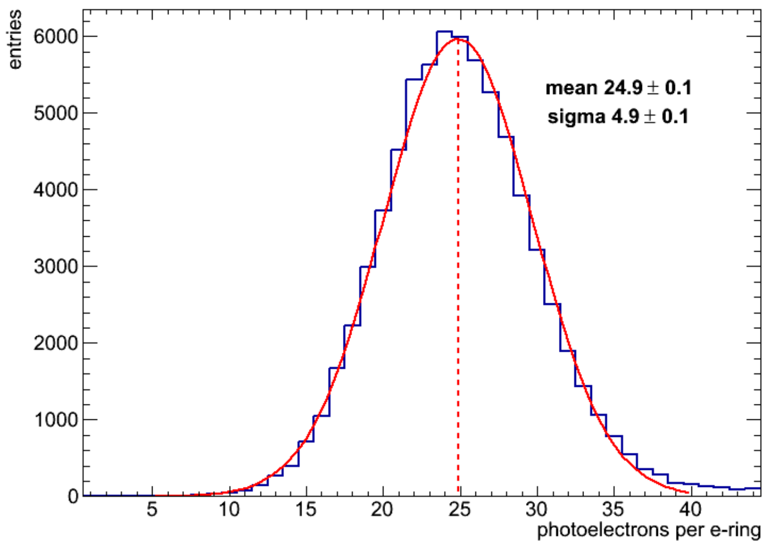


С пленками и без пленок

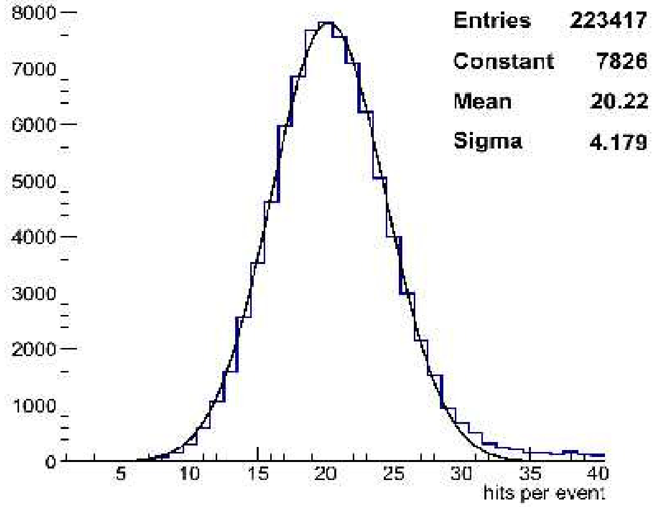


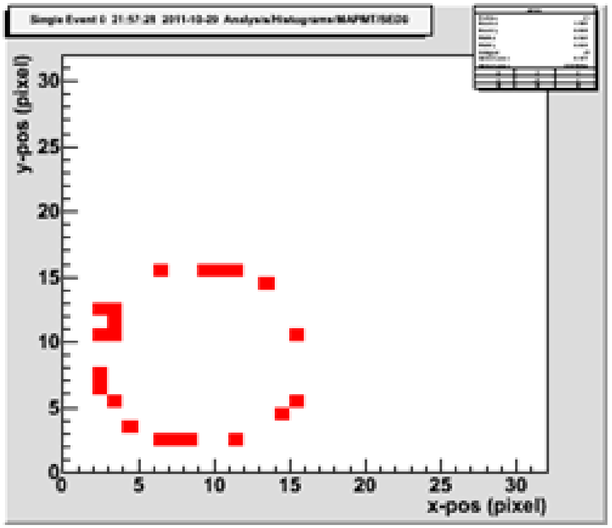
С пленкой ~ 12% больше хитов, ассоциированных

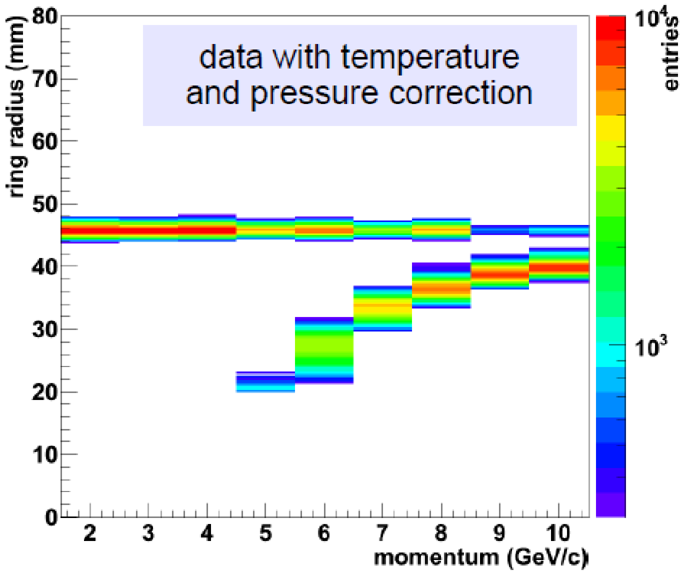


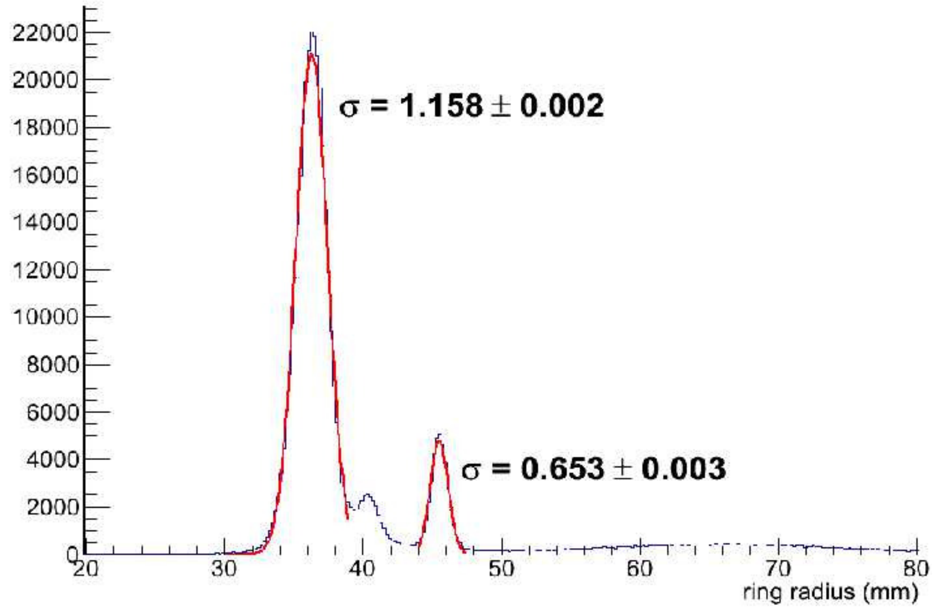


Тестовый пучок

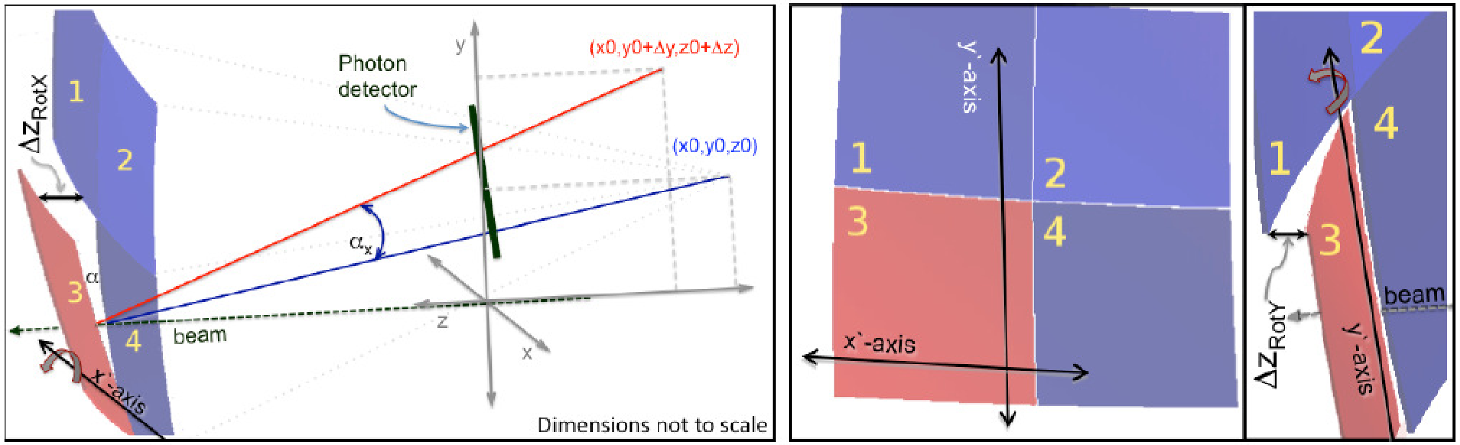


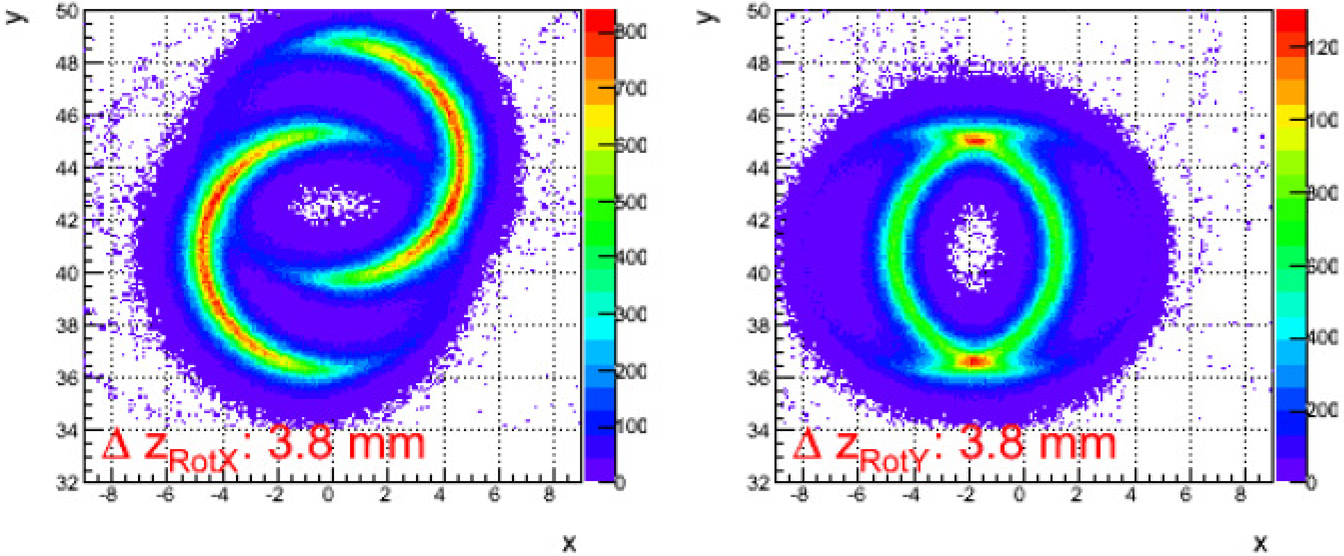






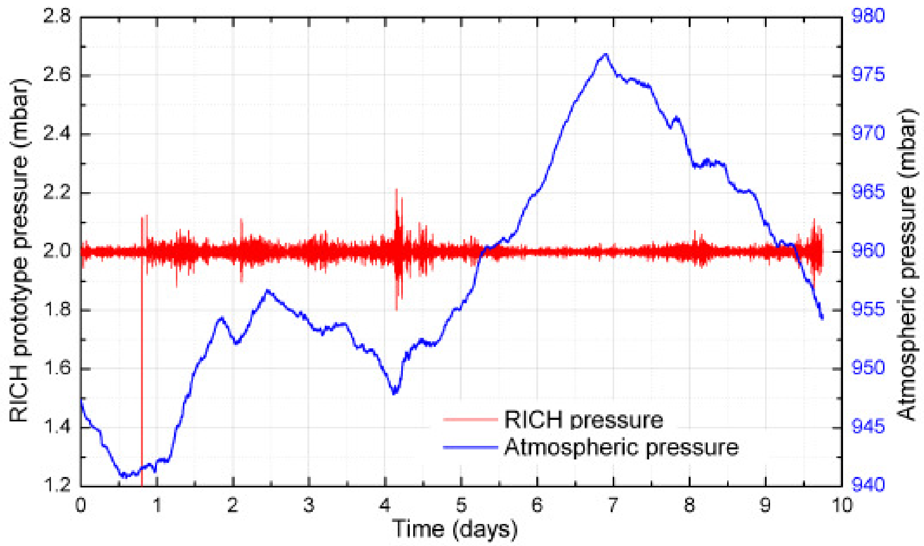
Тестовый пучок

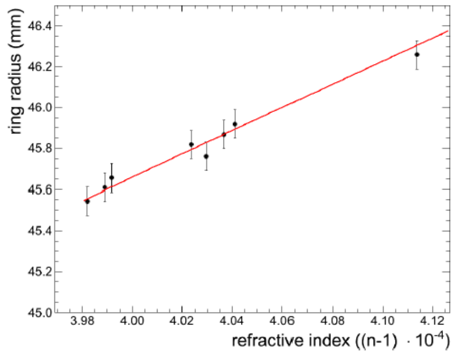


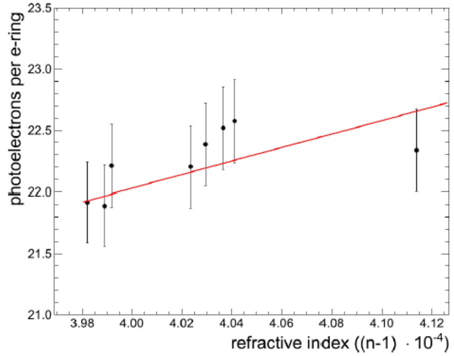


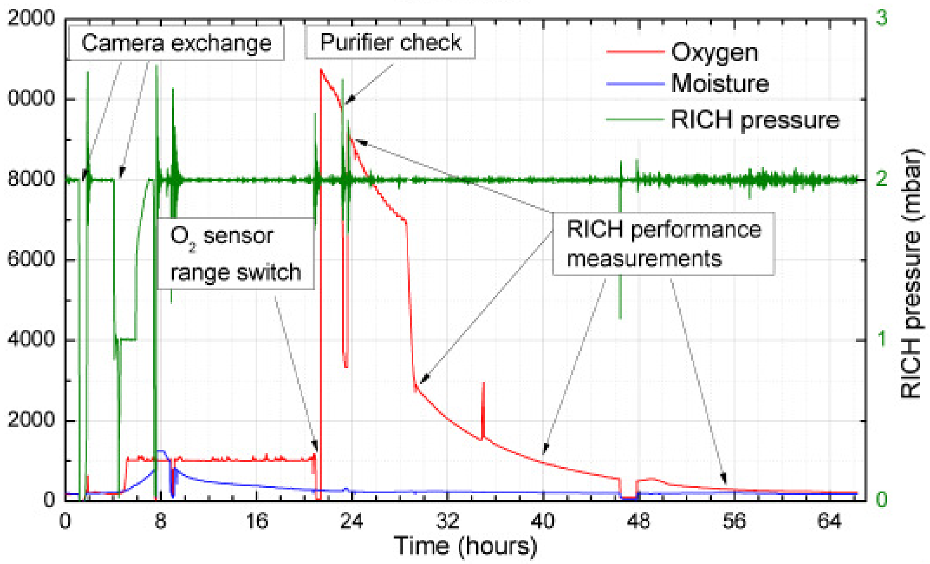
0.1 mrad – не чуствителено

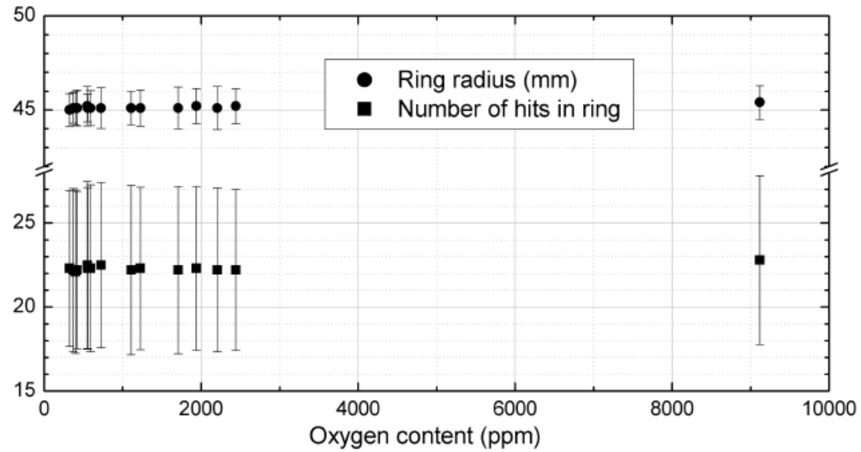
Тестовый пучок



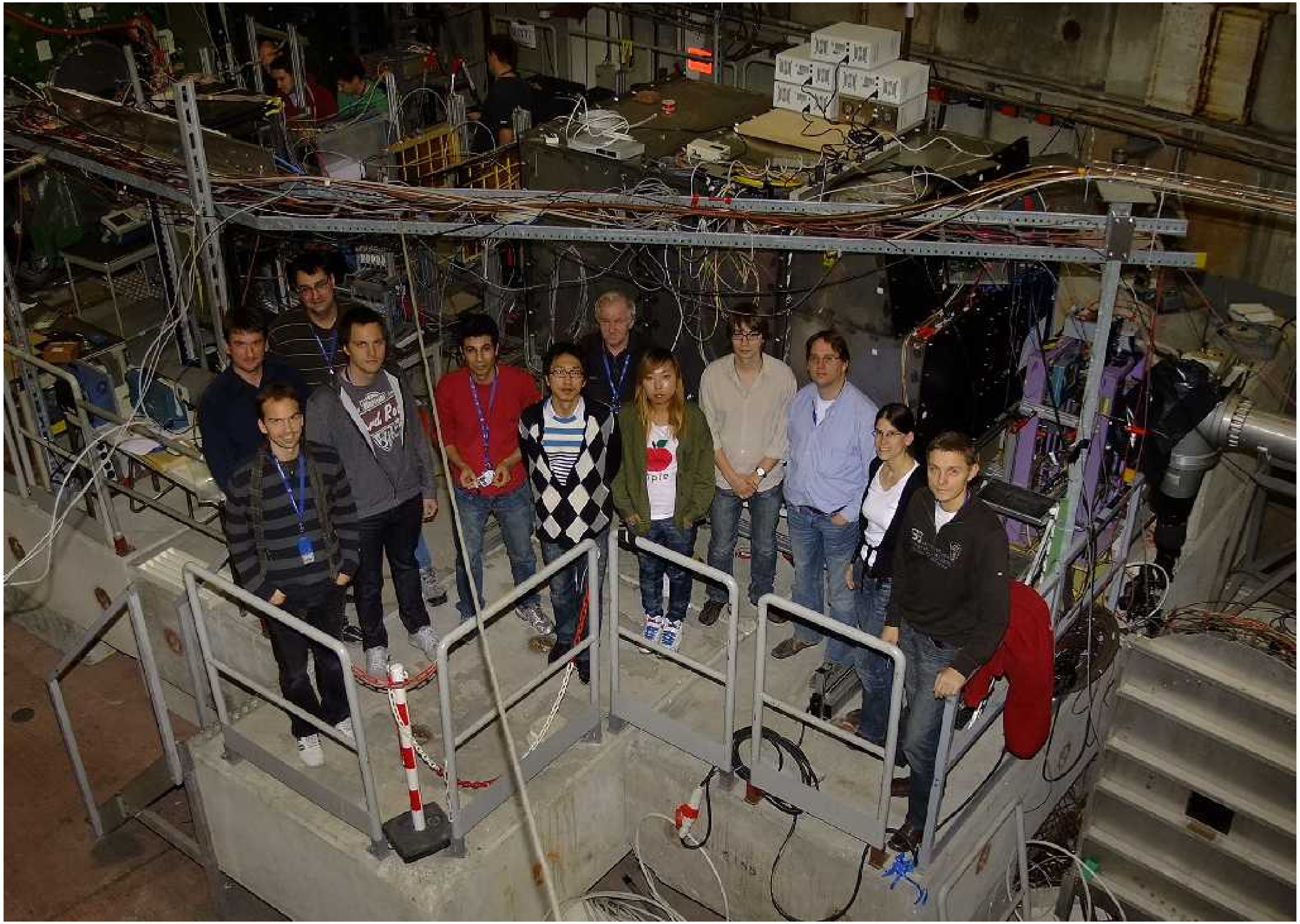




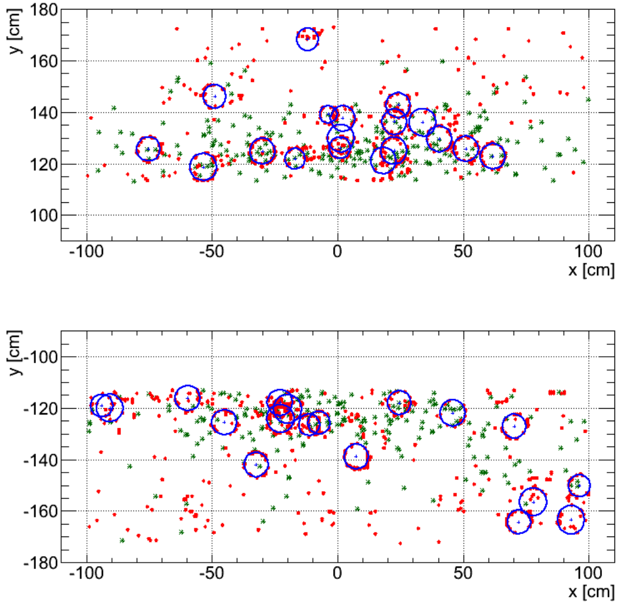




Тестовый пучок



Результаты симуляций



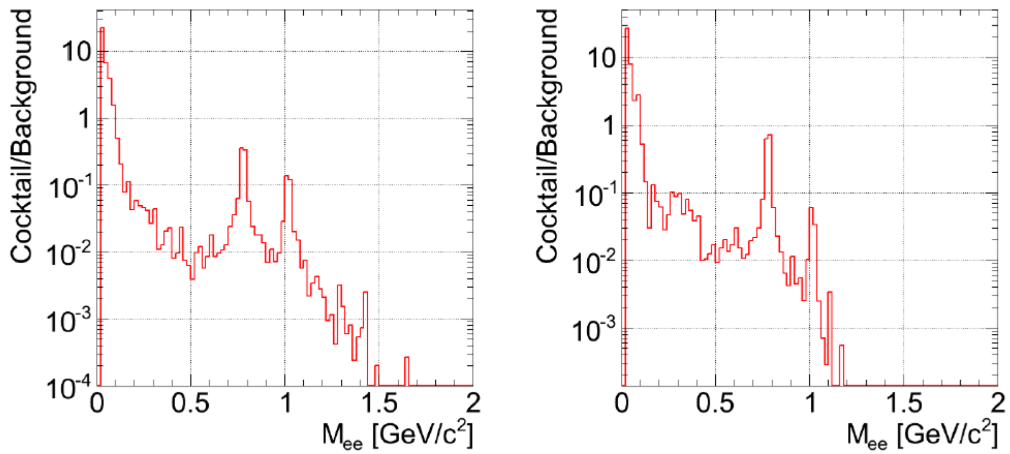


Figure 3.16 – Distributions of the cocktail to background ratio versus invariant mass for 25 AGeV (left) and 8 AGeV (right) beam energies.

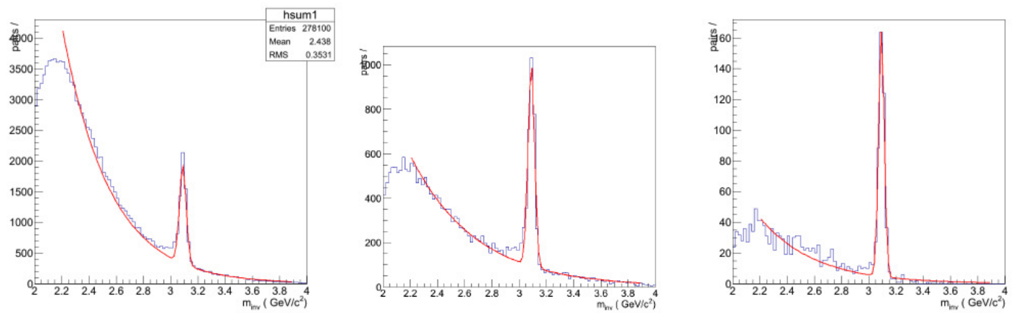


Figure 3.23 – Invariant mass spectra of particles identified as electrons for $4 \cdot 10^{10}$ central Au + Au collisions at 25 AGeV for target thicknesses of 250 µm (left) and 25 µm (centre). Right: Invariant mass spectrum for 10^{12} p + Au interactions at 30 GeV.

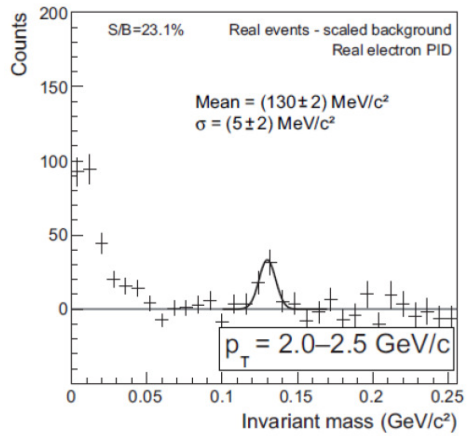
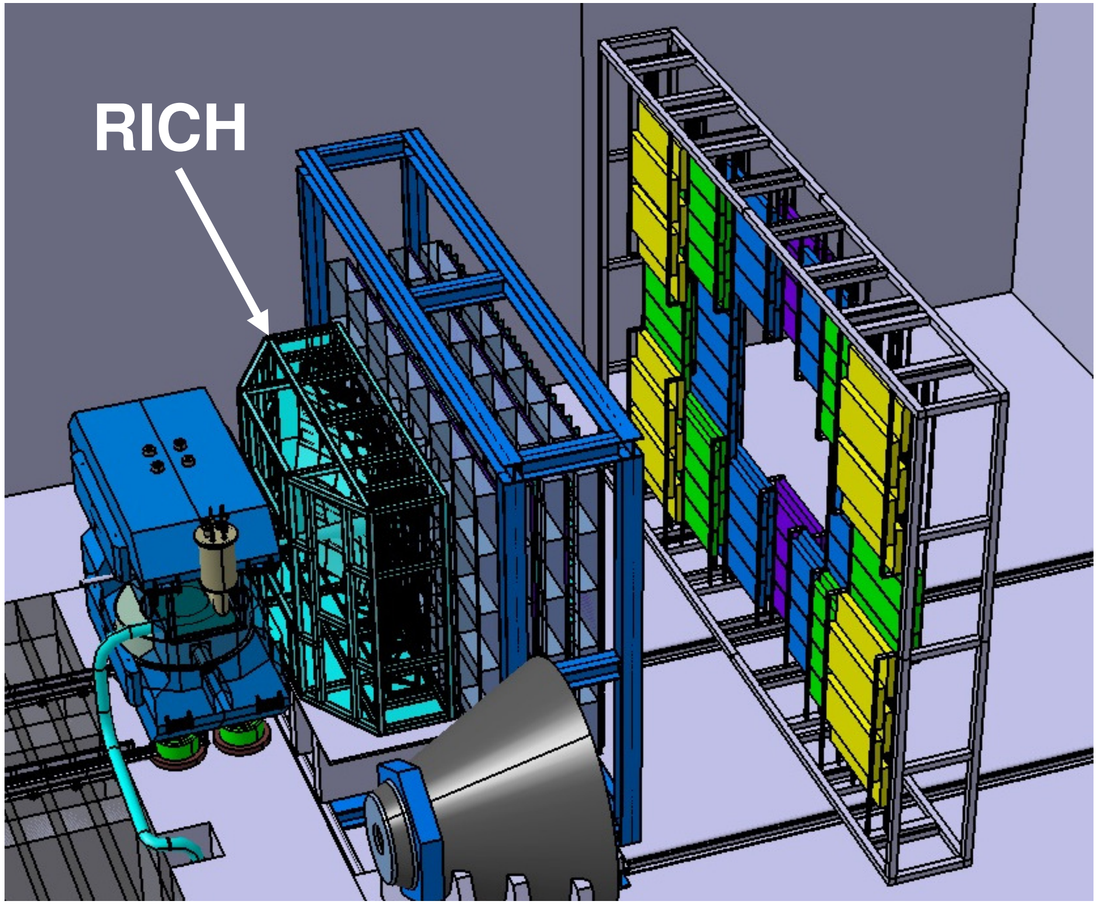


Figure 3.25 – Invariant mass distribution of $\gamma\gamma$ pairs after background subtraction. 20000 UrQMD events from central Au + Au collisions at 25 AGeV beam energy have been analysed. In addition, 1000 π^0s have been embedded into every event. (Figure taken from [36].)

Responsibilities: Overview

Item	BUW	JLUG	PNPI	PNU	ITEP	JINR	GSI
Photodetector Modules	X	X		X			
Front-End Electronics	X						X
Mirrors		X					
Camera Body & Support Struct.	X		X				
Detector support structure			X				
Mirror Support Structure		X	X				
Overall Support Structure			X				
Mirror Alignment System		X	X				
Low & High Voltages	X						
Gas System		X	X	X			
Cooling	X		X				
Slow Control				X			
Beam-Pipe (sim. & optim.)					X		
Magnetic Shielding (sim.)						X	

Design requirements



- Right behind the magnet.
- Total length along Z is ~ 2 m.
- Cover 25° in vertical plane and 35° in horizontal plane.
- Mirror plane is horizontally divided in two halves with radius - 3 m.
- Photodetectors are above and below the beam axis.
- Slope angle of each mirror half is one degree.
- Operrated at normal T and p.

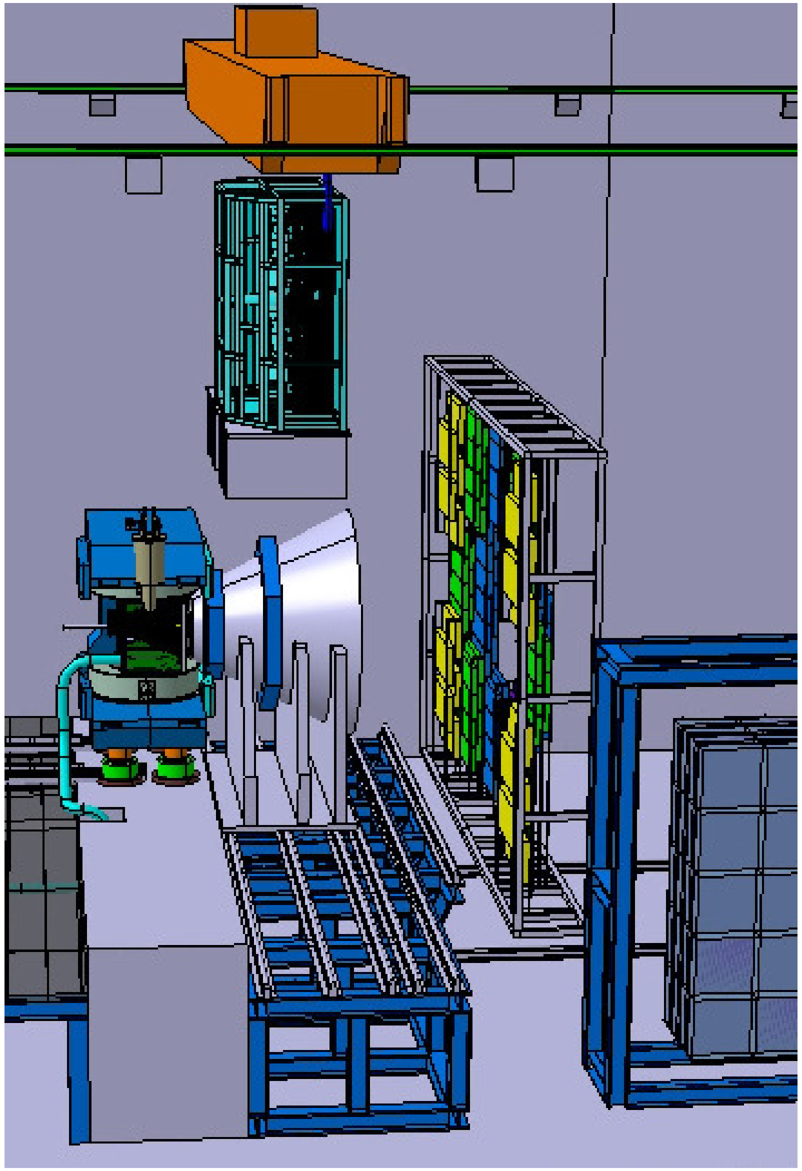
Gas system:

- CO_2 as radiator with length ~ 170 cm.
- Differential pressure stability (2 ± 0.1 mBar)
- Contaminations: oxygen content < 100 ppm, water content < 100 ppm

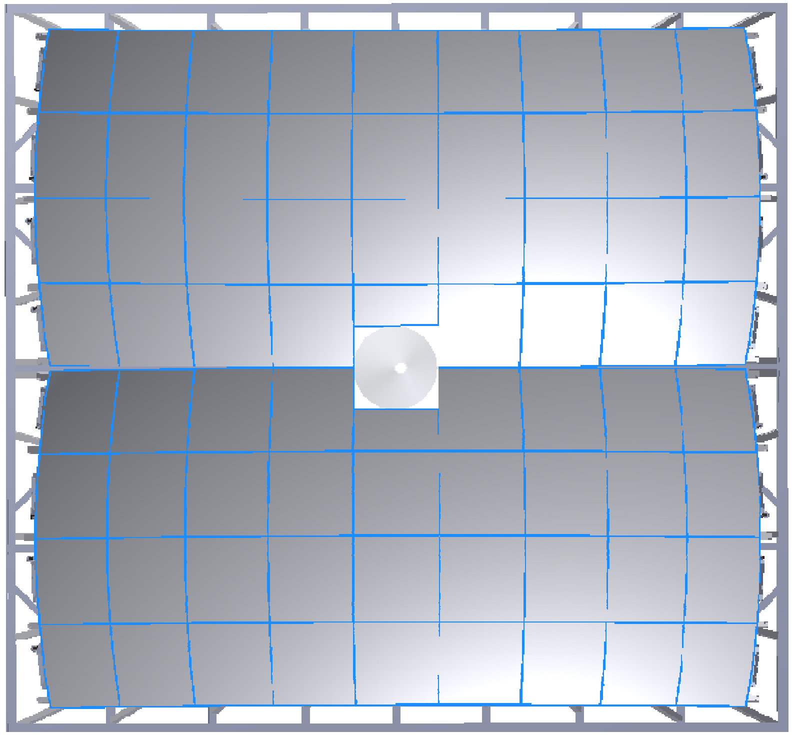
Design requirements

- The detector will be moved periodically with a crane. (share the same beam place with MuCh);

- Additional requirements for structural strength – stability of mirror system (requires a compromise with material budget in acceptances);

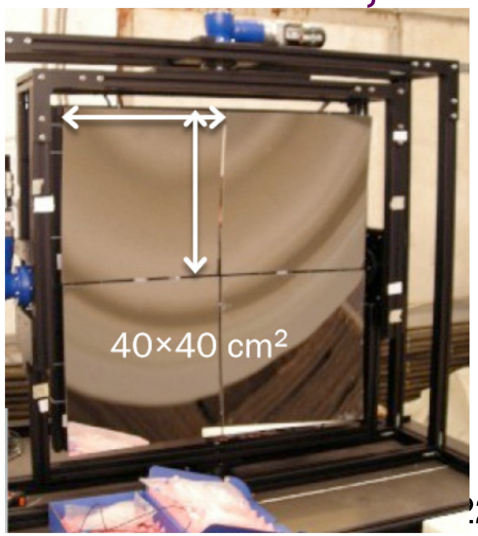


Details of the baseline design
Mirror splitting scheme

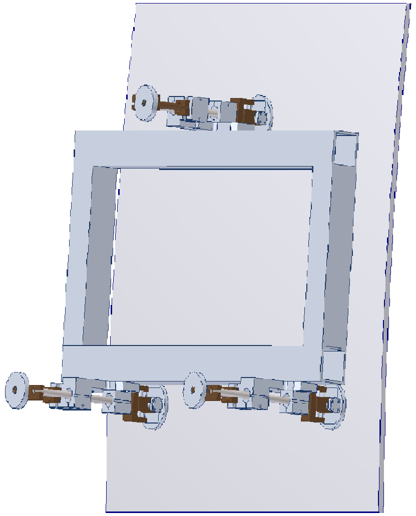


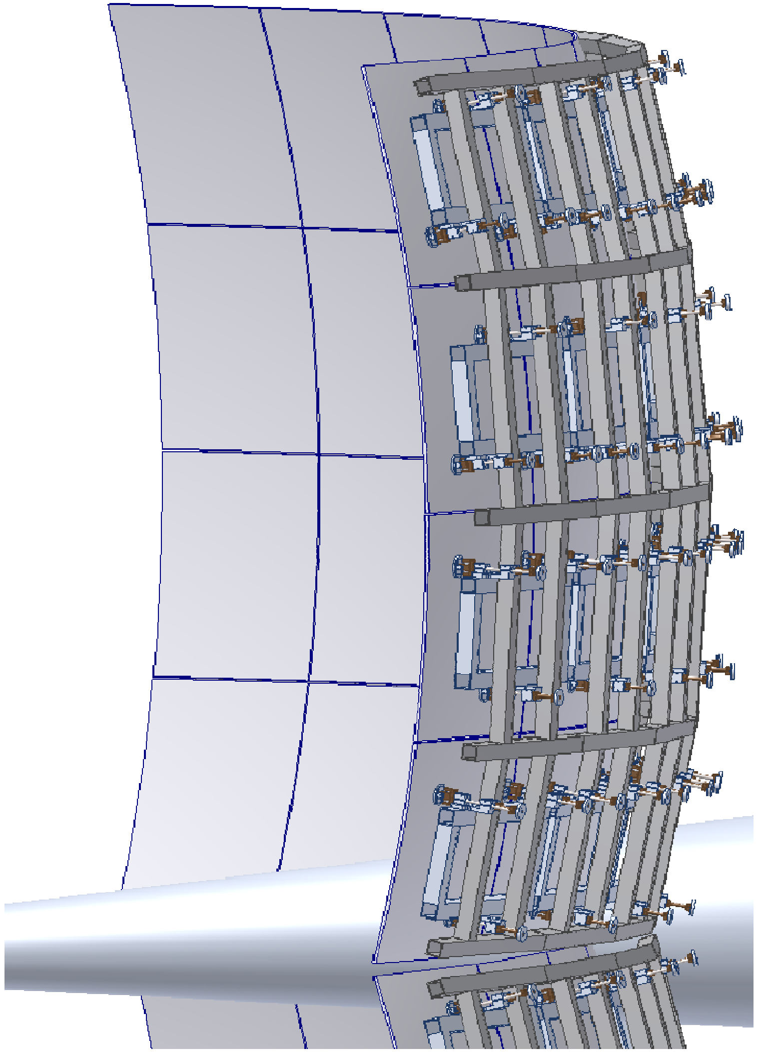
- Split in 36 parts (tiles) – 4 rows;
- Two types of trapezoidal tiles with different sizes (close to dimensions used for prototype);
- Middle rows - 9 tiles of 430(425) mm x 425 mm in an arc;
- Remaining two rows – 9x2 trapezoidal tails of 425 (412) mm x 425 mm;
- Reflecting surface of a half ~6.5m^2;

This splitting scheme allows for reasonable size of tiles close to that used and tested in the prototype and provides acceptable gaps between the tiles (about 4 mm).



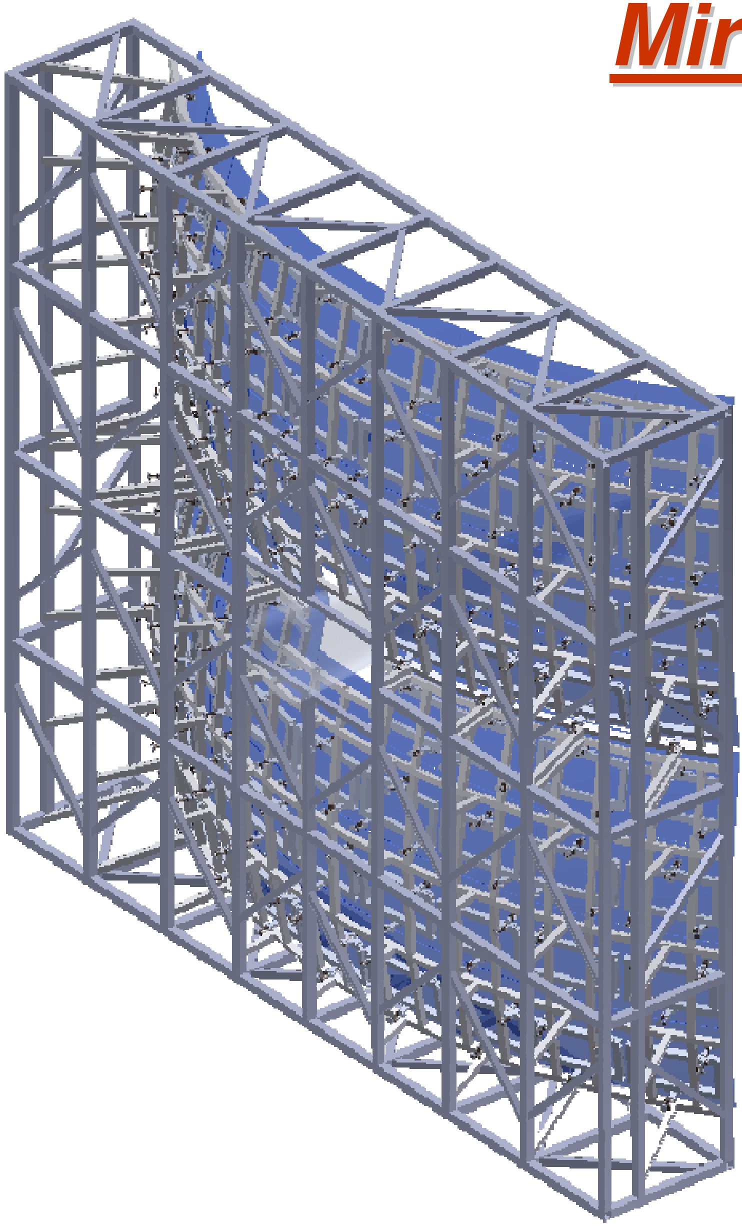
Details of the baseline design. Mirrors support frame



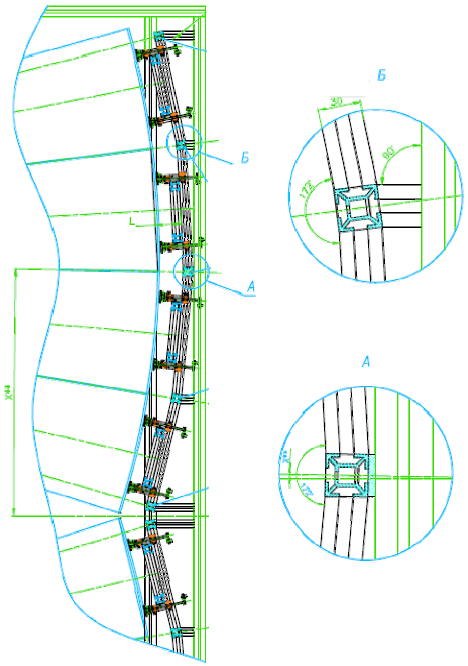


- ❖ Mounting legs are attached to a special aluminum rectangle (basic unit for assembling);
- ❖ 4 “belts” – 4 rows;
- ❖ cells match size of the tiles and parallel to the plane of the tiles;

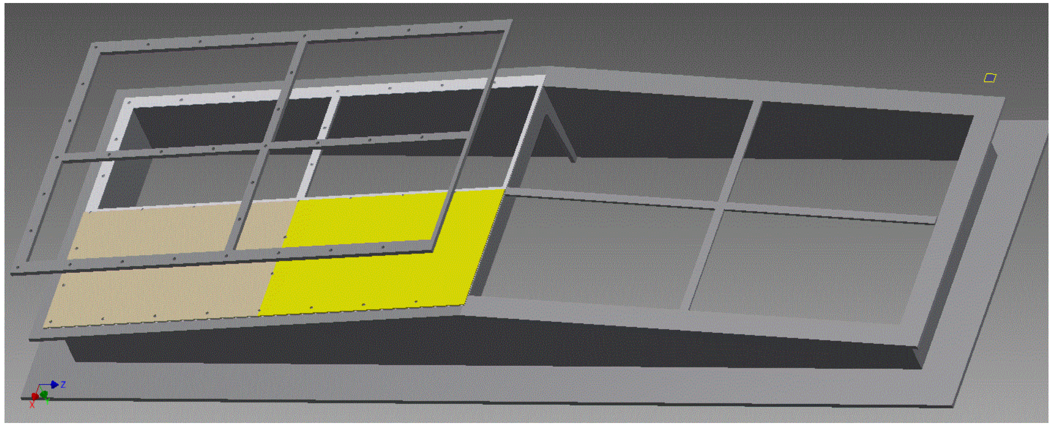
Details of the baseline design. Mirrors support frame

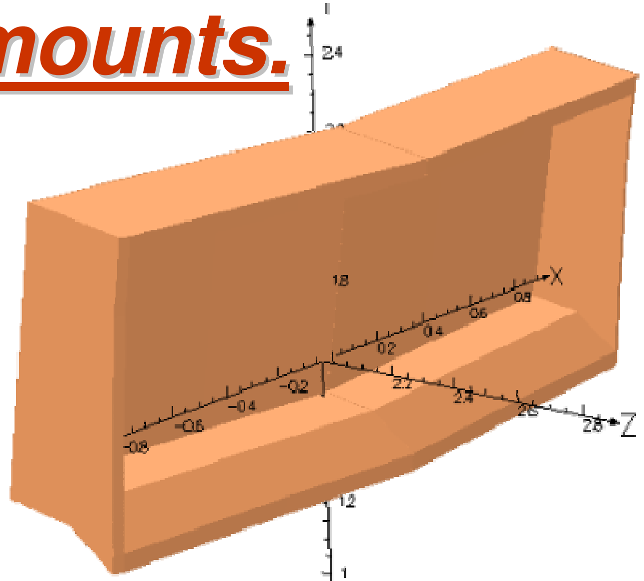


- “belts” attached to a rectangular base;
- This base is common for both halves of the RICH mirror;
- Aluminum profiles of 40 mm x 40 mm and 30 mm x 30 mm are used;
- The angle is set once with special wedges for each half of mirror.



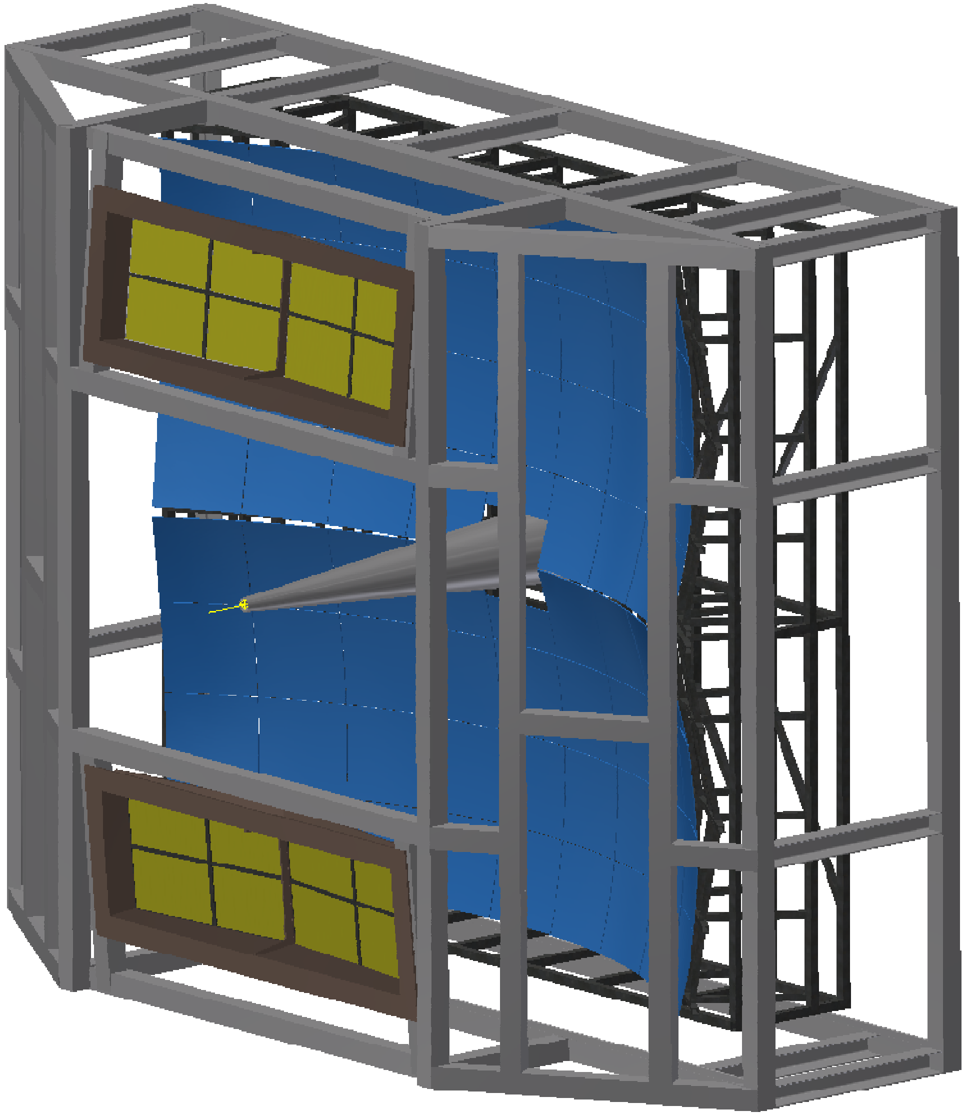
Details of the baseline design. Photon detector mounts.





- Two photon detection systems (above/below the beam line) are horizontally split into two sub planes with dimensions of 1000 mm x 600 mm;
- These two parts are arranged at the angle of 5° with respect to each other in order to optimize focusing;
- Each plane is divided into four sub-parts, corresponding to four printed circuit boards (PCB) carrying the photon sensor devices;
- Magnetic shielding: have to cover the photodetectors with special box from "Steel 08" material (weight of each ~ 1 ton).

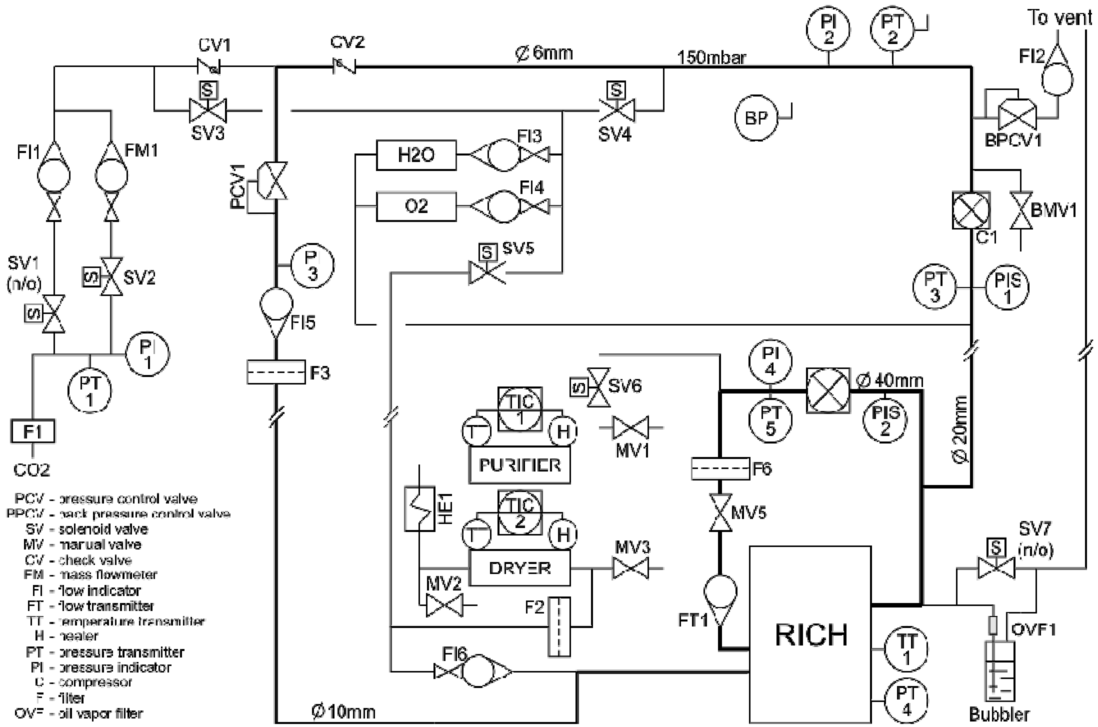
Details of the baseline design. Gas box and general view



- GB design is based on solutions tested with the prototype.
- Reinforced frame welded from 100 mm x 100 mm x 5 mm channel bars (for the possibility to move the detector using a crane).
- The design provides the ability to access inside the box to configure the mirror tiles and photodetectors.
- The frame will be covered and sealed with plastic/Al sheets.
- The front and rear panels are made of kapton foil with thickness of 200 µm. (2 mm plastic sheet may be used for the rear panel).

Details of the baseline design. Gas system

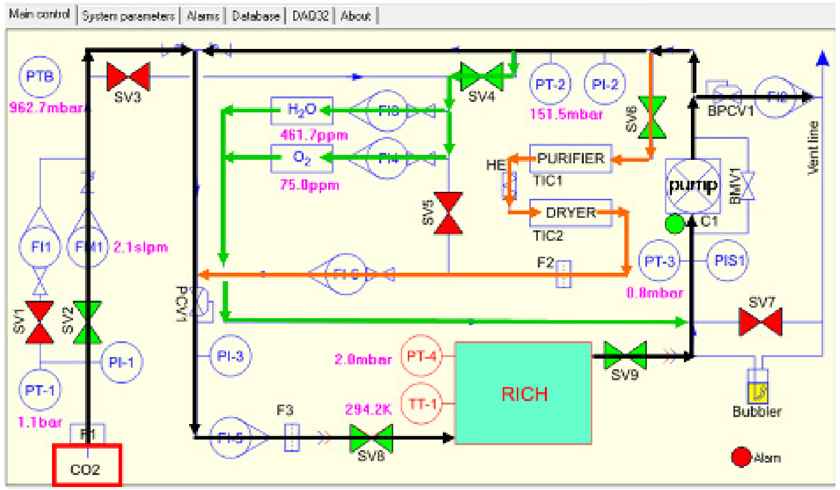
Goal - to provide pure CO_2 gas to the RICH at a stable differential pressure.

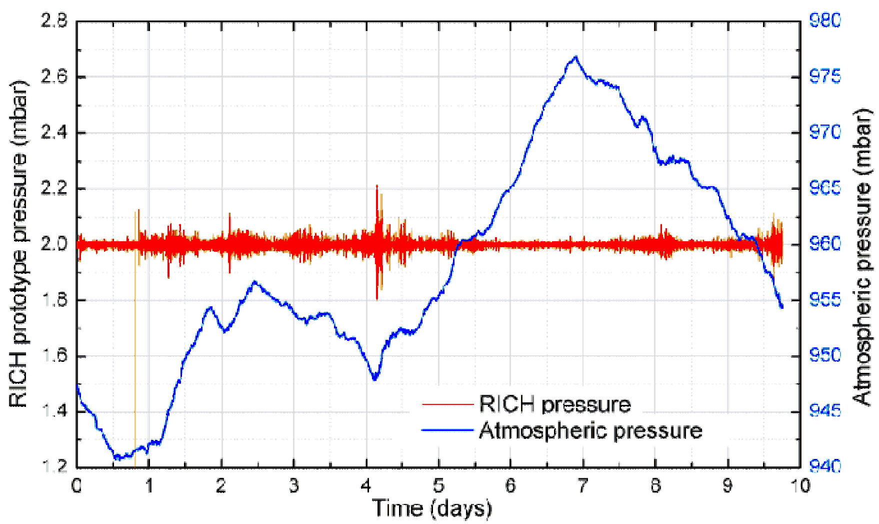


- **The design is based on well-proven solutions (PHENIX and STAR experiments, > 10 years);**
- **Two recirculation loops.**
- **The external loop provides necessary overpressure in the detector (2 ± 0.1 mBar) via control of fresh gas input flow + analysis of contamination level in gas (water and oxygen). Gas flow 0-10 l/m.**
- **Internal loop with the flow of up to 500 l/m collects the outlet gas from detector and cleans it from contaminants (H_2O & O_2).**
- **O_2 cleaner – active copper – regenerating T=473 K with 5%H_2+CO_2 mixture.**
- **The dryer filled with a 3Å molecular sieve, T=295 K, regeneration T=620 - 670K.**

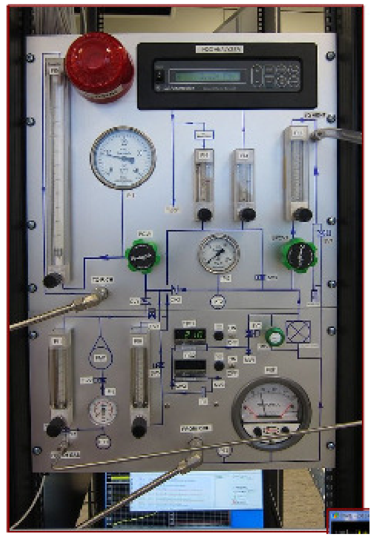
Details of the baseline design. Gas system

The internal loop is very similar to the gas system used in the prototype.





- **The system has been successfully tested during the test beams.**
- **The internal loop with the pump and the purification unit will be located close to the RICH detector directly in the CBM cave (E10).**
- **This is a small unit of about 1.2m height and 0.5m² floor space and will allow to have a large flow using short pipes of 40mm diameter.**
- **A computer driven DAQ/control system monitors and stored all of the process variables including the RICH differential pressure.**

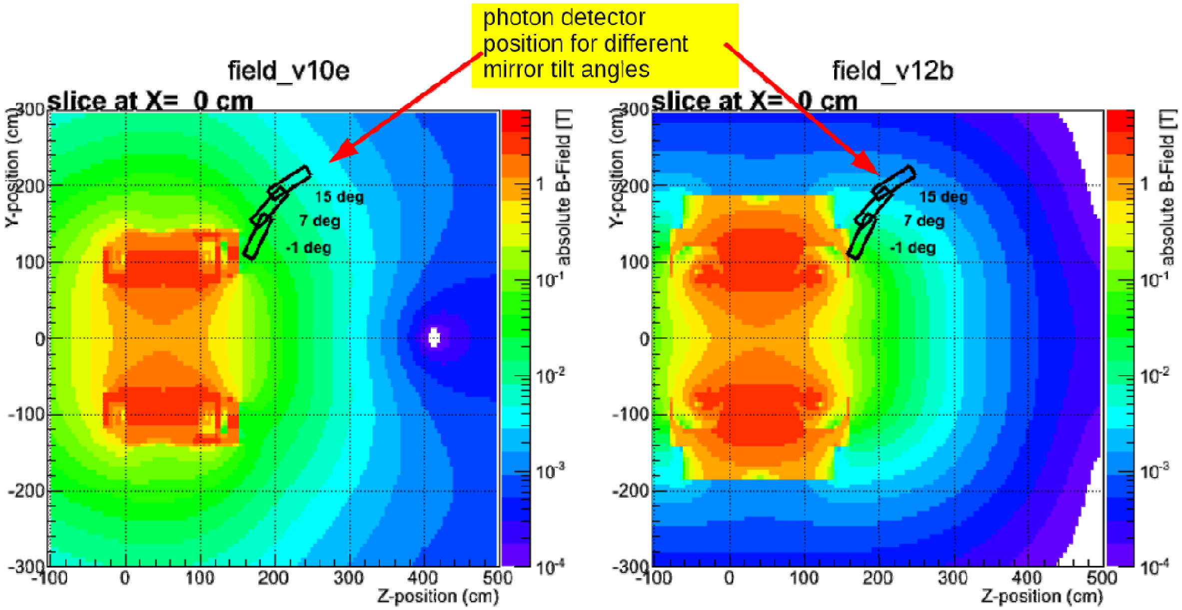


Дополнительное R&D

At least two options have to be considered for the main design.

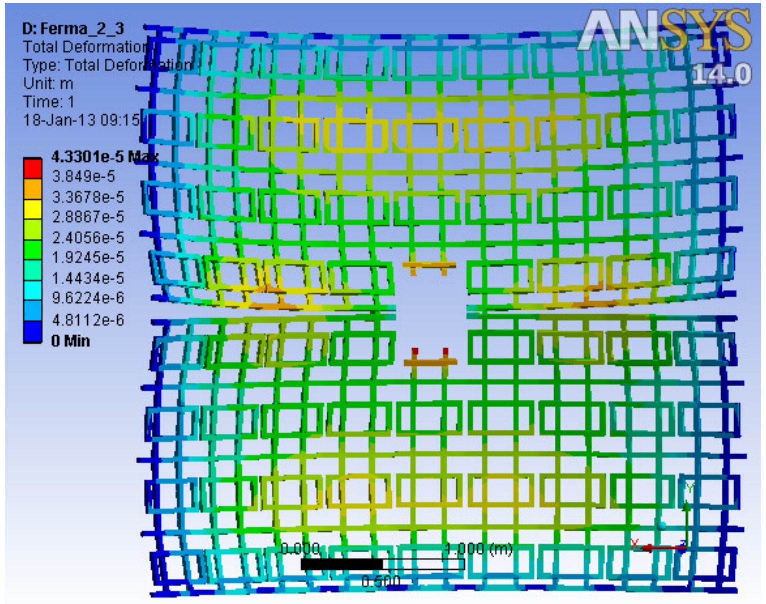
1. Change of the mirror tilt angle

- **Allows to move photodetector to a small magnetic field region → the weight of the magnetic shield can be significantly reduced.**
- **Provides more convenient access to electronics.**
- **Ring reconstruction procedure have to be improved in order to cope with the (predictable) elliptic shapes of the rings.**

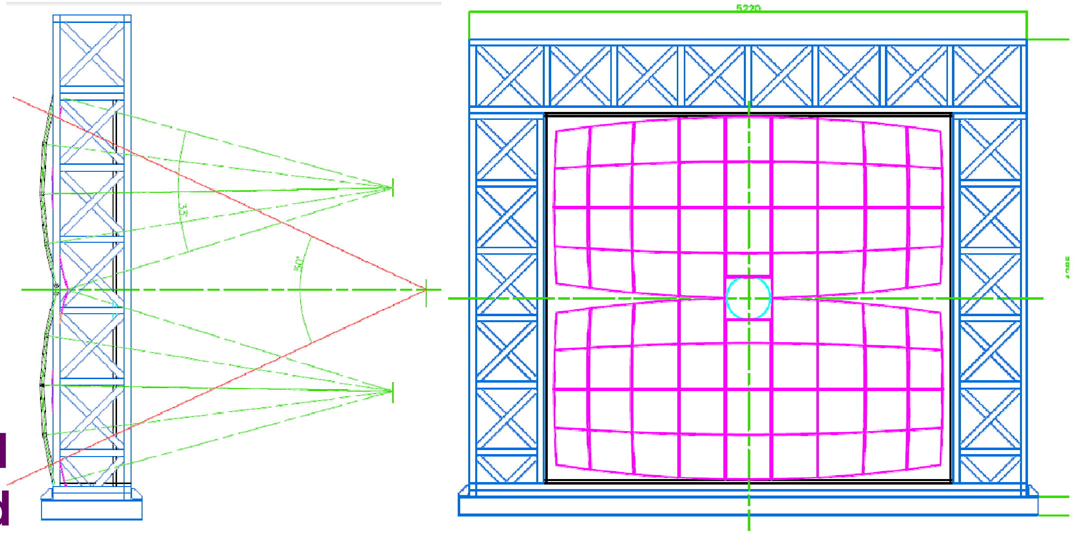


Дополнительное R&D

2. Design with reduced amount of material



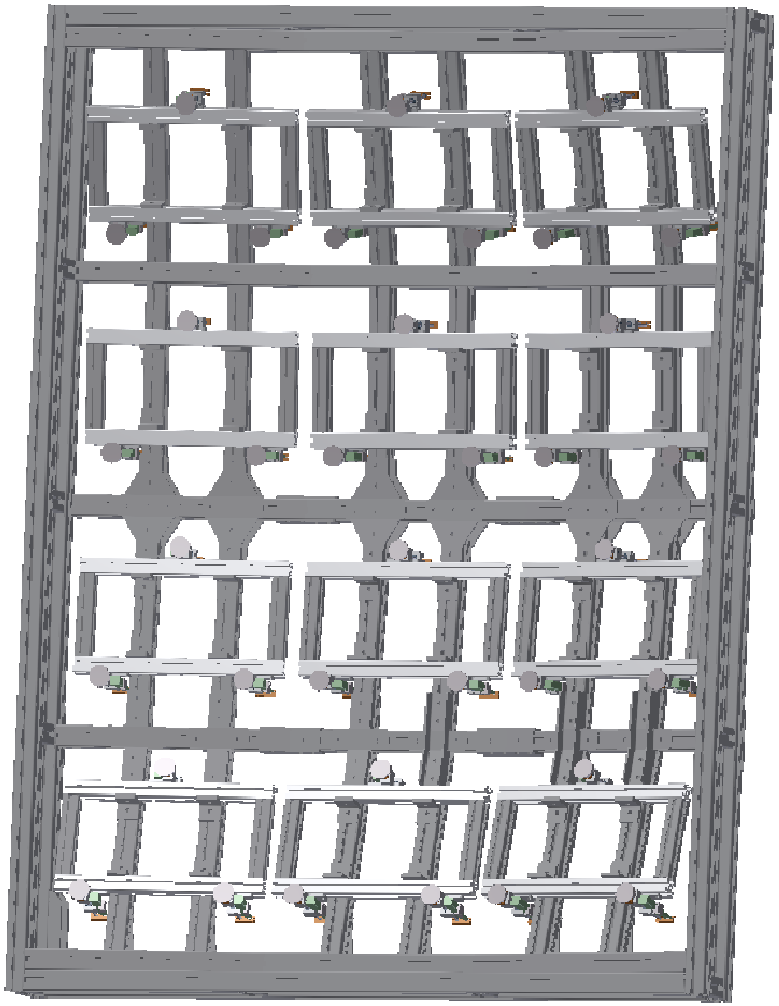
- ANSIS shows that In the case of rigid fixation of the perimeter of “belt” structure – the level of gravitational deformation less than 150 μm (for any mirror angle).
- The idea is to keep only the “belt” structure in acceptance.
- Possible solution with rigid frame at perimeter is shown.



For both options:
sizes and mirror spliting – ok
Mirror mounts - ok
Belt structure - ok
Supporting frame - changes needed
Gas box - changes needed

Plans for prototype deployment

As a reaction for the risks we plan to build supporting frame prototype (3 x 4 tiles).

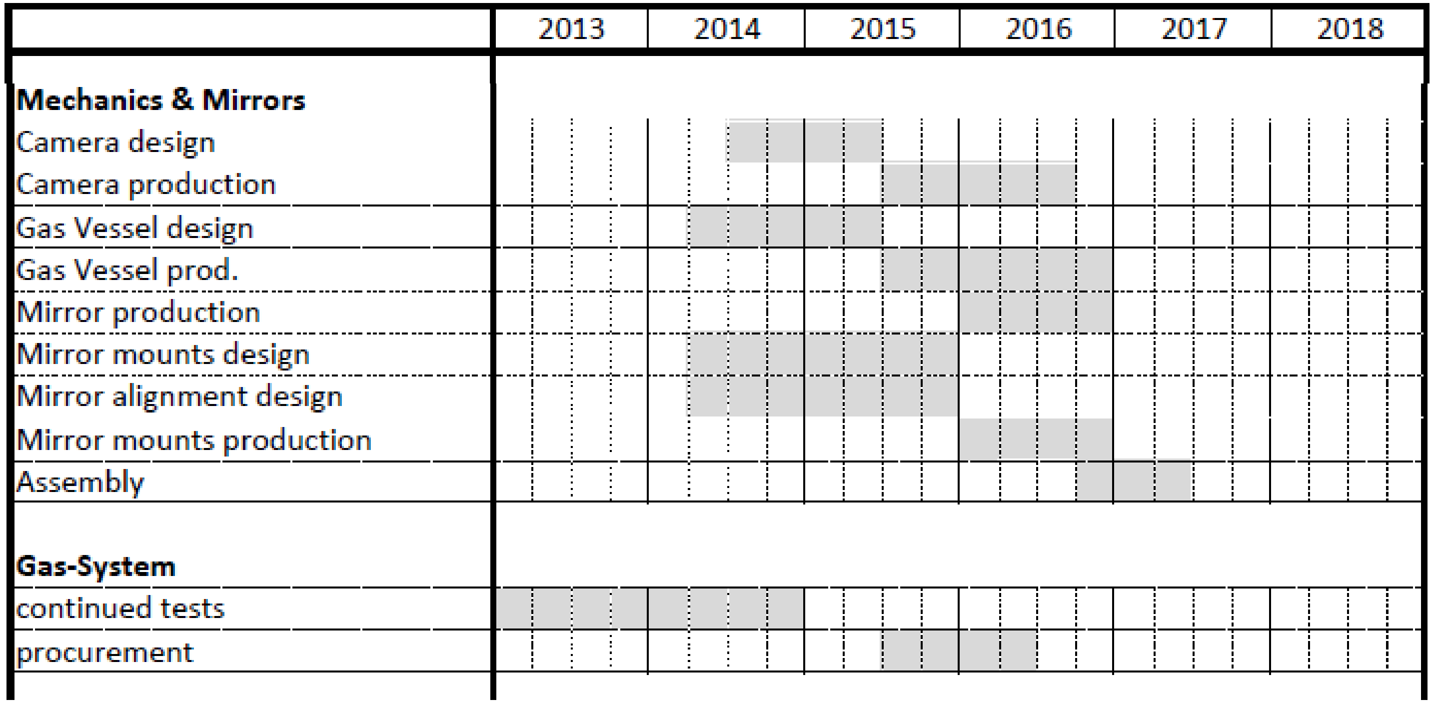


Main goals for this prototype:

- Develop assembly technology.
- Select type of connections.
- Estimate level of manufacturability, convenience of assembly, adjustment possibilities.
- Identify possible problems and fix them.
- Strength tests;
- Mechanical response (shaking, acceleration) tests;
- The behavior in time tests;

Schedule and milestones

According to the plan we have to prepare a complete specification by the 2nd quarter of the next year, when the final design should start.



To follow the timetable we have to decide on all options (tilt mirrors, magnetic shielding, etc.) till the end of this year.

Costs

Costs stated in brackets include VAT

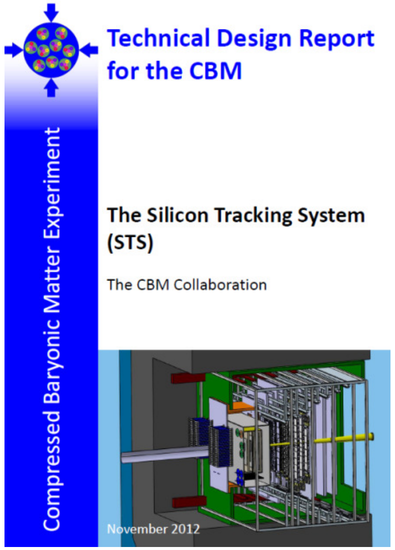
Item	Unit	Number of units	sub-total (k€)
Photon detector			**2723 (3241)**
H8500 MAPMT+base[a]	piece	864+50	2133 (2538)
altern. R11265+base[b]	*piece*	*3456+100*	*3911 (4655)*
WLS	total	1	20 (24)
FEBs	int. syst. (55 kch)	1	450 (536)
camera body	piece	2	120 (143)
Optics			**112 (134)**
mirrors[c]	piece	72	72 (86)
align. syst.	module	2	40 (48)
Mechanics			**1540**
vessel	piece	1	300
vessel support structures	piece	1	250
mirror mounts	piece	72	150
mirror support structures	piece	2	490
camera support structures	piece	2	50
overall support structures	piece	1	300
Gas system			**130**
components & mainten.	piece	1	120
monitoring	piece	1	10
Services			**490 (584)**
HV supply	full crates	2	95 (113)
LV supply	system	1	35 (42)
DAQ/Monitoring	unit	1	50 (60)
cooler system	shared with CBM	1	60 (71)
cables, crates, etc.	total	1	200 (238)
transport	total	1	50 (60)
Grand Total			**4995 (5629)**

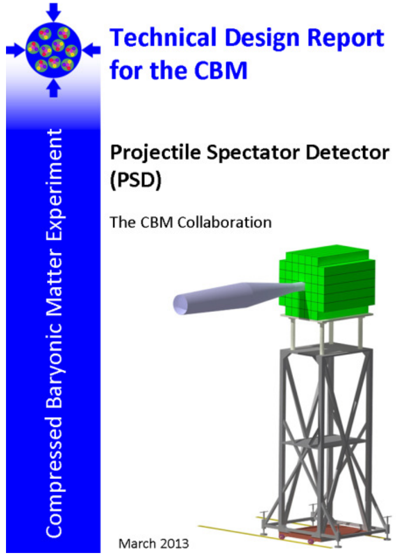
Mechanics includes full maintenance and service provided by PNPI

RICH TDR Review mee...

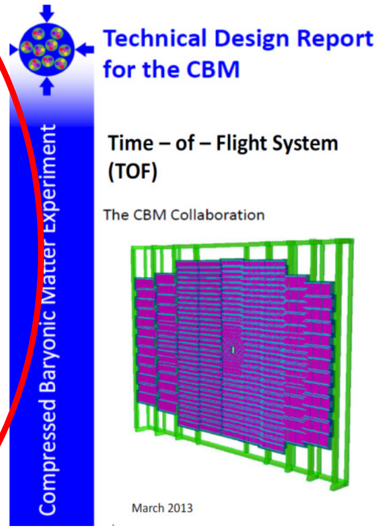
CBM Technical Design Reports

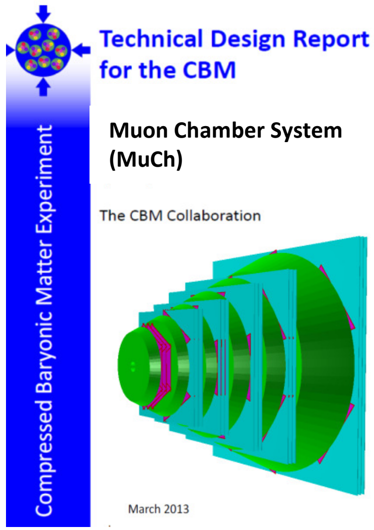
Submitted in 2012/2013:





To be submitted in 2013:





Backups