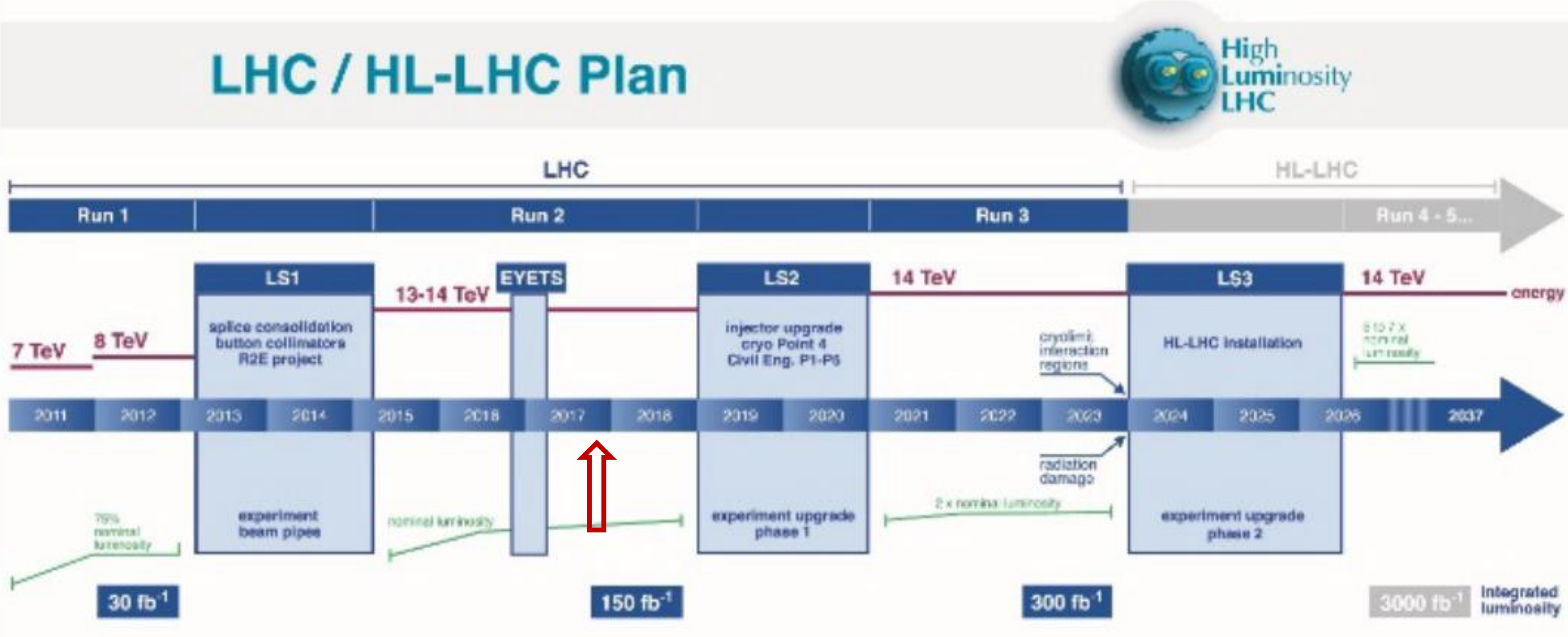
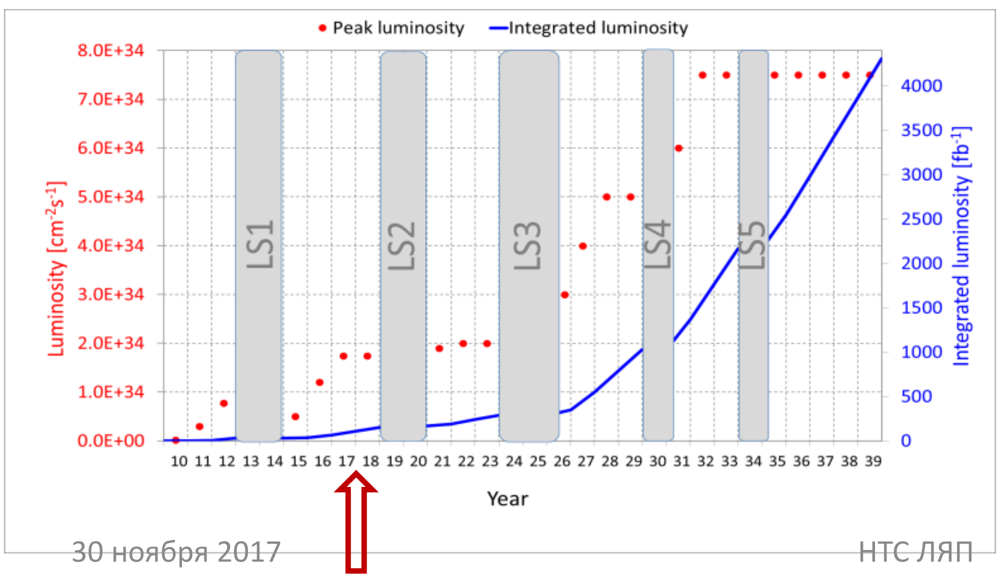
Участие ОИЯИ в модернизации детектора АТЛАС - продление проекта

Проект в рамках темы 02-0-1081-2009/2019

А. Чеплаков (ЛФВЭ)
А. Гонгадзе (ЛЯП)

- *Мотивация*
- *Модернизация LHC и детектора АТЛАС*
- *Участие групп из ОИЯИ (отчет и планы)*



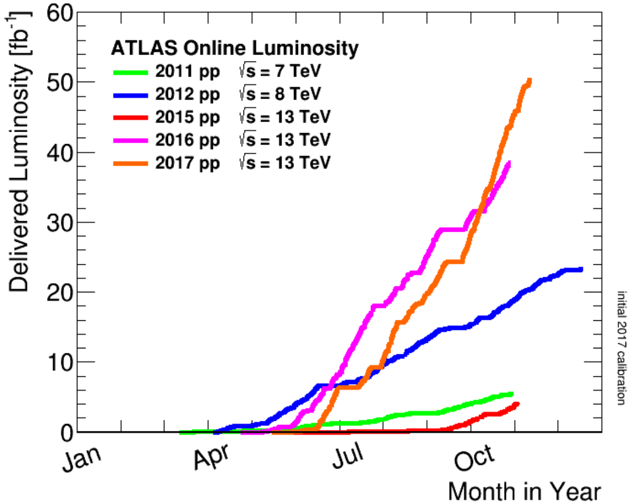


Работы по Фазе-I модернизации LHC и детекторов должны завершиться во время 2-й длительной остановки (LS2) в 2019-2020, а по Фазе-II (HL-LHC эра) - в период 2024-26.

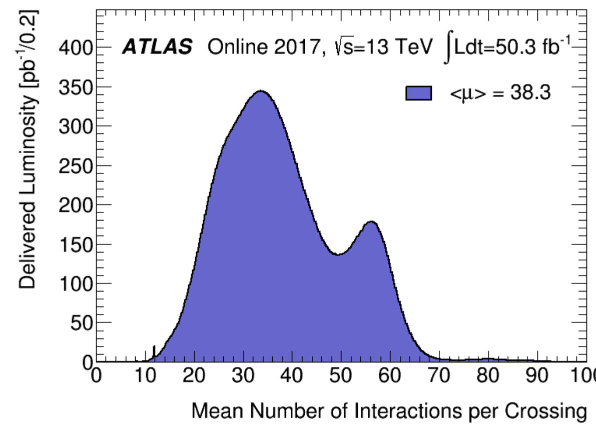
Интегральная светимость 3000 fb^{-1} будет обеспечена к ~2035.

АТЛАС и HL-LHC

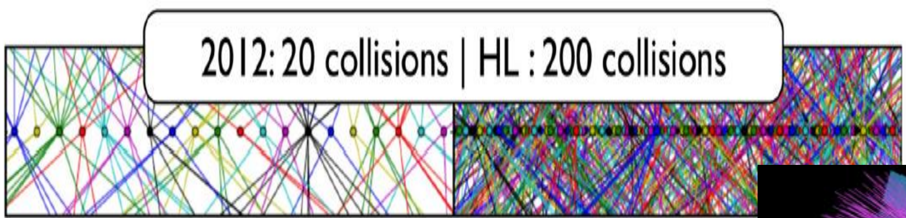
Полная светимость как функция времени для периода 2011-2017 (только p-p данные)

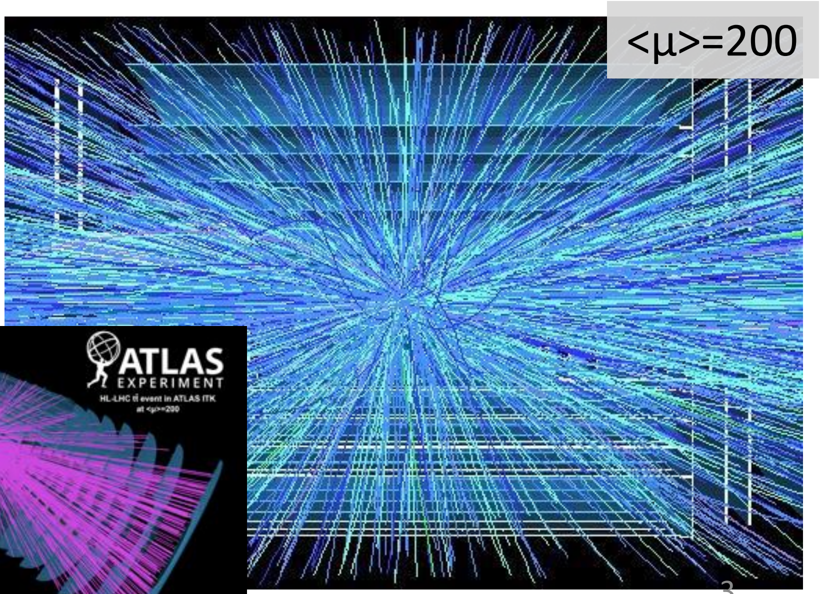


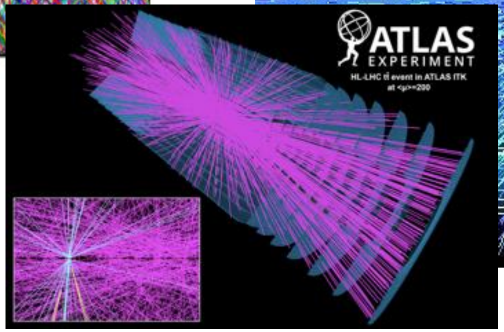
Среднее число p-p взаимодействий на одно пересечение пучков протонов



АТЛАС в 2026:







Высокое качество экспериментальных данных не должно ухудшиться!

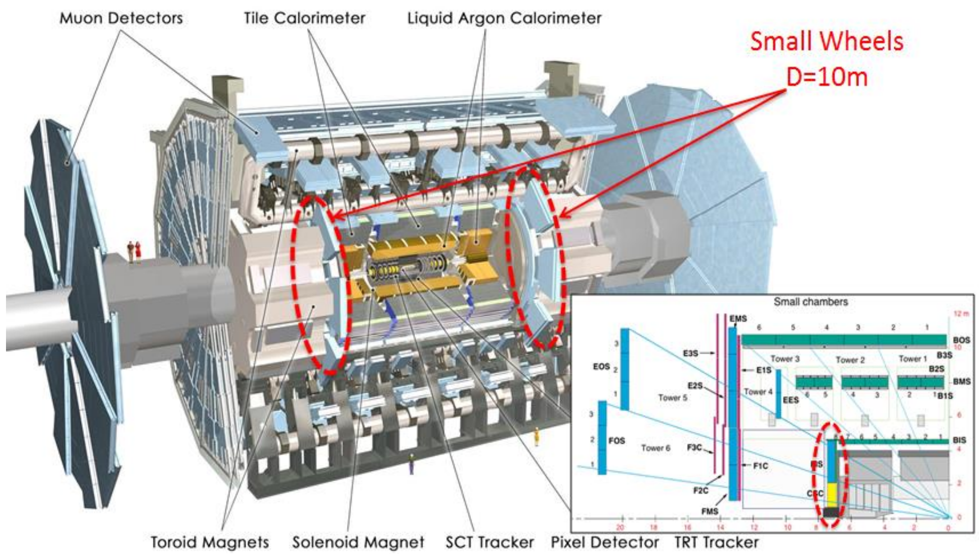
Фаза-1 модернизации детектора АТЛАС (до 2020)

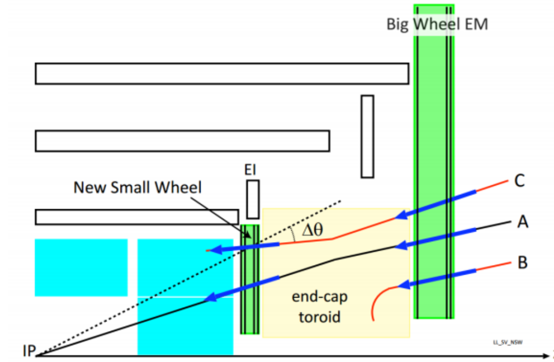
ОИЯИ

Включает 5 основных проектов:

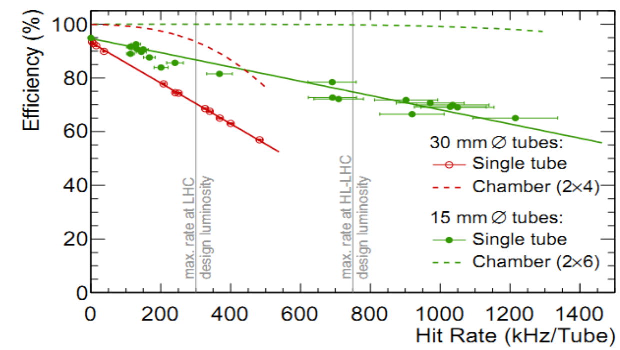
- ❑ **Малое мюонное колесо (NSW)**
  - Точность срабатываний триггера в торцевой части мюонного спектрометра, доступные загрузки детектора
- ❑ **Жидкоаргоновый калориметр**
  - Использование информации о форме ливня на уровне триггера для электронов и фотонов
- ❑ **Быстрый трекер (FTK)**
  - Обеспечивает трековую информацию для триггера высокого уровня
- ❑ **Модернизация системы сбора данных**
  - Модернизация оборудования для L1-триггера в калориметрах, мюонном спектрометре и DAQ
- ❑ **Передний детектор протонов (ATLAS Forward Proton, ±240m)**
  - Регистрация двух протонов под малыми углами

Модернизация мюонного спектрометра (проект NSW)





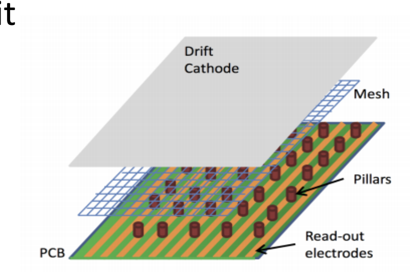
“Ложный” триггер

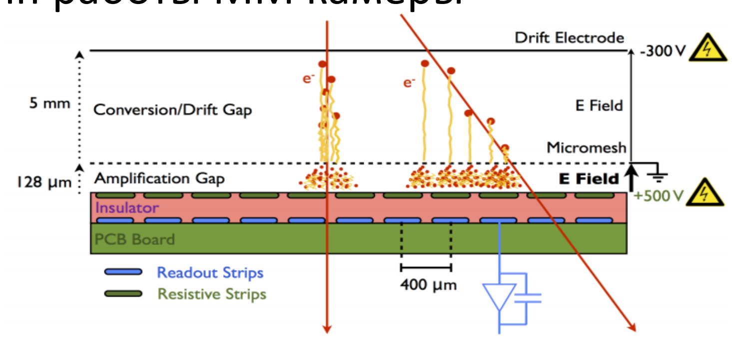


Деградация MDT

- Planar geometry
- Simple components: cathode, readout PCBs, mesh
- Large area can be achieved fairly simply and with relatively low cost
- Industrialization (PCB fabrication)
- Excellent high rate capability
- Small amplification gap (50 – 150 μm) → space charge effects are very limited
- Segmentation of readout strips → limit “dead” time

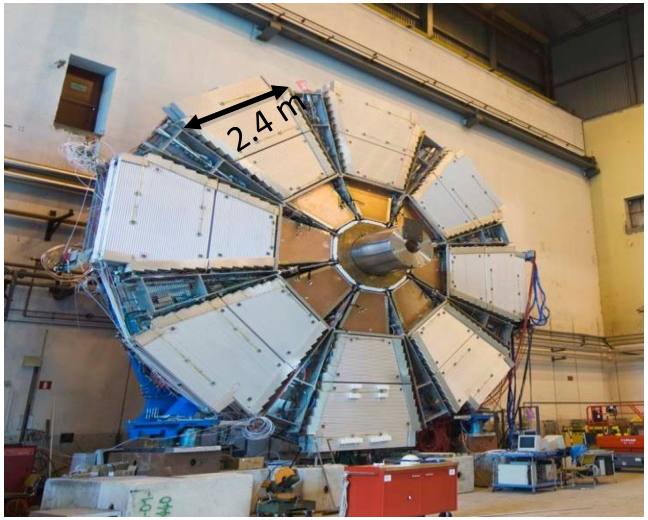
Принцип работы ММ камеры





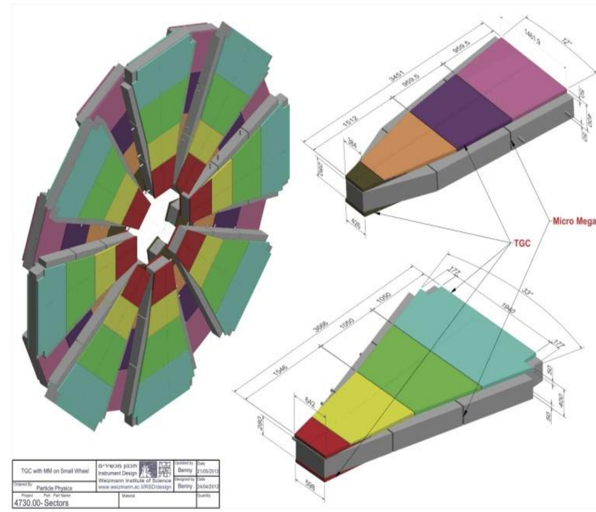
Проект NSW

SW = CSC+MDT+TGC

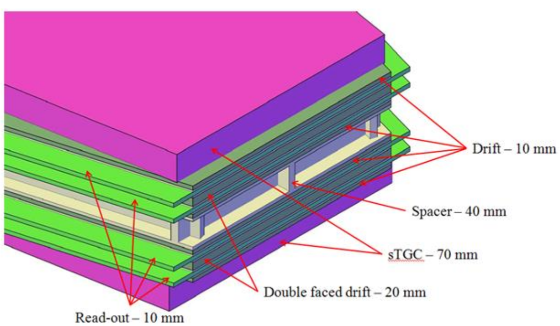


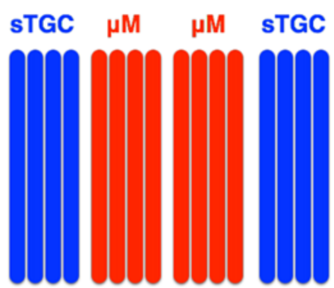
NSW = Micromegas+sTGC

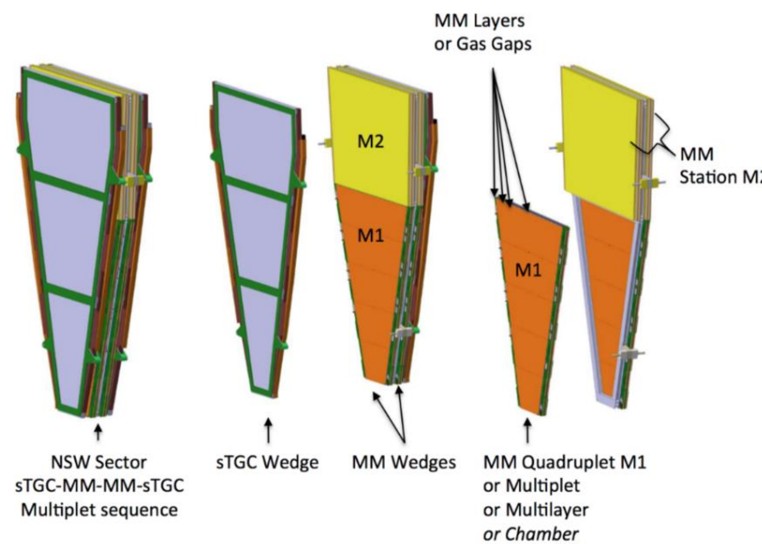
128 MM и 192 sTGC камеры в 16 секторах



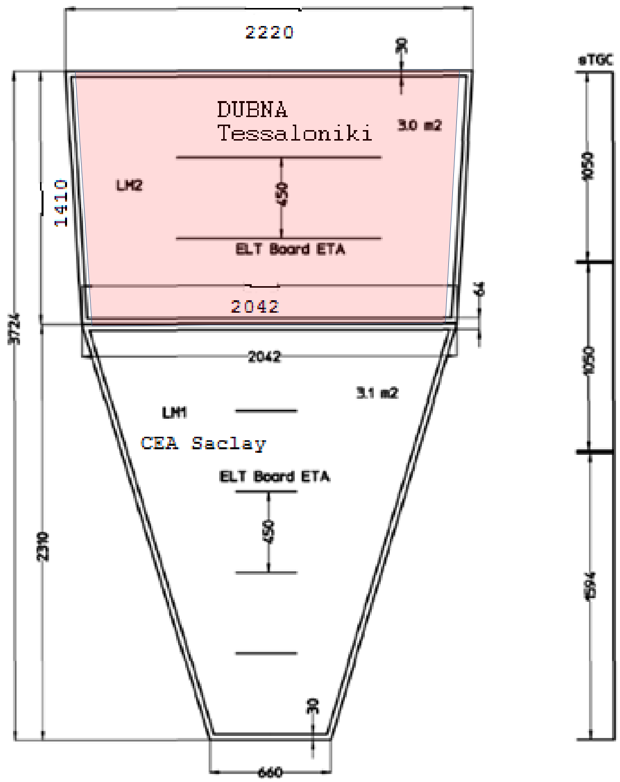
Структура MM+sTGC квадруплеты







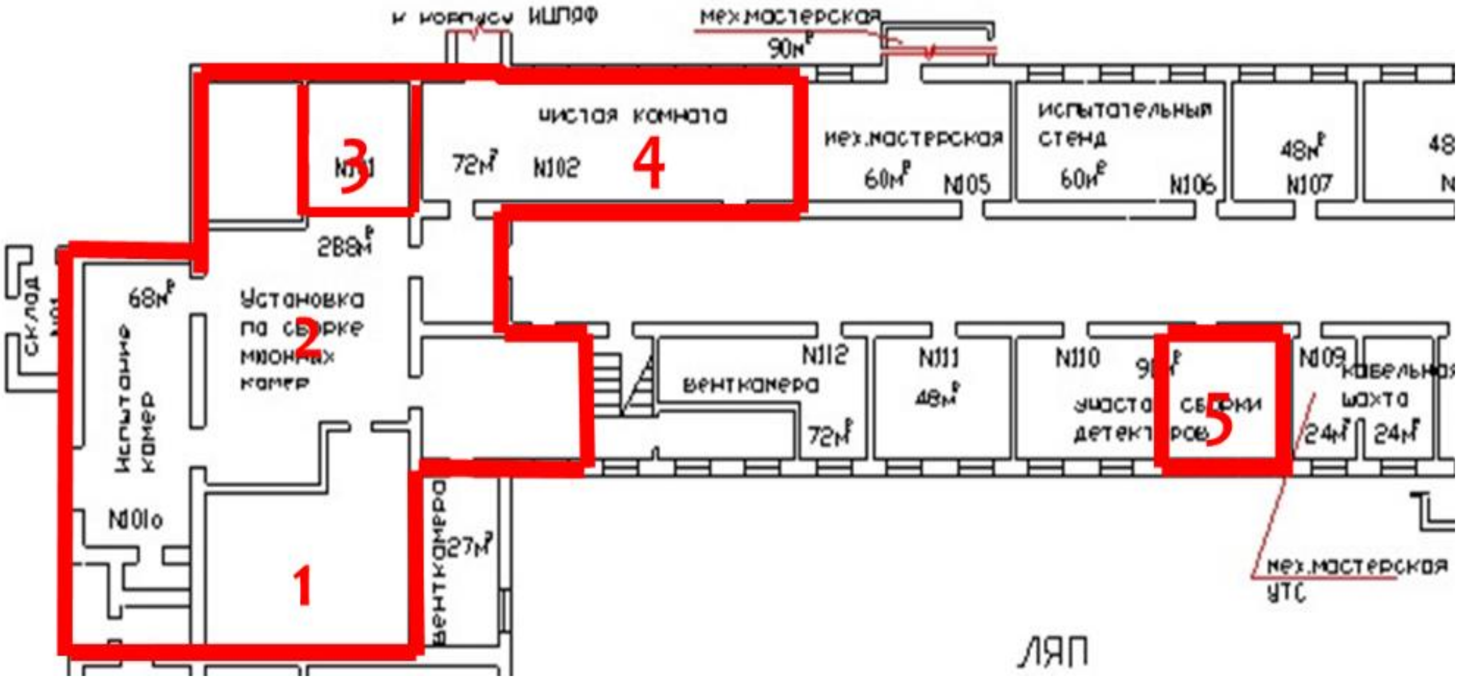
Проект NSW



<u>Обязательства ОИЯИ</u> – изготовление модулей LM2 (внешняя сторона Большого Сектора) – совместно с *<u>AUTh, Thessaloniki</u>*

- Изготовление и тестирование всех 64 RO панелей
- Сборка и тестирование 32 квадруплетов

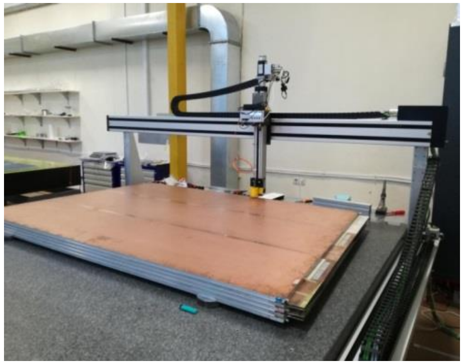
Участок производства и сборки детекторов в ЛЯП



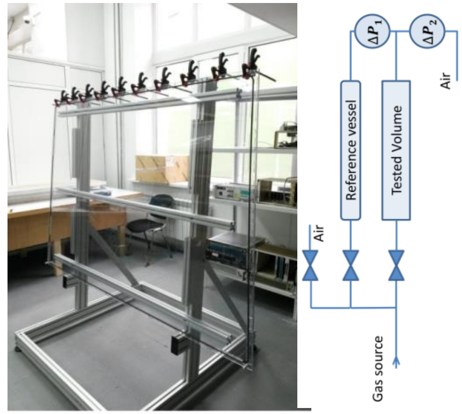
5 помещений (принудительная вентиляция, контроль температуры и влажности):

1. Чистая комната (72м^2, ISO 7) для производства панелей и их тестирования
2. Зал (150м^2) для тестирования квадруплетов на стенде с «космикой»
3. Комната (25м^2) для проверки панелей на утечки газа
4. Чистая комната (50м^2,ISO 6) для сборки и тестирования квадруплетов
5. Помещение (25м^2) для мойки панелей

Участок производства ММ панелей и квадруплетов изнутри



Проверка геометрии панелей и квадруплетов (100μm на 3м²)



Газовый стенд

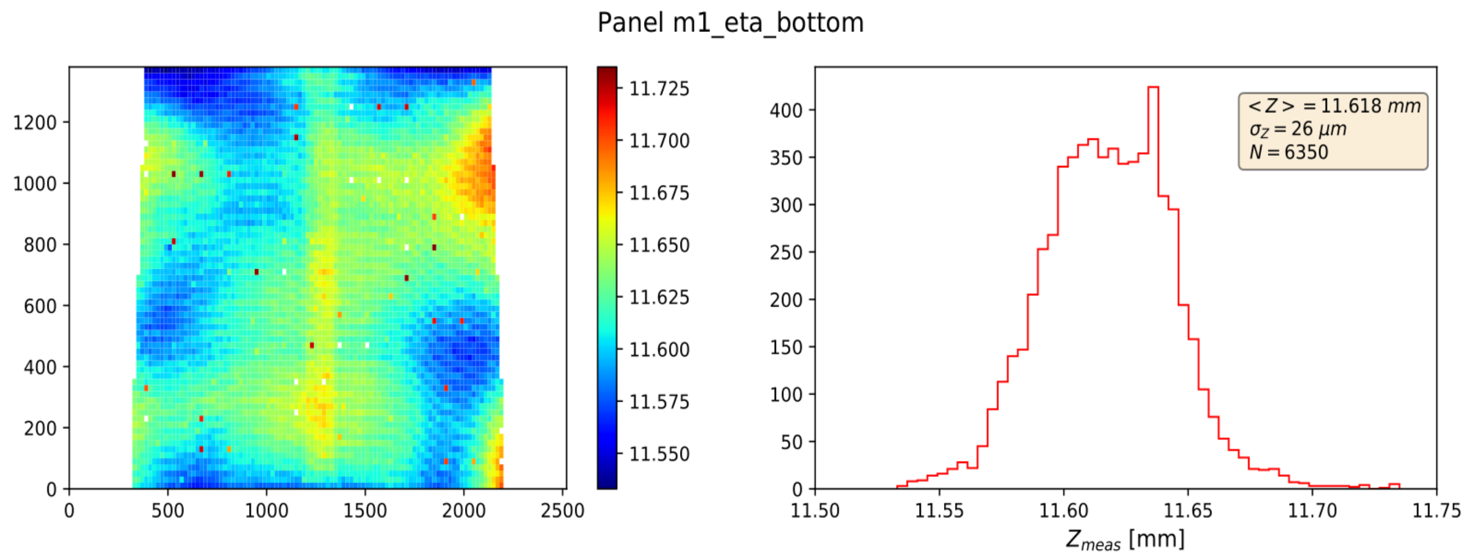
Стенд прецизионной сборки квадруплетов

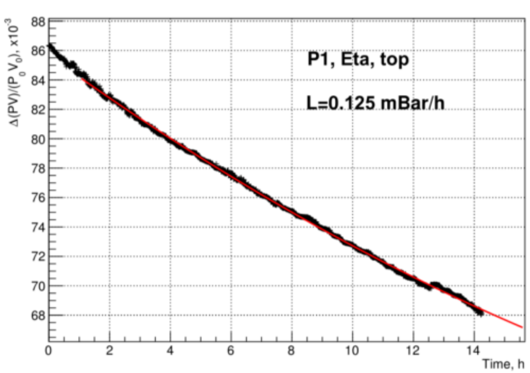
Стенд испытания квадруплетов с помощью космических мюонов

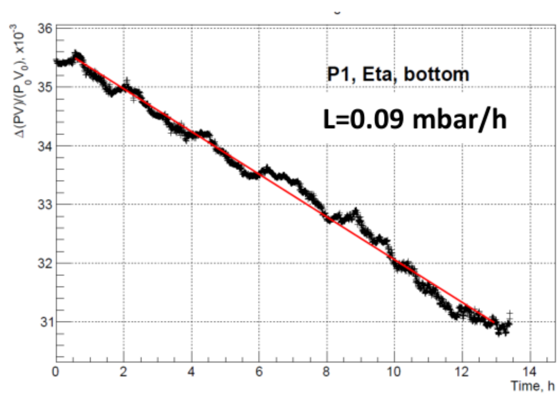
Этапы сборки ММ панели

Июль 2017 – Site Review. 4 MM RO изготовлены - ОК, ожидаем поставку новых PCB

Участок производства ММ панелей и квадруплетов – некоторые измерения

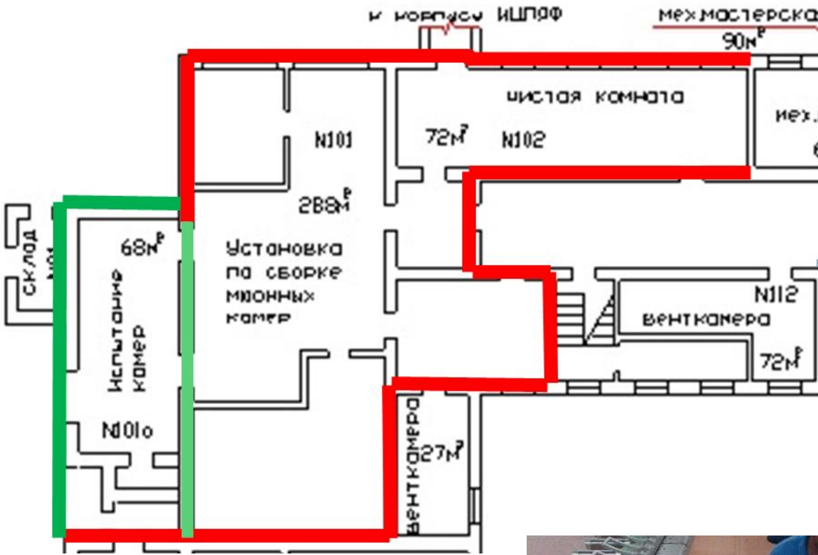


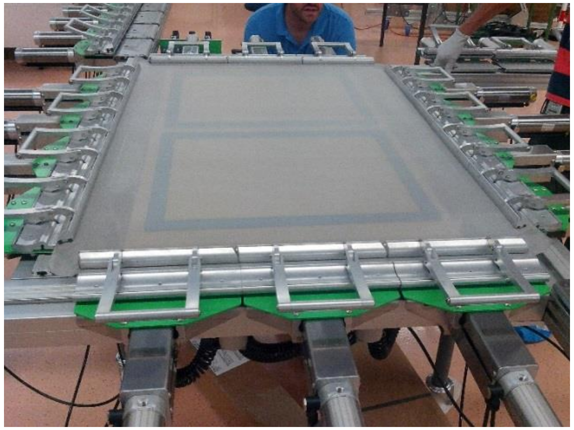




Panel, side	Abs. leak, ml*bar/min	Equivalent QP pressure drop rate, mBar/h
Eta-1,top	0.11	0.125
Eta-1,Bottom	0.079	0.09
Stereo-1, top	0.073	0.085
Stereo-1, bottom	0.088	0.1
Σ	0.35	0.4

Создается второй участок для производства Микромегас камер!





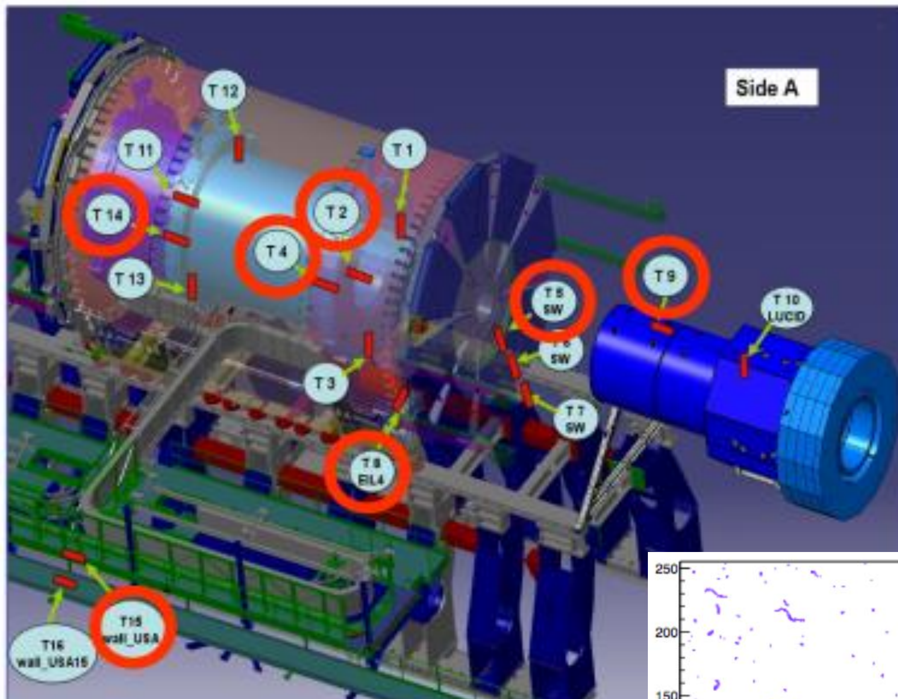
Приобретено и установлено необходимое оборудование

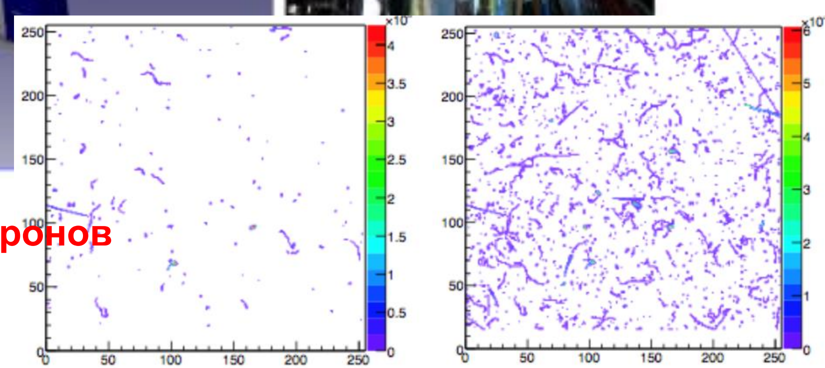
- Oven
- DuPont photoresist PC1025 (64 мкм)
- Mesh
- Test PCBs and photomasks from our Gerber files

Мониторы светимости БАК и радиационного фона в шахте

ATLAS GaAsPix

15 GasAs:Cr based Timepix detectors were installed in the ATLAS pit
in 2016-2017 to monitor the radiation background





- ✓ **Высокая эффективность регистрации фотонов и нейтронов**
- ✓ **Лучшая радиационная стойкость**

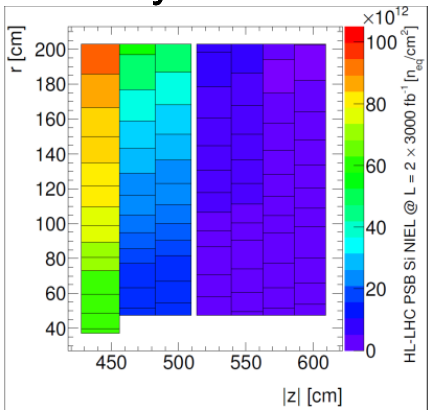
Продолжатся работы по on-line обработке, алгоритмам идентификации и визуализации

Изображение на детекторе
1 кадр=500μs и 100 кадров

Модернизация калориметров (LAr) - 1

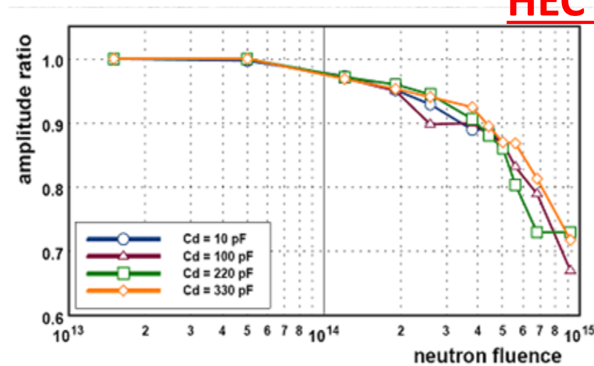
До недавнего времени оставались открытыми несколько сценариев:

- Выживет ли «холодная» электроника → будет ли необходимость открыть криостат?
- Нужно ли менять передний калориметр или добавить новый miniFCal?

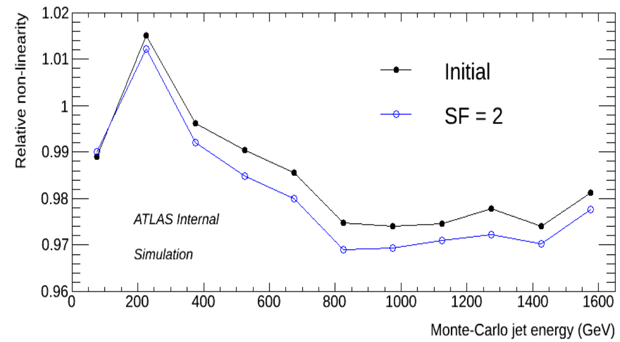


Нейтроны в HEC

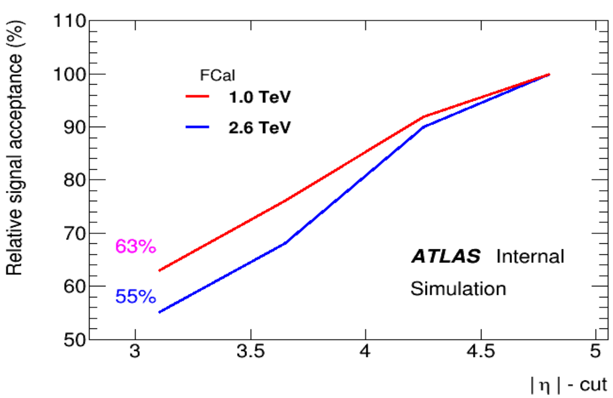
HEC электроника



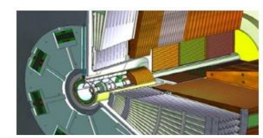
Деградация сигнала (ИБР-2 в 90-е)

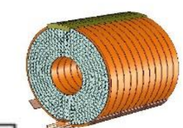


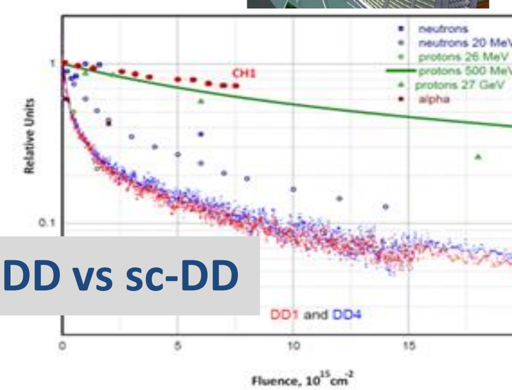
Изменения линейности ~0.5% - ОК



miniFCal



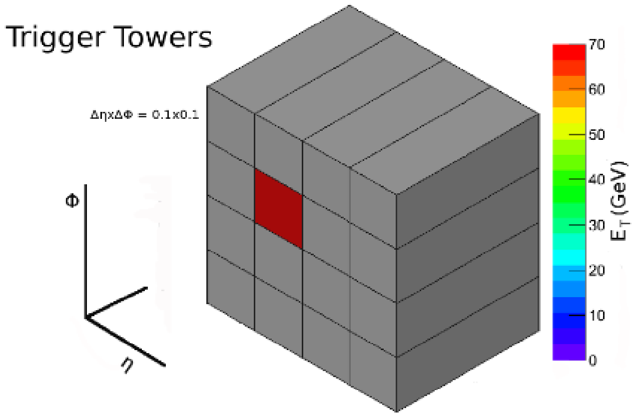




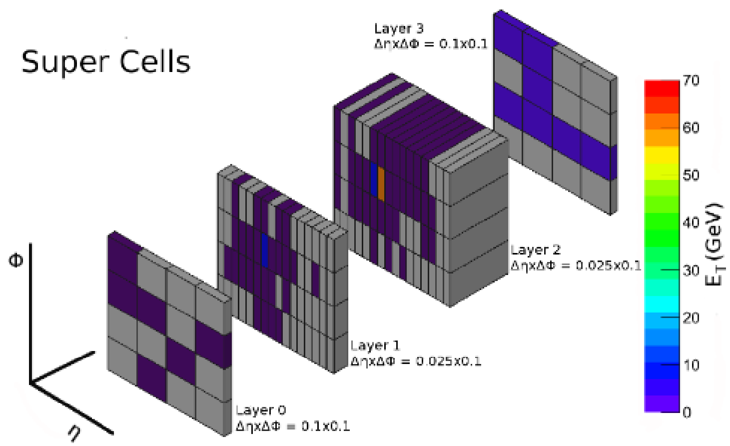
pc-DD vs sc-DD

Уровень деградации детекторов будет «приемлемым»…

Модернизация калориметров (LAr) - 2



(a)

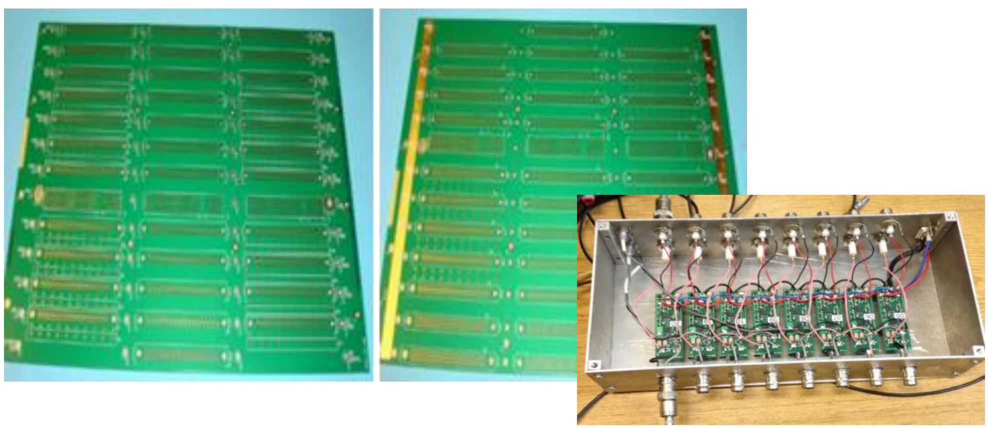


(b)

An electron (with 70 GeV of transverse energy)

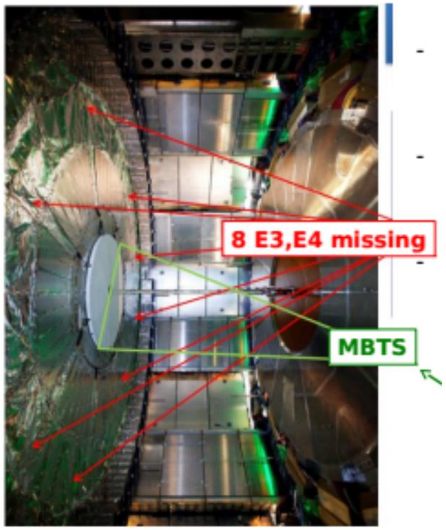
Главная задача – улучшить качество L1-триггера, повышая эффективность идентификации струй и снижая эффект от «pile-up».
Увеличение калориметрической информации через гранулярность промежуточных слоев в ЕМ =>
10 «супер-ячеек» вместо одной триггерной «башни»

- Замена триггерной электроники и основной платы
- Новые блоки LTDB (LAr Trigger Digitizer Board)
- Оптические кабели …

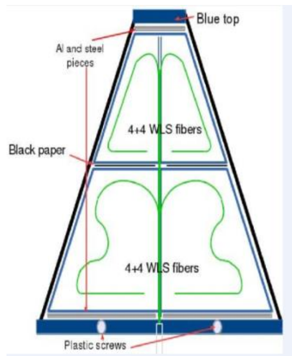


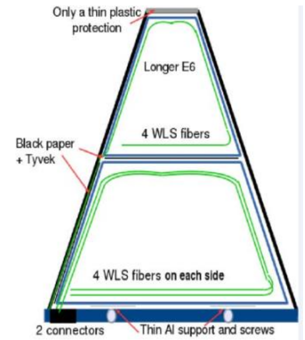
- ✓ **Прототип основной платы (Е. Ладыгин + TRIUMF)**
- ✓ **Прототип усилителя-формирователя**
- ✓ **Радиационные испытания платы и кабелей на ИБР-2**

Модернизация калориметров (TILE)

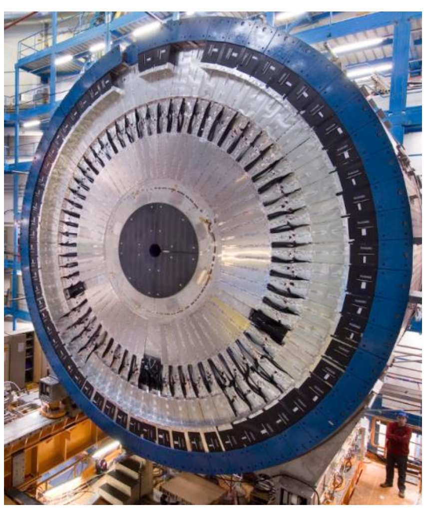


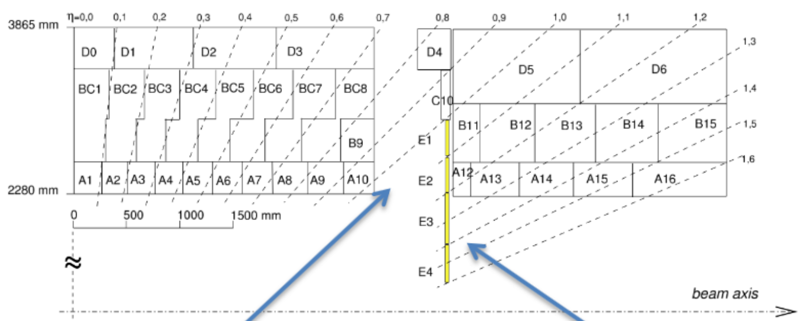
Проведена замена MBTS сцинтилляторов (создан стенд, выполнены испытания и выбран новый дизайн)





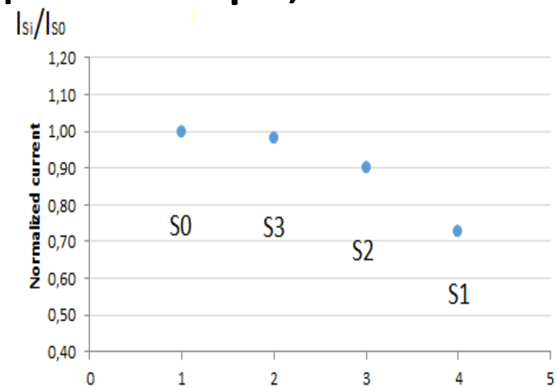
Новые радиационно-стойкие сцинтилляторы, UPS-923A





Gap scintillators
E1 (1.0 < |η| < 1.1)
E2 (1.1 < |η| < 1.2)

Crack scintillators
E3 (1.2 < |η| < 1.4)
E4 (1.4 < |η| < 1.6)



Тесты на ИБР-2: до $2 \cdot 10^{14}$ n/cm^2

Фаза-2 модернизации детектора АТЛАС (до 2026)

- Каждая детекторная система потребует существенной модернизации для HL-LHC (полная замена внутреннего трекера на новый “all-Si” детектор)
- Работы по Фазе-1 формируют основу для Фазы-2
- К концу 2017 все TDR будут готовы, MoU – весна-лето 2018

- Планы ОИЯИ – это модернизация Мюонного спектрометра и Калориметров

Мюонный спектрометр: участие в создании новых sRPC

Калориметры (замена всей электроники, кроме «холодной»):

TILE – участие в проекте «Демонстратор», рад. стойкие сцинтилляторы

LAr – участие в разработке FE- электроники (HEC LTDB)

– участие в разработке HEC-предусилителя общей интегральной схемы и сертификация чипов

– продолжение экспериментов на У-70 для создания модели поведения калориметрического сигнала при работе HL-LHC (включая моделирование физ. процессов в FCal)

(подробности в Проекте)

List of the project participants
(including FTE)

Muon spectrometer

A. Gongadze-1, G. Chelkov-1 (DLNP), N. Zimine-1 (VBLHEP) - coordinators
I. Gongadze-1, L. Gongadze -1, M. Gostkin-0.5, A. Guskov-0.1, D. Dedovich-0.9,
M.Demichev-0.5, D. Kharchenko-0.5, D. Kozhevnikov-0.2, U. Kruchonak-0.4,
N. Kuznetsov-0.1, I. Minashvili-1, S. Mokrenko-0.2, A. Nozdrin-0.1,
S. Porokhovoy-0.2, I. Potrap-1, T. Rudenko-0.9, P. Smolyanskiy-0.8, R. Sotenskii-1,
I. Troeglazov-1, E. Tskhadadze-0.2, A. Zhemchugov-0.2 (DLNP)
Yu. Filippov-1, A. Ivanov-0.3 (VBLHEP),
I. Titenkov-0.4, A. Zabaluev-0.2 (ATOM)

Calorimeters

A. Cheplakov-1, E. Ladygin-1, (VBLHEP), I. Minashvili-1 (DLNP) - coordinators
V. Kukhtin-1, S.Nagorny-1, N. Javadov-0.9, F. Ahmadov-0.2 (LHEP)
A. Artikov-0.5, N. Atanov-0.3, Yu. Davydov-0.5, V. Glagolev-0.2, A. Shalyugin-0.3,
A. Simonenko-0.3, V. Tereschenko-0.4 (DLNP)
S. Kulikov-0.1, M. Bulavin-0.1 (FLNP)

Collaborators:

CERN (Switzerland), **CEA Saclay** (France), **INFN** (Italy), **German cluster, Univ. of Thessaloniki** (Greece), **Tomsk State University** (Russia), **Czech TU in Prague, Institute of Experimental and Applied Physics, (**Czech Republic), **X-Ray Imaging Europe** (Germany)**, Freiburg; FMF, Universitat Freiburg** (Germany), **MPI Munchen** (Germany), **BNL** (USA), **INFN Milano** (Italy), **TRIUMF** (Canada) **Stockholm University** (Sweden), **Institute of Physics, Prague** (Czech Republik), **Charles University, Prague** (Czech Republik), **Univ. Blaise Pascal Clermont-Ferrand** (France), **Uni. Arizona** (USA), **Slovak Academy of Sciences, Bratisvala** (Slovakia)

44 участника = 27 FTE (27 физиков, 13 инженеров and 4 техника)

Финансы

Форма 26

Expenditures, resources, financing sources			Costs (kUSD) Resource requirements	Proposals of the Laboratory on spending profile - finances and resources: 1st year	2nd year	3rd year
Expenditures		LM2 quadruplets production, transportation, integration and commissioning	220	90	70	60
		R&D for LAr electronics	95	10	55	30
		GaAsPix visualization project	45	15	15	15
		R&D for TILE scintillators and electronics	55	15	15	15
		Construction/repair of premises				
		Materials:				
		FE electronics for ATLAS MM	40	40		
		Aluminum profiles and corners	15	15		
		Epoxy glue	5	5		
		Different materials	6	2	2	2
		LAr readout chips	10		5	5
		Rad hard scintillators	30	10	10	10
Required resources	Standard hour	Resources of – Laboratory design bureau; – JINR Experimental Workshop; – Laboratory experimental facilities division; – accelerator; – computer. Operating costs.				
Financing sources	Budgetary resources	Budget expenditures including foreign-currency resources.	511	202	172	137
	External resources	Contributions by collaborators. Grants. Contributions by sponsors. Contracts. Other financial resources, etc.	180	180	?	?

Форма 29

Estimated expenditures for the Project "Upgrade of the ATLAS Detector"

	Expenditure items	Full cost, kUSD	1st year	2nd year	3rd year
	Direct expenses for the Project				
1.	Accelerator, reactor (hours)	800h	400	200	200
2.	Materials	106	72	17	17
3.	Equipment	405	130	155	120
4.	Payments for agreement-based research	100	100		
5.	Travel allowance, including:	296			
	a) non-rouble zone countries	290	90	100	100
	b) rouble zone countries	6	2	2	2
	c) protocol-based				
	Total direct expenses	907	394	274	239

PROJECT LEADER

LABORATORY DIRECTOR

LABORATORY CHIEF ENGINEER-ECONOMIST

Все затраты – бюджет ЛЯП

Просим поддержать нашу заявку на продление проекта «Модернизация детектора АТЛАС»

(тема 0-2-1081-2009/2019)

на период 2019-2021

Backup slides

Referee report

on the project

Upgrade of the ATLAS detector

(within the JINR theme 02-0-1081-2009/2019)

The ATLAS detector has been developed and constructed with a large participation of the JINR scientists and engineers. The important contributions have been done in different detector systems: muon detector, liquid-argon calorimeter, tile calorimeter, in development of trigger, DAQ, procedures of calibration and data analysis etc. Excellent performance of the detector made it possible to obtain outstanding physics results, the most significant and resonant of which was discovery of the Higgs boson.

CERN approved the LHC upgrade program, with Phase-I upgrade starting in 2019-2020 and Phase-II in 2024-2026. The LHC upgrade requires a relevant upgrade of the ATLAS detector in order to conform to conditions of much higher luminosity what leads to increase of detector rates. Besides, irradiation of some parts of the detector during the past years of the ATLAS operation already resulted in partial degradation of their performance. Participation of the JINR group in the ATLAS upgrade would be a natural extension of their previous activity in detector development.

In the project under consideration, the authors present the obtained in 2015-2017 results and propose their plans of participation in the ATLAS upgrade program. These plans include upgrade of the Calorimeters and the Muon Spectrometer. Some of these works have started already.

Works on calorimetry.

For the LAr Calorimeter, several options of upgrade were considered. Extensive works on simulation were done in order to estimate the degradation effect due to electronics irradiation. It was shown that the energy non-linearity increase is negligible. This result allowed the Collaboration to avoid the cryostat opening.

For the FCal, the option of thinner LAr gaps was investigated, and it was demonstrated that there is no need in replacement of the FCal.

There were many irradiation tests fulfilled at the IBR-2 reactor and the U-70 accelerator in Protvino, where various components of the mini-FCal and HEC calorimeters were tested, and conclusions about the promising sensors and materials for future applications have been done.

Much attention is given to development of the LAr calorimeter electronics including radiation tolerant front-end electronics as well as readout and trigger electronics. Some prototypes have been developed and tested already.

Radiation-hard plastic scintillators were proposed by the JINR group for installation in the endcup area of the LAr calorimeter, and there is in progress the study of radiation hardness of plastic scintillators for Inter-TileCal counters.

Another big field of activity is upgrade of the ATLAS Muon Spectrometer.

A significant achievement of the JINR group is construction of the workshop for production of Micromegas detectors and for the quadruplets assembly. Micromegas detectors will be used in the New Small Wheels which will replace the current Small Wheels in the endcup Muon Spectrometer. The production site was commissioned and mass-production of the Micromegas chambers has started in 2017. The whole complex includes clean rooms for production and assembling, test stand for semi-automatic measurements of geometrical characteristics, gas leakage stand, high voltage stand for readout panels, cosmic ray stand for testing of the quadruplet quality control, and other equipment.

The novel technology of GaAs-based semiconductor pixel detectors has been implemented by the JINR group for monitoring of the neutron fluence in the ATLAS cavern.

Concluding, the JINR group fulfilled a huge work on construction of the ATLAS detector in the past, and has extensive plans of participation in the ATLAS upgrade. The experience of participants leaves no doubt that the goals of this upgrade will be reached.

The requested resources are reasonable for this large-scale project.

I recommend to approve the project "Upgrade of the ATLAS detector" with the first priority.

Head of Sector, DLNP JINR
Doctor of Science

A.Kulikov

Referee report on the Project "Upgrade of the ATLAS Detector"

(JINR participation)

The LHC Upgrade program is very well motivated by prospects of the full exploitation of the physics accessible with a total luminosity of 3 ab^{-1}. The large luminosity will allow to probe into signatures of new physics predicted by models such as SUSY in the multi-TeV region. Large data sample will allow precision measurements of the Higgs couplings, studying of rare channels (e.g. $H \rightarrow \mu\mu$) and the Higgs self-coupling. Measurement of the weak boson scattering cross-section remains rather important for BSM physics, as well as searches for heavy resonances.

The increased instantaneous luminosity at the HL-LHC results in average number of p-p interactions per bunch crossing ~ 200, which requires detectors to operate at high trigger rates and after exposure to large particle fluences. It is also worth noting that many components of the detectors are already 10-15 years old and will be approaching the end of their lifetimes. That is why some systems of the ATLAS detector would need to be upgraded in order to coop with high trigger rates and occupancies, to maintain good performance in tracking, flavor tagging and in precisely reconstructing the full range of physics objects (leptons, jets, E^T_{miss}) over large acceptance.

The ATLAS Phase-II Upgrade project includes replacement of the inner detector by a new all-silicon tracker, installation of a new trigger system with 500 kHz rate and a new readout for calorimeters and muon spectrometer. The Phase-I and Phase-II activities are carrying out in parallel. The JINR group is participating in the upgrade of the muon spectrometer and calorimeters from the beginning and since then has achieved rather good results. I would mention the construction and commissioning of the workshop for production of the Micromegas chambers. This important event marks the appearance in Dubna a new detector technology which could be applicable in the experiments at NICA. Interesting results were obtained in the radiation tests of the diamond sensors and new scintillators. Further developments of the Timepix detectors based on GaAs:Cr materials also may find many useful applications.

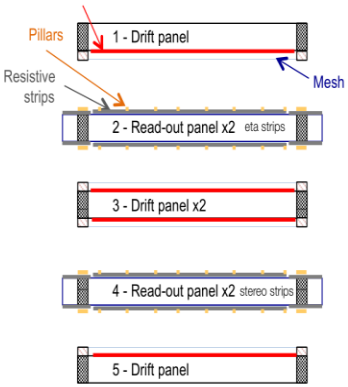
The JINR group has presented the project which includes activities in various areas of the ATLAS Upgrade. The responsibilities taking by the group in the detector development are realistic, although challenging. It is not clear for me how the required production rate in the DLNP micromegas workshop will be achieved. There is no slippage in tight schedule of the muon quadruplets production.

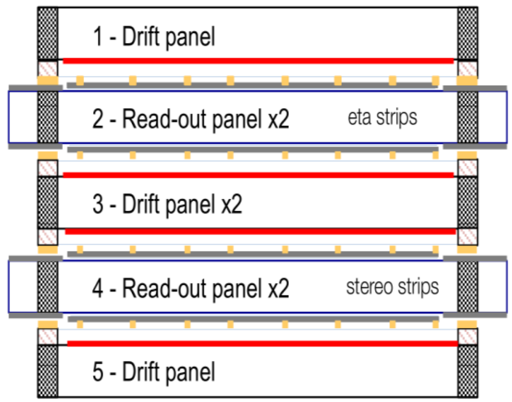
In general, the project is aimed at very important improvements of the ATLAS detector, it is based on 25 years of the group involvement in the detector development and maintenance. It is well balanced in terms of requested resources and the personnel. So, I would recommend the project continuation for the next 3 years.

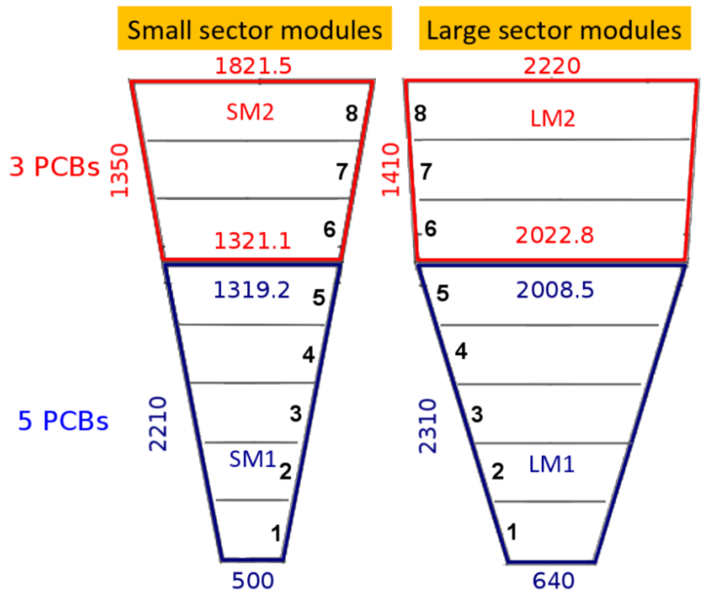
16.11.2017 Nikolay Piskunov

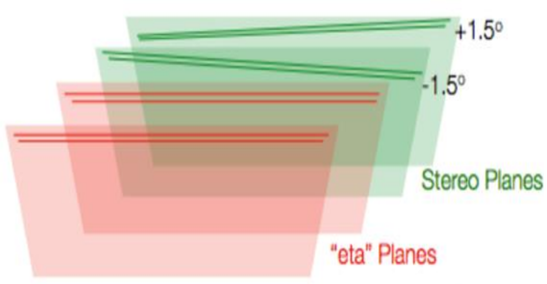
VBLHEP JINR

ATLAS NSW details









Double-sided panel with readout boards in back-to-back configuration. ‘Eta’ planes carry strips perpendicular to the precision coordinates, on ‘Stereo’ planes they are inclined by 1,5º.

Dubna MM

MM production technology

I.Giomataris et al, NIM A560 (2006) 405

1) PCB (gerber file → industry → DLNP)
2) Photoresistive film lamination (50 - 150 µm) ---- *LAMINATOR*
3) Mesh lamination ---- *MESH STRETCHER*
4) Photoresistive film lamination (50 - 150 mm) ---- *LAMINATOR*
5) UV exposure through mask ---- *UV INSOLATOR*
6) Chemical development ---- Chemical Development Unit