Strange matter production in heavy ion collisions at Nuclotron (BM@N project)

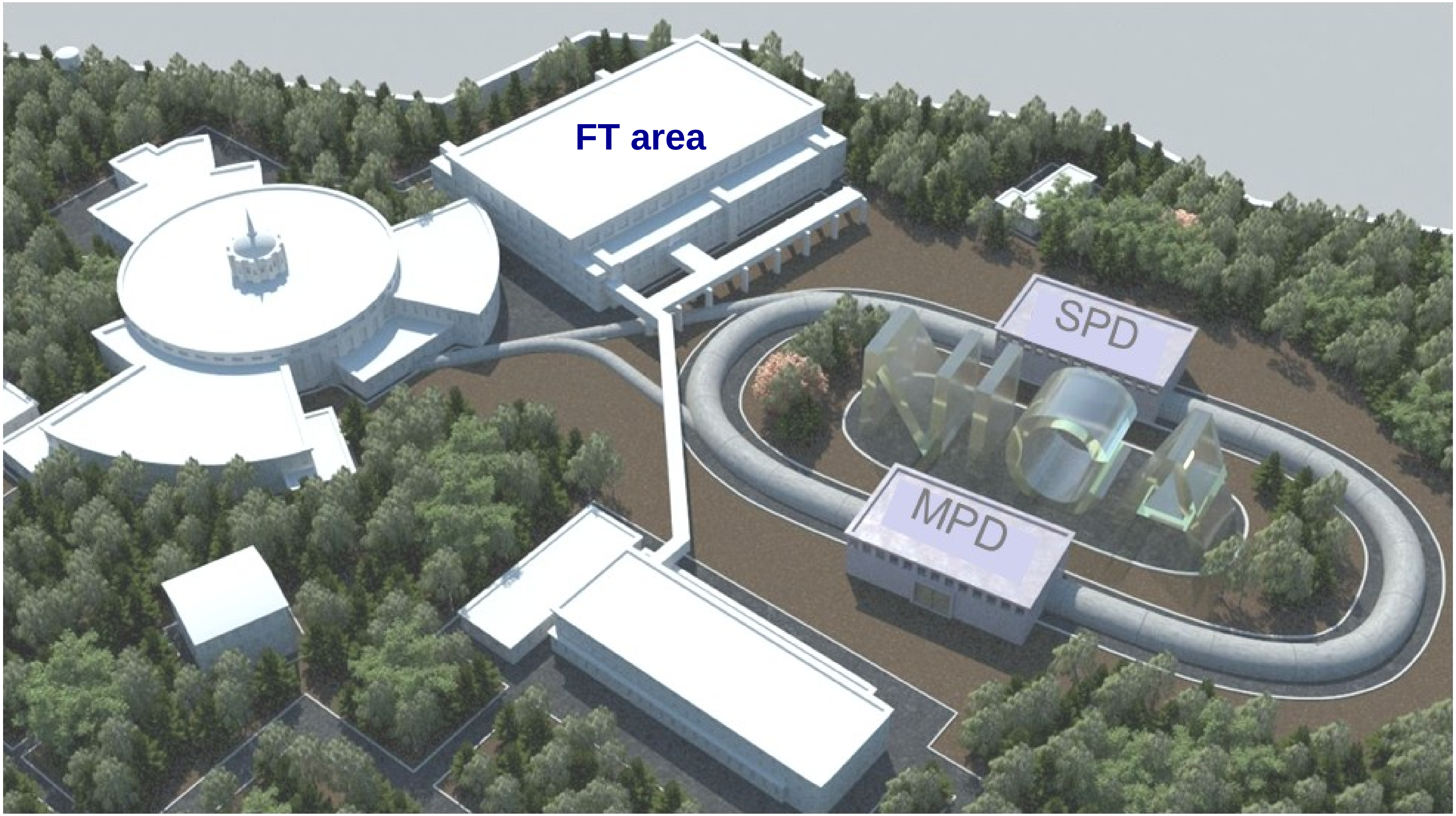
Baryonic Matter at Nuclotron

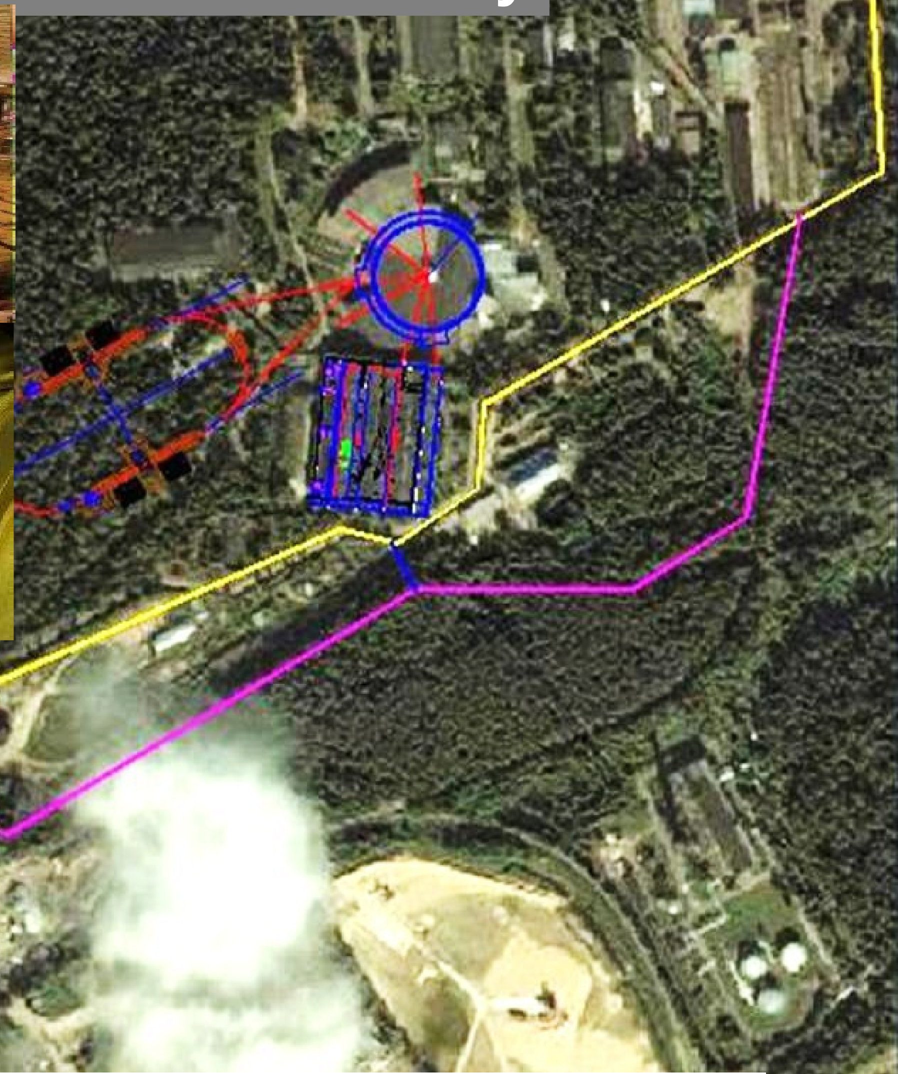
V.P.Ladygin for BM@N Collaboration

XXI-th Baldin ISHEPP, 13 September 2012

Nuclotron-based Ion Collider fAcility (NICA)



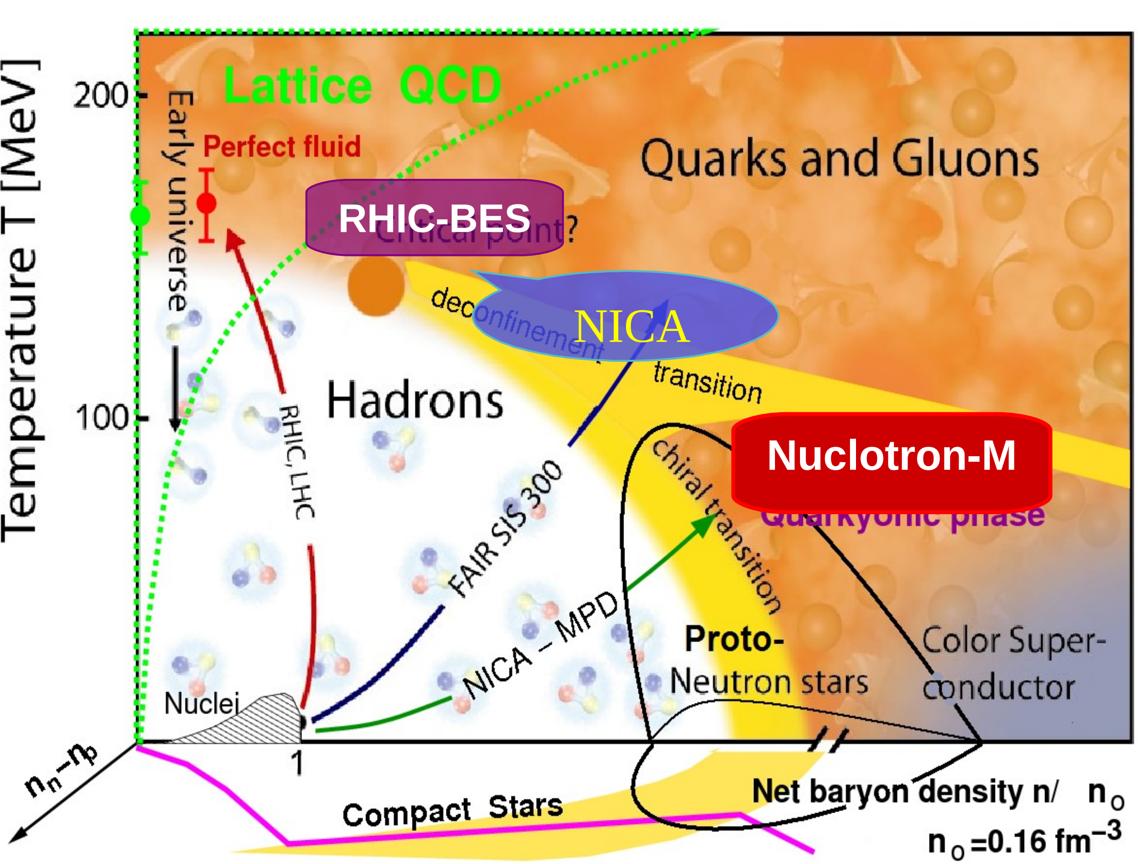
NICA: Nuclotron-based Ion Collider fAcility



- **Flagship project at JINR**
- **Based on the development of the Nuclotron facility**
- **Optimal usage of the existing infrastructure**
- **Modern machine which incorporates new technological concepts**
- **First colliding beams - 2017**

NICA advantages:

- **Energy range $\sqrt{s_{NN}}$ = 4-11 GeV - highest baryon density**
- **Available ion species: from p to Au**
- **High luminosity: Au+Au up to 10^{27}**



Energy Range of NICA

The most intriguing and unexplored region of the QCD phase diagram:

- **Highest net baryon density**
- **Onset of deconfinement phase transition**
- **Discovery potential:**
  a) Critical End Point (CEP)
  b) Chiral Symmetry Restoration
  c) Hypothetic Quarkyonic phase
- **Complementary to the RHIC/BES, NA61/CERN, CBM\&HADES/FAIR experimental programs**

Comprehensive experimental program requires scan over the QCD phase diagram by varying collision parameters: system size, beam energy and collision centrality

The NICA Project Goals

1) Heavy ion colliding beams 197Au79+ 197Au79+ at

$\sqrt{s_{NN}}$ = 4 ÷ 11 GeV (1 ÷ 4.5 GeV/u ion kinetic energy)

at $L_{average}$ = 1E27 cm-2s-1 (at $\sqrt{s_{NN}}$ = 9 GeV)

2) Polarized beams of protons and deuterons in collider mode:

p↑p↑ $\sqrt{s_{pp}}$ = 12 ÷ 27 GeV (5 ÷ 12.6 GeV kinetic energy)

d↑d↑ $\sqrt{s_{NN}}$ = 4 ÷ 13.8 GeV (2 ÷ 5.9 GeV/u ion kinetic energy)

$L_{average}$ = 1E30 cm-2s-1 (at $\sqrt{s_{pp}}$ = 27 GeV)

3) The beams of ions and polarized protons and deuterons for fixed target experiments:

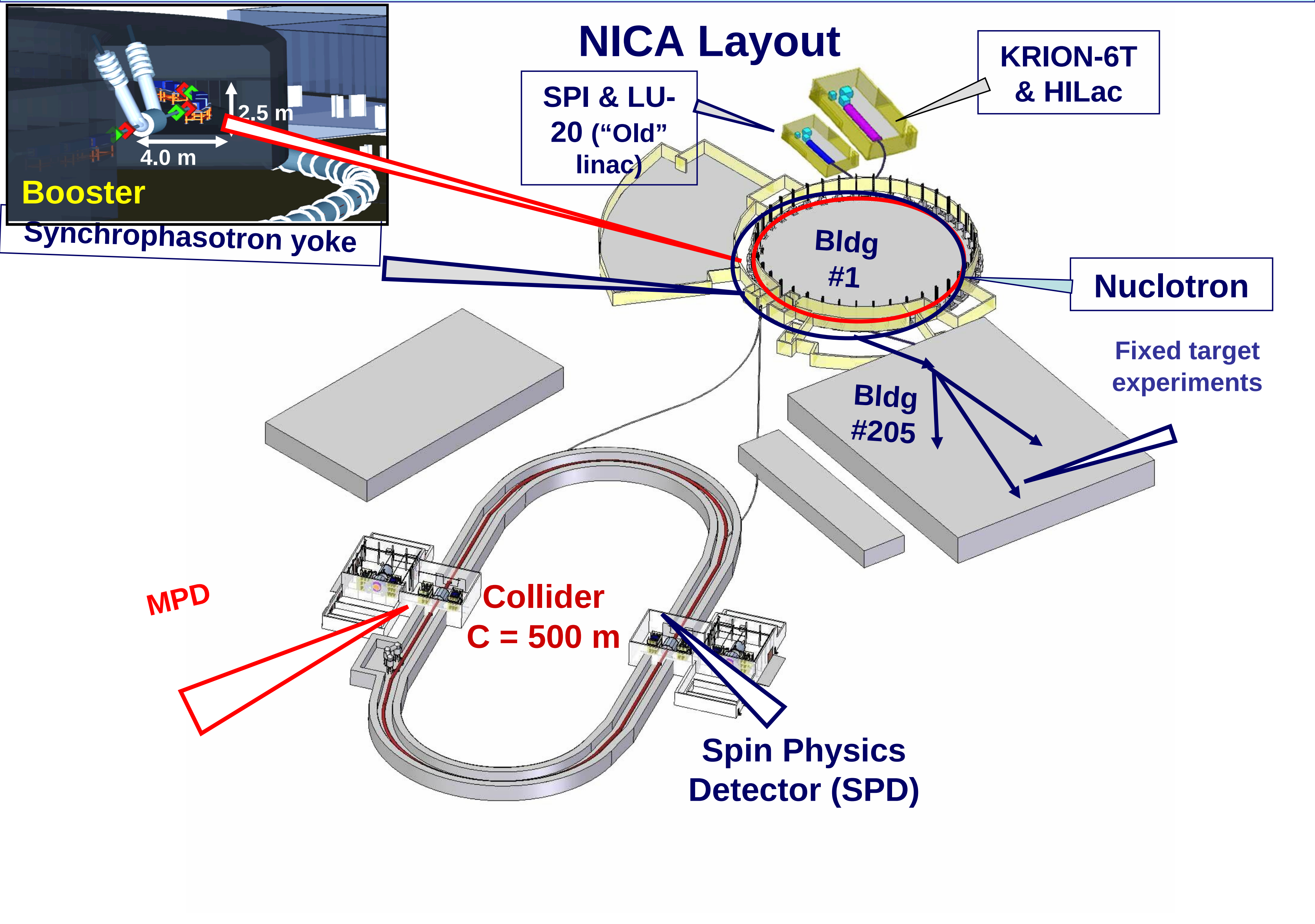
Li -Au = 1 ÷ 4.5 GeV /u ion kinetic energy
p, p↑ = 5 ÷ 12.6 GeV kinetic energy

d, d↑ = 2 ÷ 5.9 GeV/u ion kinetic energy

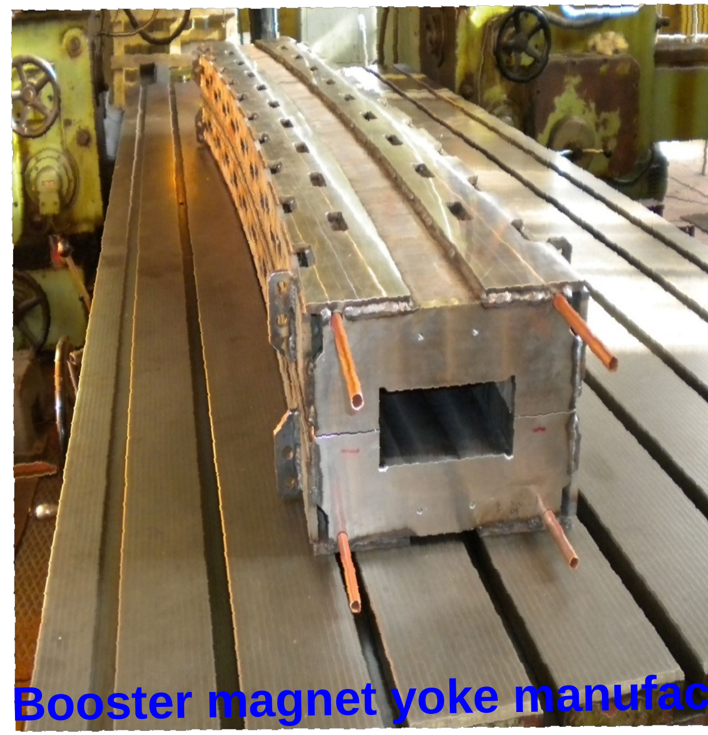
4) Applied research on ion beams at kinetic energy

from 0.5 GeV/u up to 12.6 GeV (p) and 4.5 GeV /u (Au)

Facility Scheme and Operation Scenario



Nuclotron for FT experiments



d, d↑, Li,C… = 1 ÷ 6.0 GeV/u ion kinetic energy

Au = 1 ÷ 4.65 GeV /u ion kinetic energy (10^7 /sec with booster)

P = 1 ÷ 12.6 GeV kinetic energy

Participants

Countries: **Belarus, Bulgaria, Moldova, Romania, Russia, Slovakia, Ukraine + Germany + France**

Russia: INR, SINP MSU, IHEP + 2 University
Germany: GSI, Frankfurt U., Giessen U., FIAS

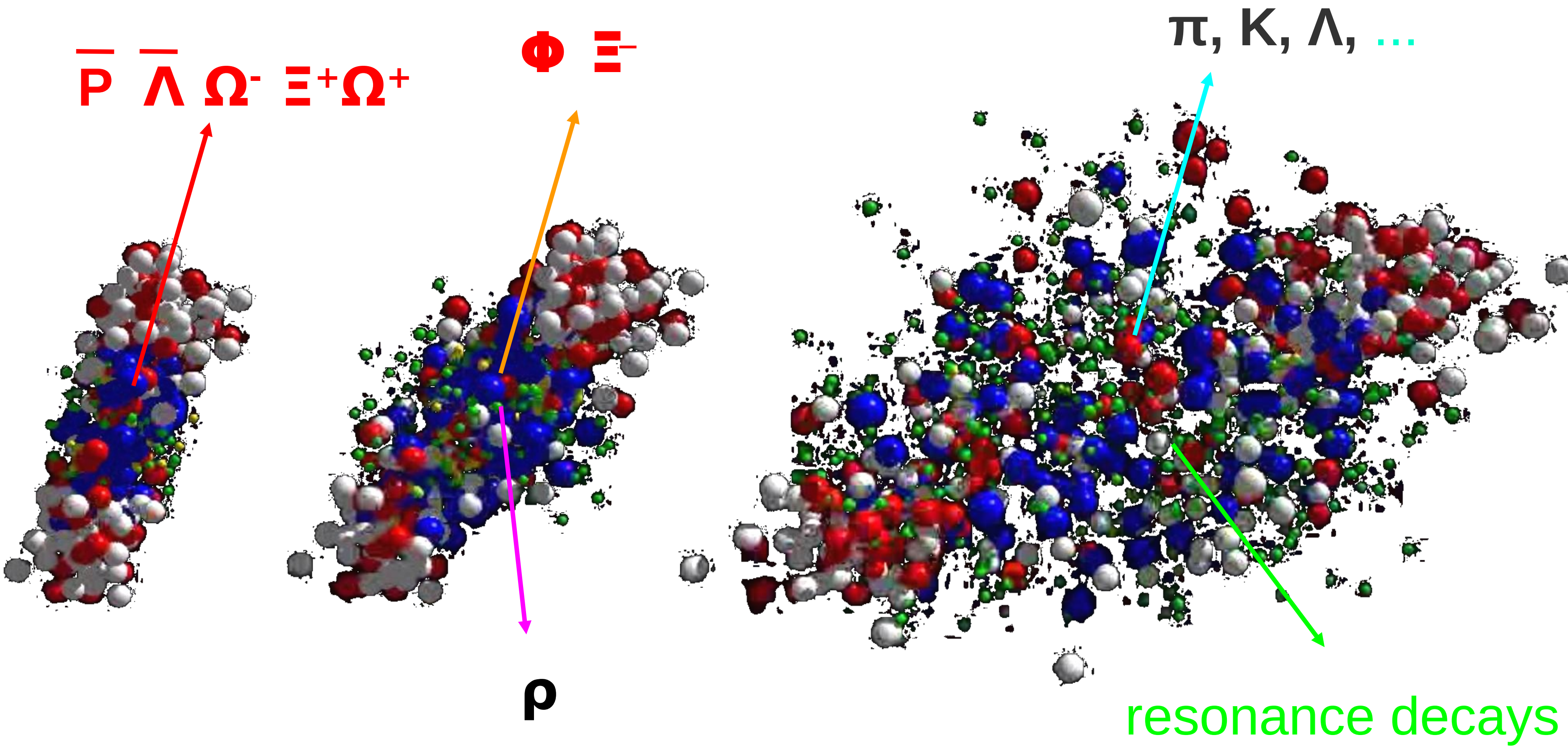
+Institutes from CBM-MPD Consortium

Goal of the experiment

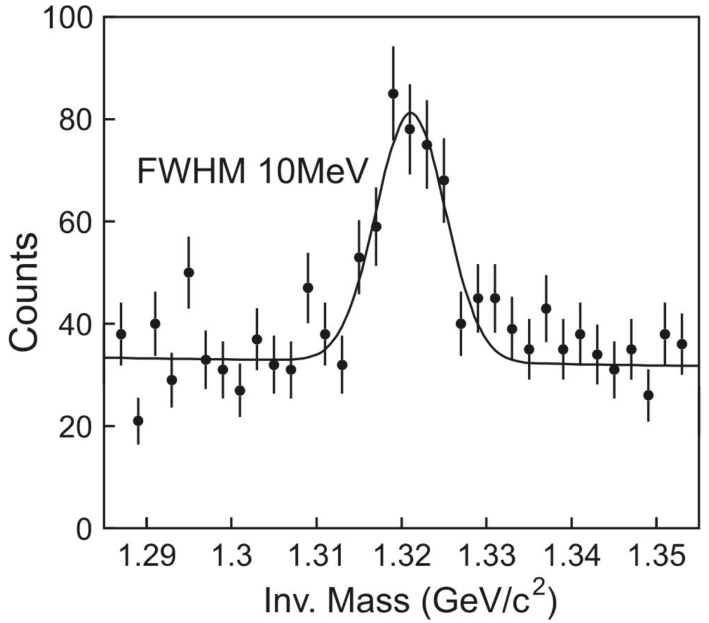
Measurements of the multistrange objects (Ξ, Ω, exotics) and hypernuclei in heavy ions collisions using extracted beams at Nuclotron close to the **threshold production** at the nuclear density of about **3-4 ρ_0**

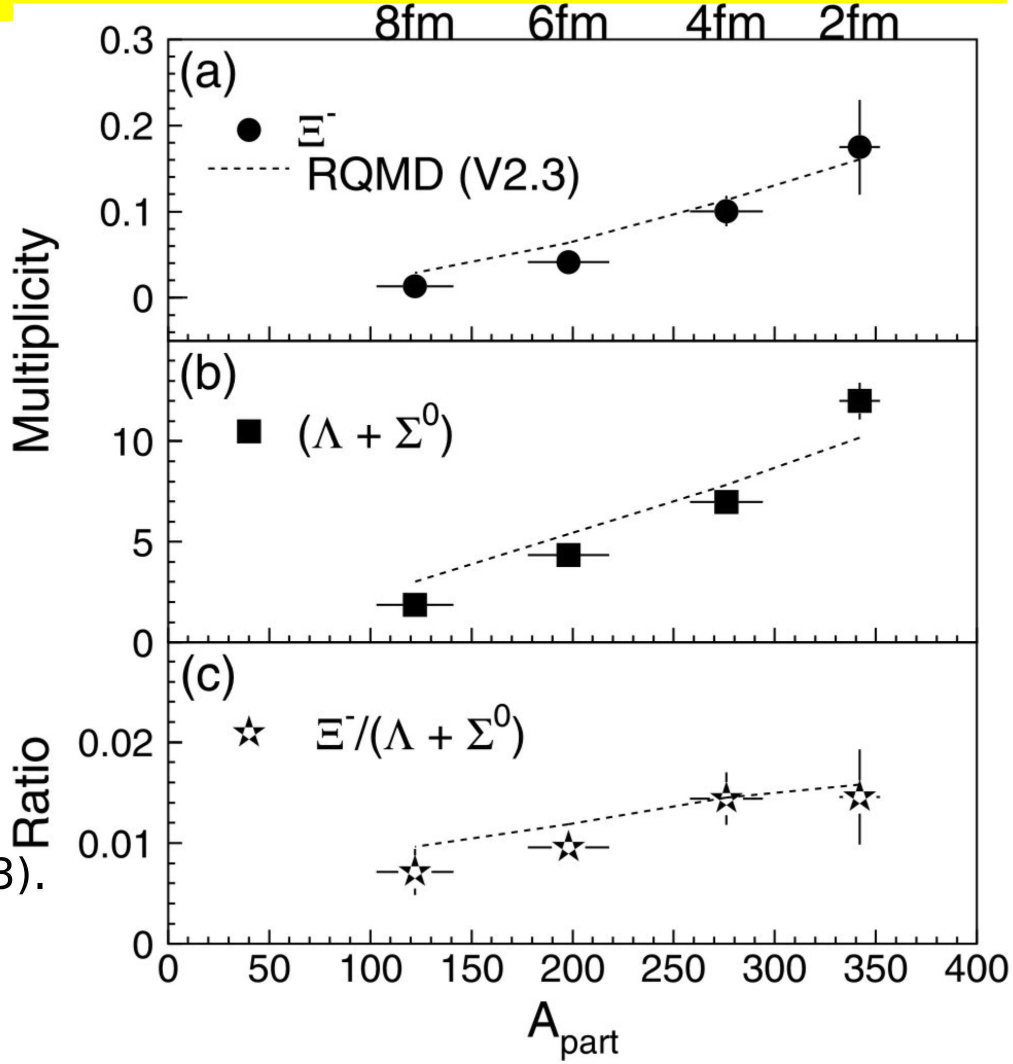
The detector for the first stage of the experiment will be based on the developments for CBM, MPD and SPD (HADES)

Messengers from the dense fireball at Nuclotron beam energies



Ξ^- Hyperons at AGS: Au+Au 6 AGeV





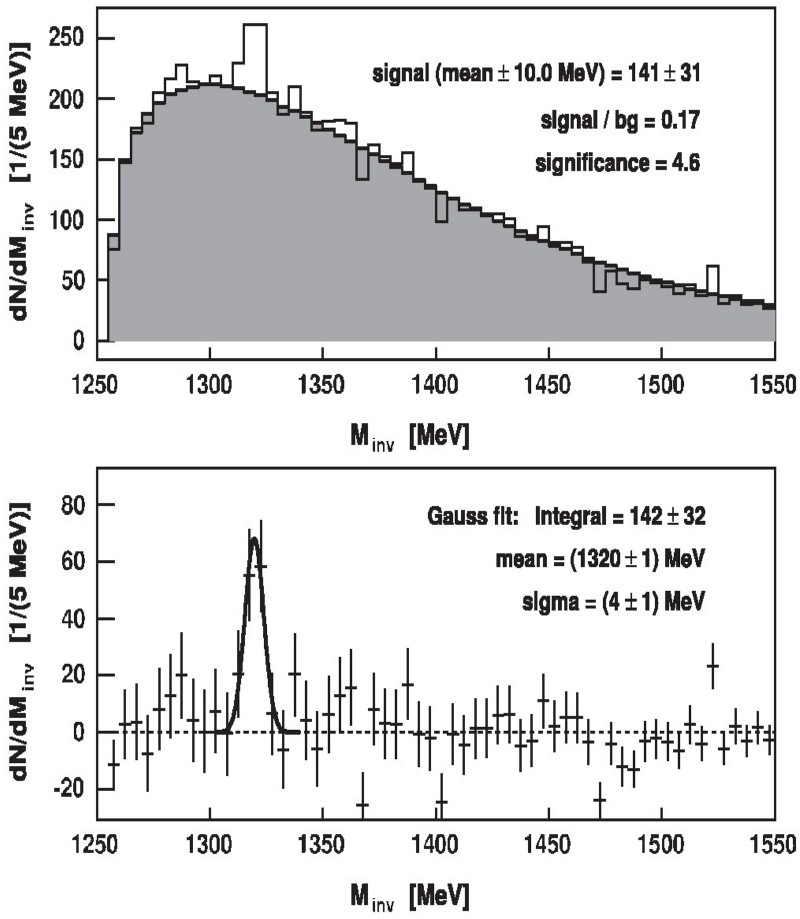
E895 Collaboration

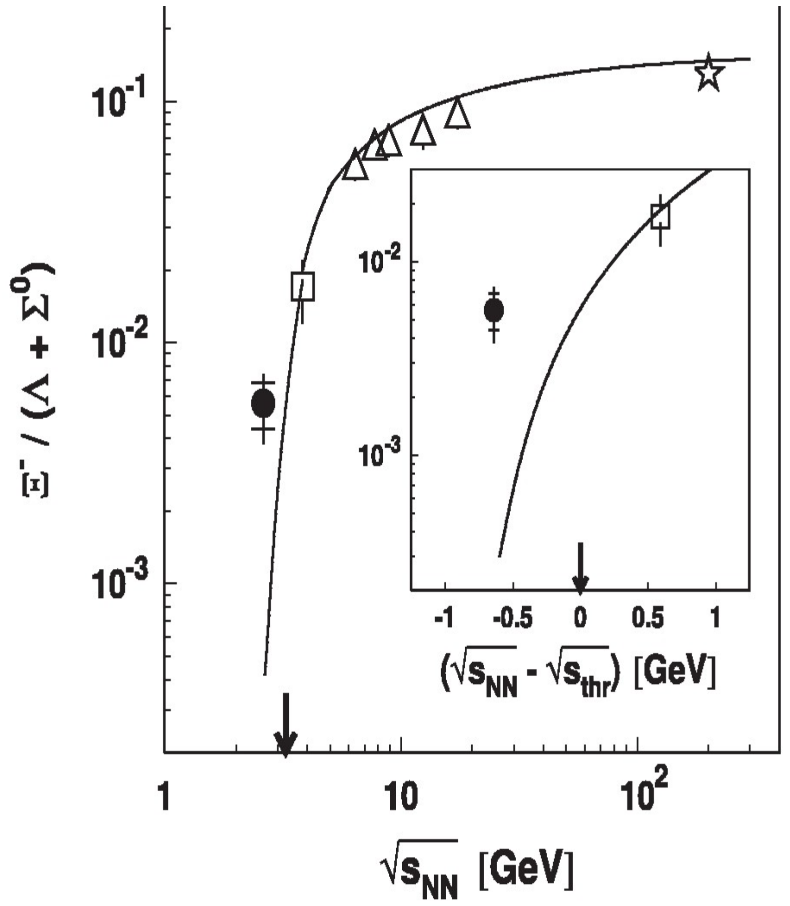
P. Chung et al.,

Phys. Rev. Lett. **91**, 202301 (2003).

~ 250 Xi measured

Deep sub-threshold Ξ^- production in Ar+KCl at 1.76 GeV at HADES

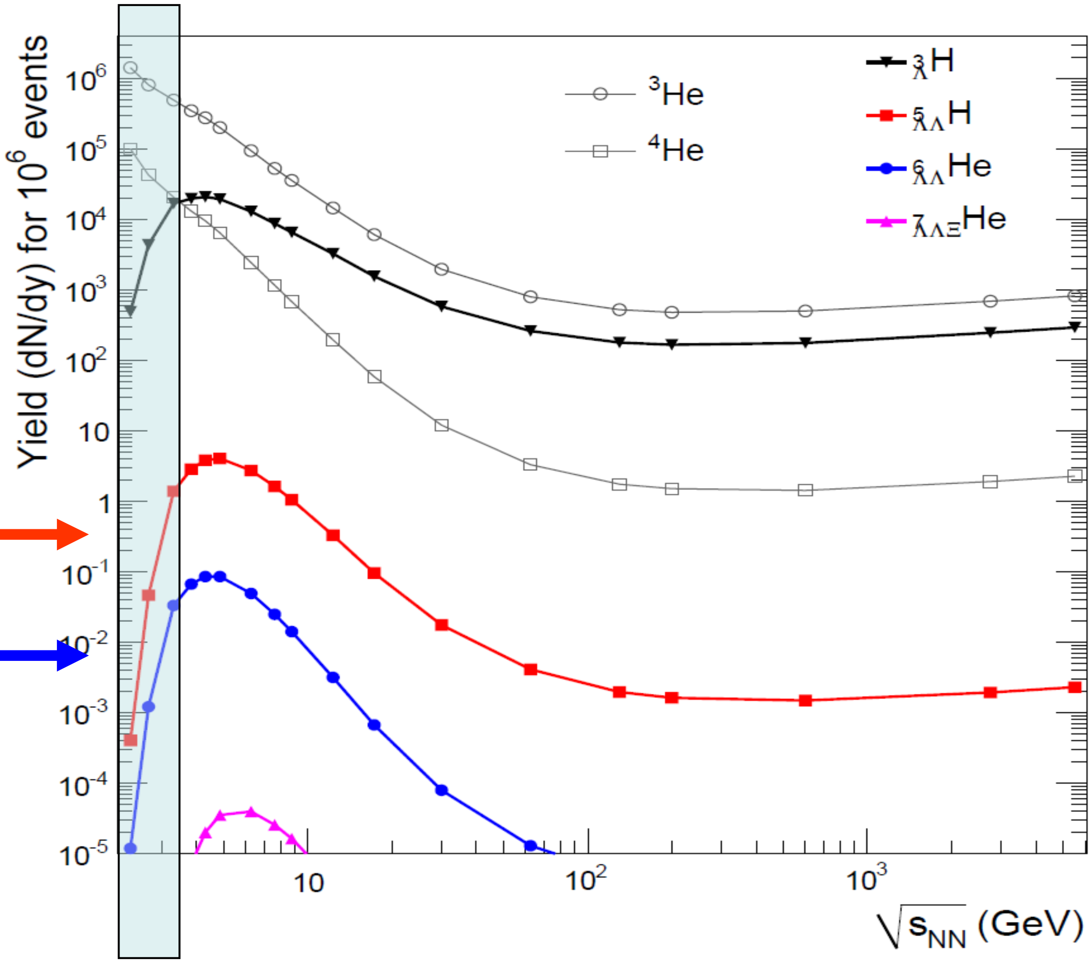




Yield of (multi-s) hypernuclei in A+A collisions

Thermal model:

A. Andronic, P. Braun-Munzinger, J. Stachel, H. Stöcker, arXiv:1010.2995v1 [nucl-th]

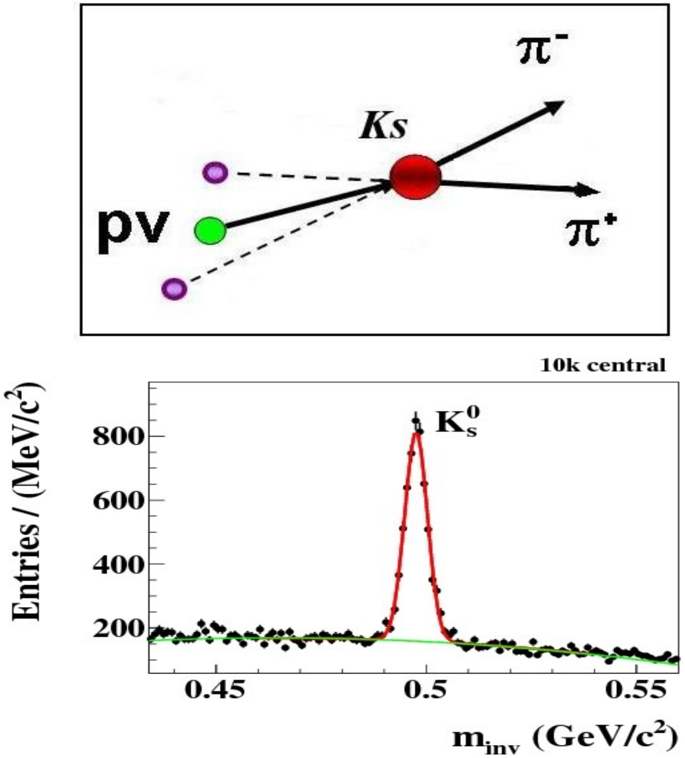


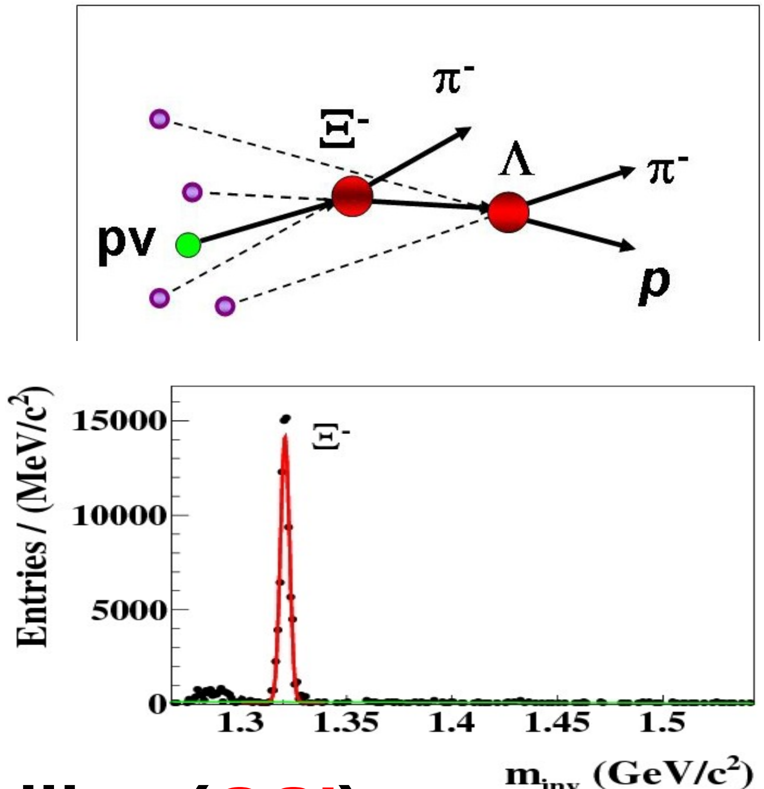
Yield of $_{\Lambda\Lambda}{}^5H \approx 10^{-6}$

Yield of $_{\Lambda\Lambda}{}^6He \approx 4 \cdot 10^{-8}$

Nuclotron ($\sqrt{s_{NN}}$ = 3.3 GeV)

Feasibility studies for large aperture setup layout at 4 GeV

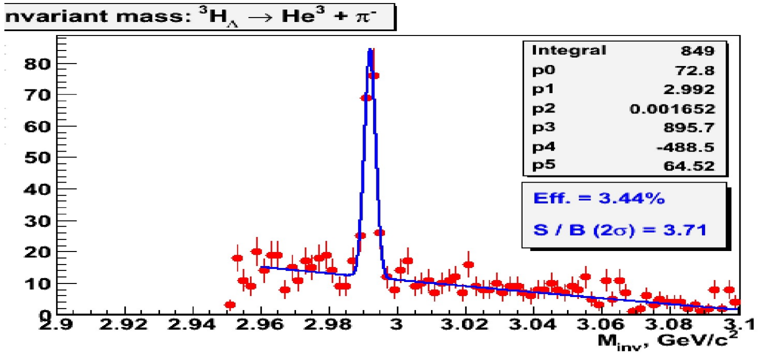


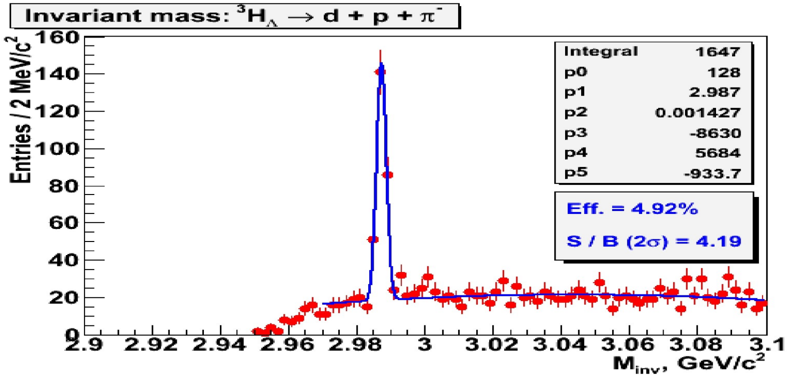


Simulation – I.Vassiliev (GSI)

Hypernuclei production for large aperture layout at 4GeV

$^{3}H_{\Lambda}$ reconstruction in CBM (200k events)





Simulation – A.Zinchenko et al. (LHEP JINR)

Counting rate and beam time estimation

Hyperons production in Au+Au @ 4 GeV

Particle	E_{thr}NN GeV	M central	M m.bias	ε %	Yield/s m. bias	Yield/week m. bias
Ξ^-	3.7	$1\cdot10^{-1}$	$2.5\cdot10^{-2}$	3	75	$4.5\cdot10^{7}$
Ω^-	6.9	$2\cdot10^{-3}$	$5\cdot10^{-4}$	3	1.5	$9\cdot10^{5}$
Anti-Λ	7.1	$2\cdot10^{-4}$	$5\cdot10^{-5}$	15	0.15	$9\cdot10^{4}$
Ξ^+	9.0	$6\cdot10^{-5}$	$1.5\cdot10^{-5}$	3	$4.5\cdot10^{-2}$	$2.7\cdot10^{4}$
Ω^+	12.7	$1\cdot10^{-5}$	$2.5\cdot10^{-6}$	3	$7.5\cdot10^{-3}$	$4.5\cdot10^{3}$

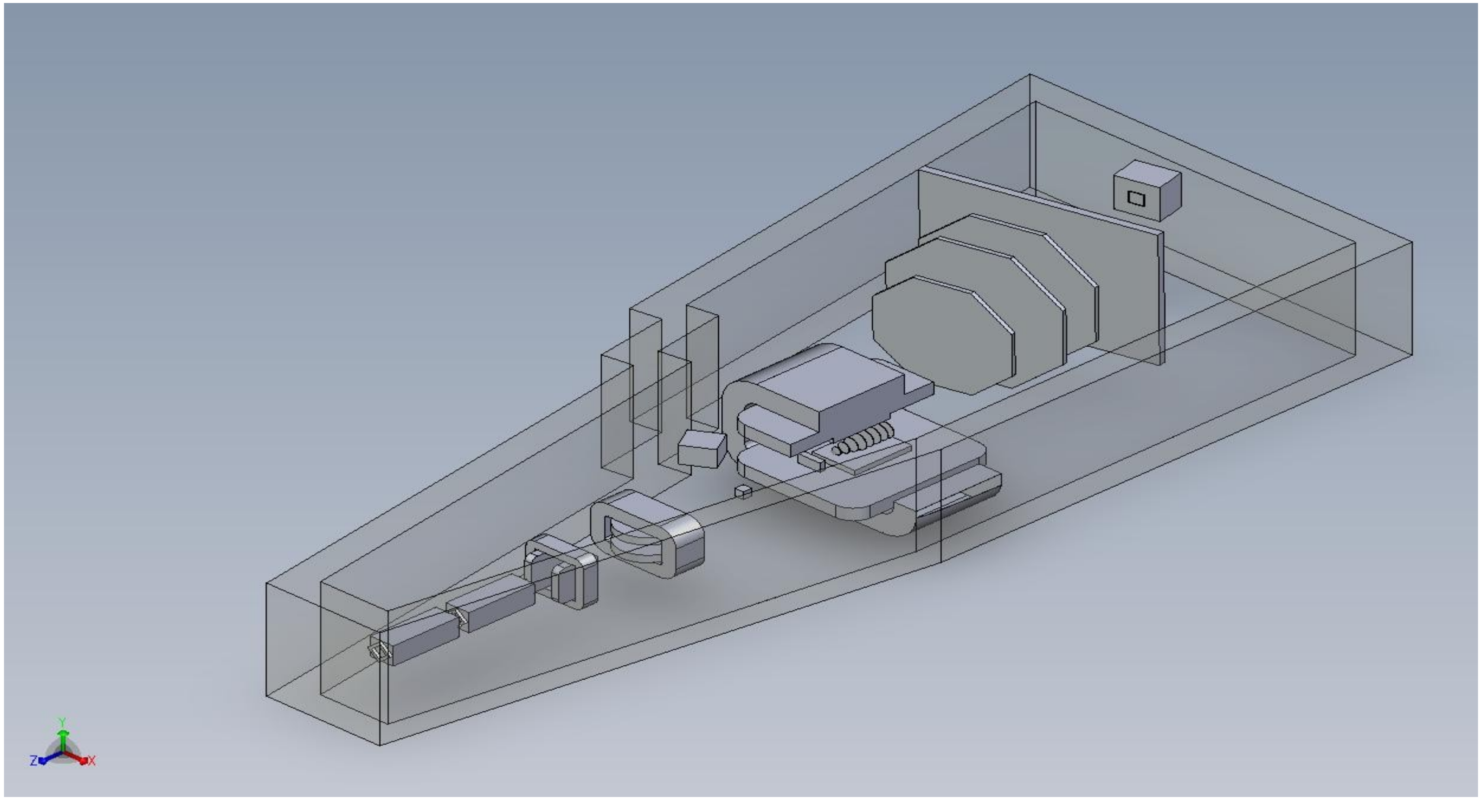
Hypernuclei production in Au+Au @ 4 GeV

Hyper nuclei	M central	ε %	Yield/s central	Yield/week central
$_{\Lambda}^{3}H$	$2\cdot10^{-2}$	8	16	10^{7}
$_{\Lambda\Lambda}^{5}H$	$1\cdot10^{-6}$	1	$1\cdot10^{-4}$	60
$_{\Lambda\Lambda}^{6}He$	$3\cdot10^{-8}$	1	$3\cdot10^{-6}$	1.8

0.1 MHz min.bias interactions

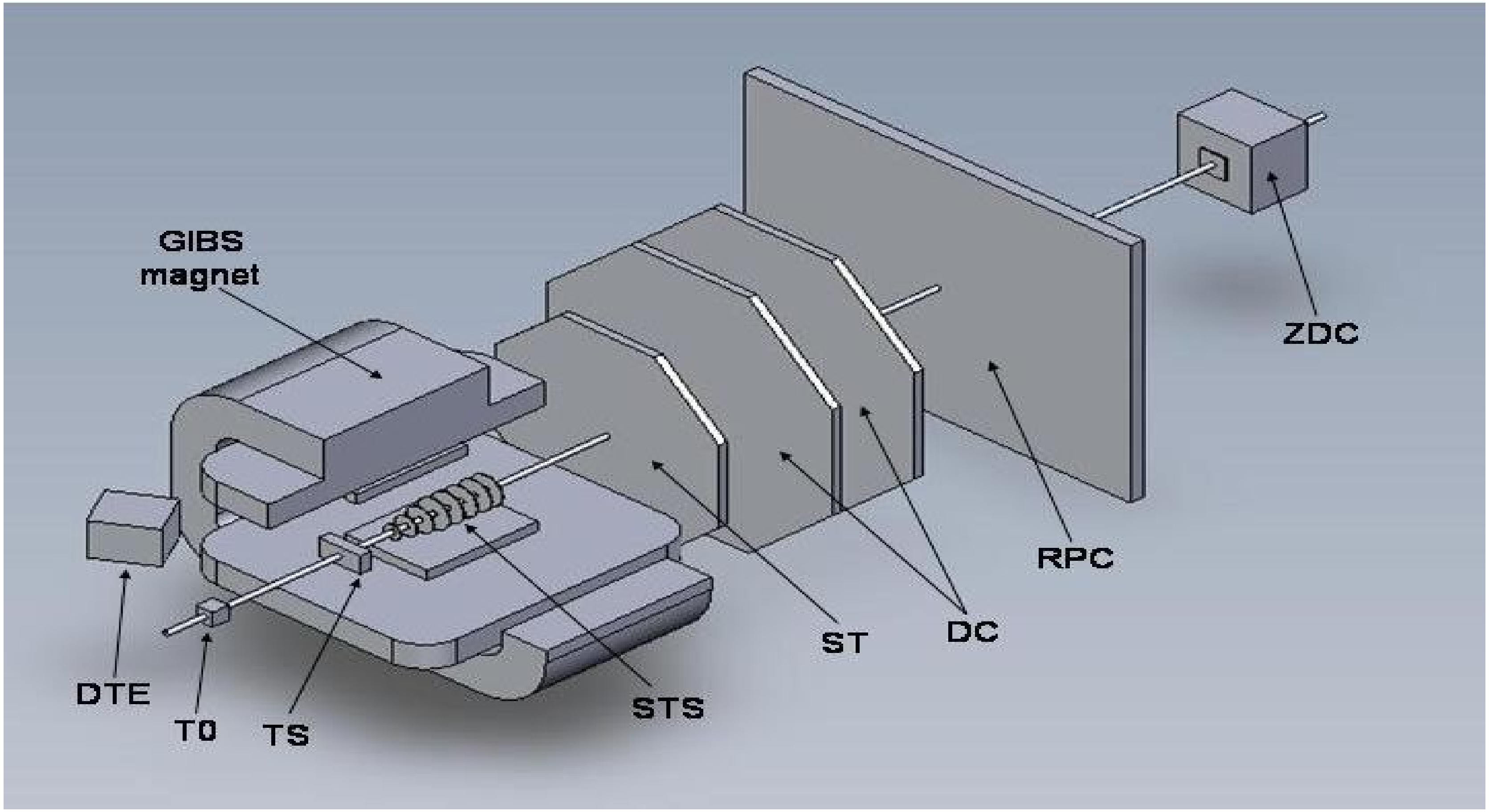
(beam is 10^7 Au/sec and thin - 1% Au target)

The detection system at the beamline 6V in the experimental hall 205

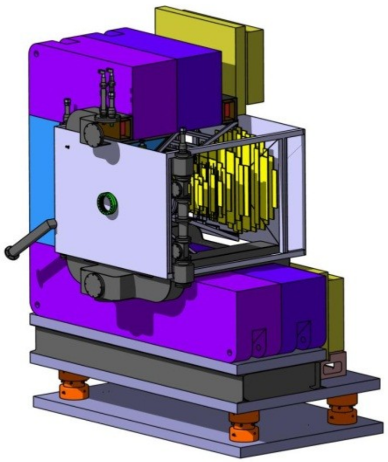


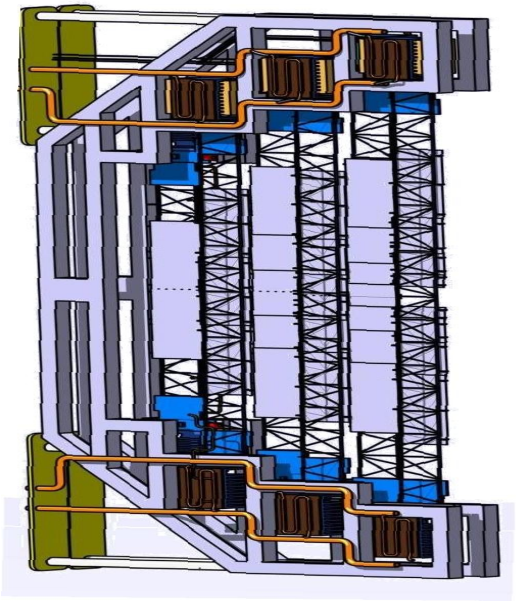
At the first stage of the experiment the existing magnetic optics: 2 lenses, 2 rotating magnets and large analyzing magnet of the 6V beamline will be used.

Large Acceptance Spectrometer with Tracker



Tracker (silicon or hybrid)



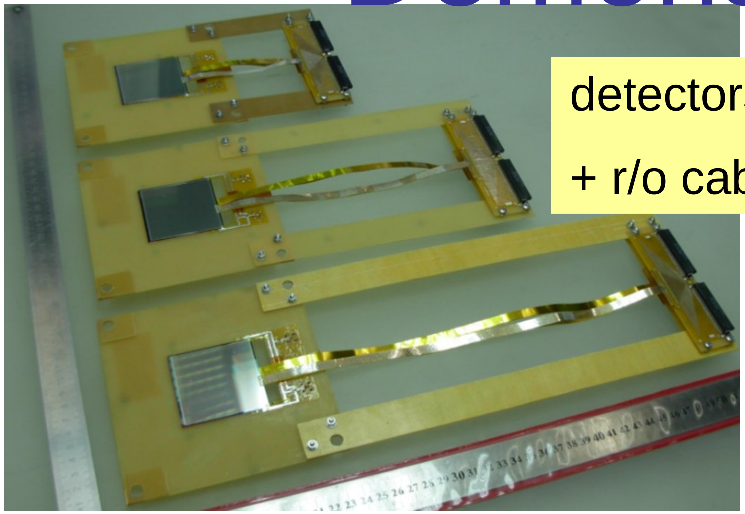


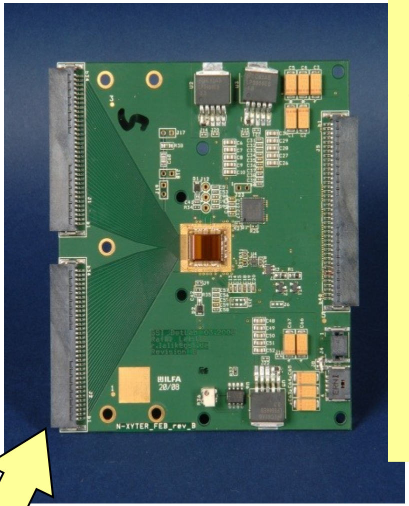
For Nuclotron experiment also **CBM GSI**

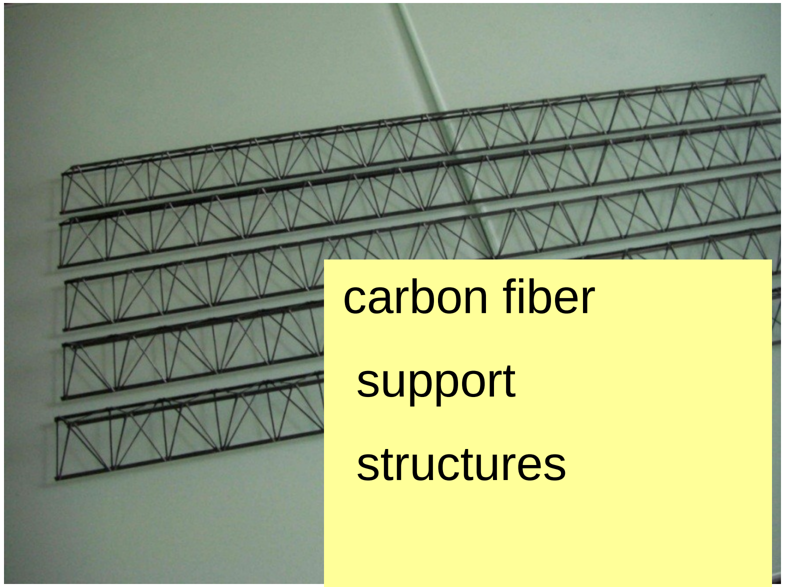
8 Stations (last 4 with smaller size) **MPD JINR**

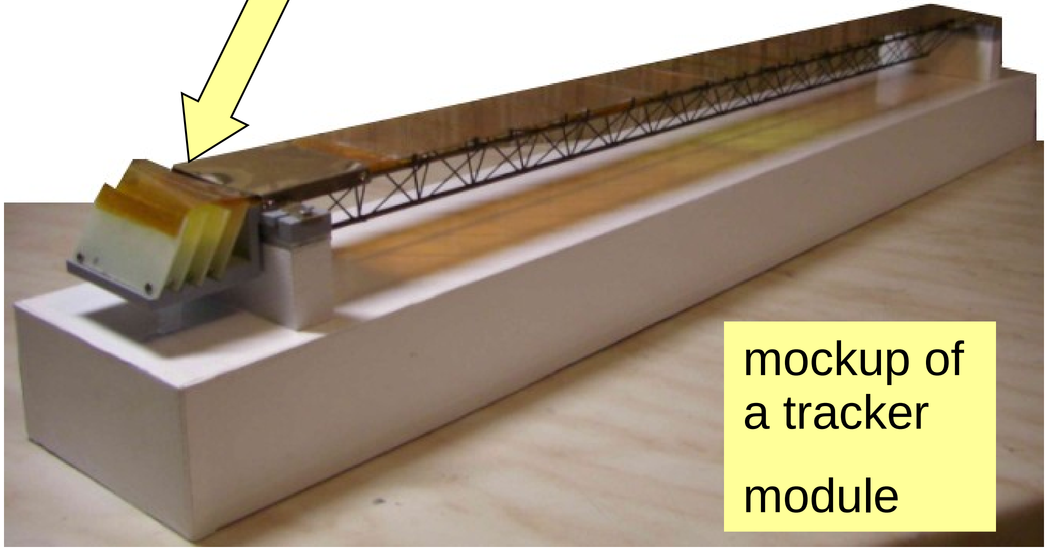
(last 4 - GEMs and straws)

Demonstrator module

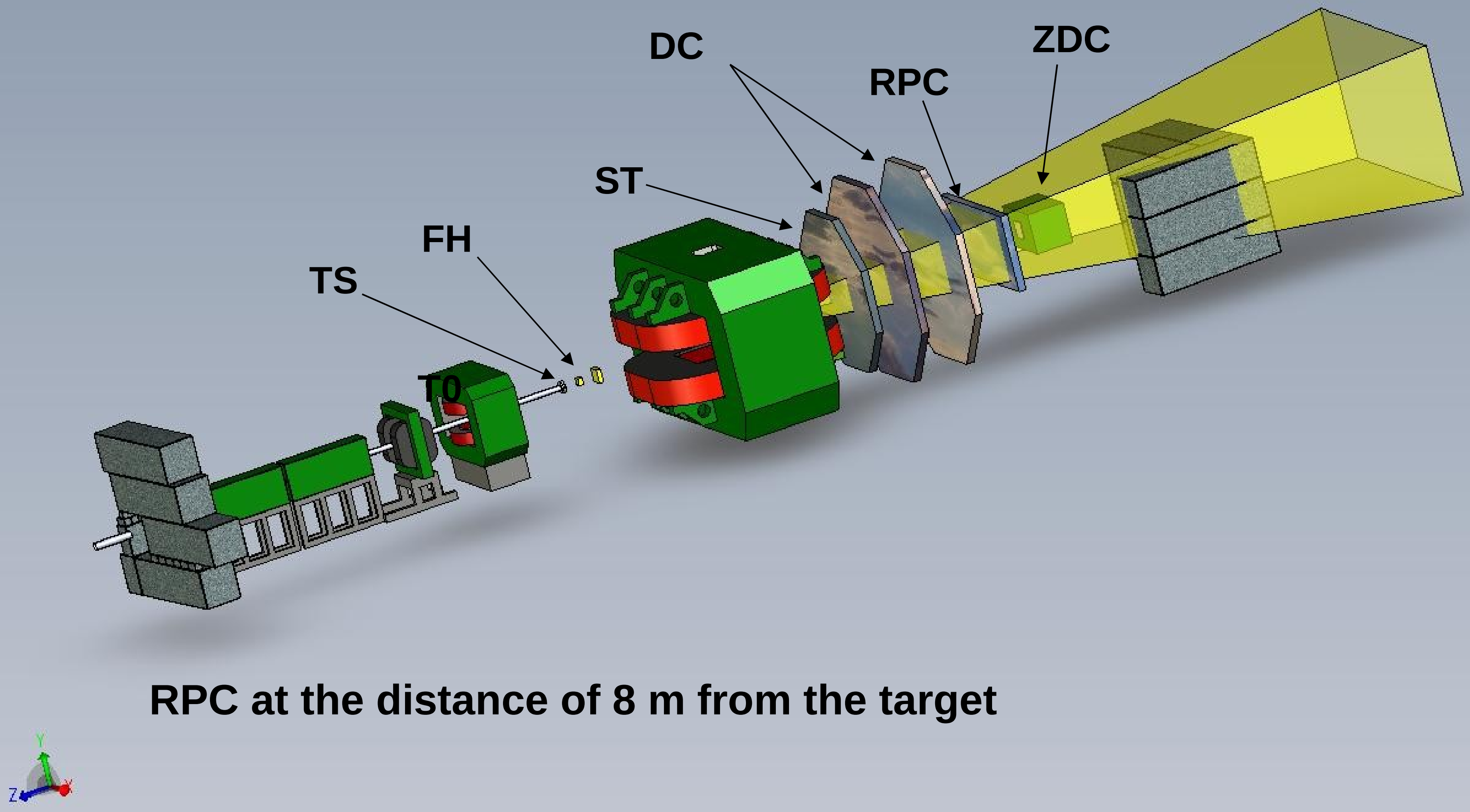






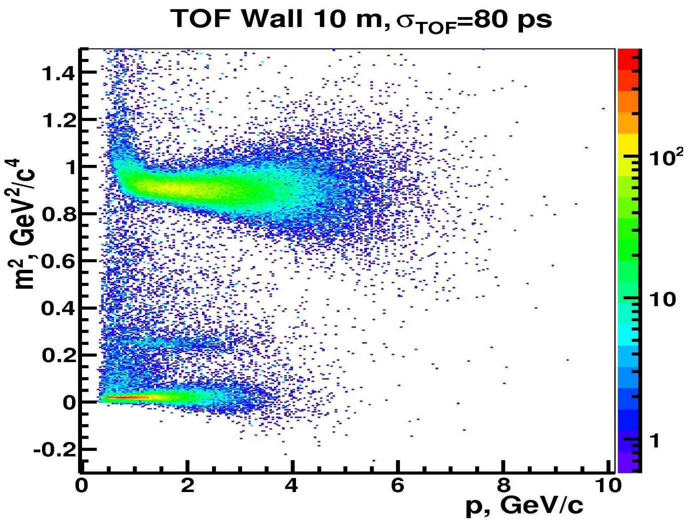


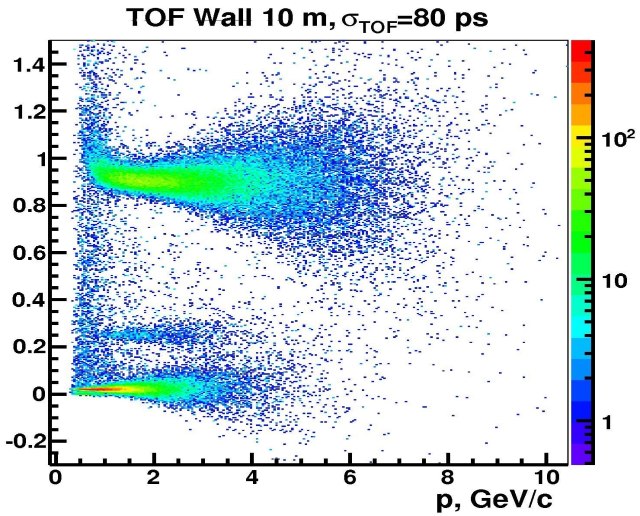
Stage 1 of BM@N setup



RPC at the distance of 8 m from the target

PID using TOF and momentum



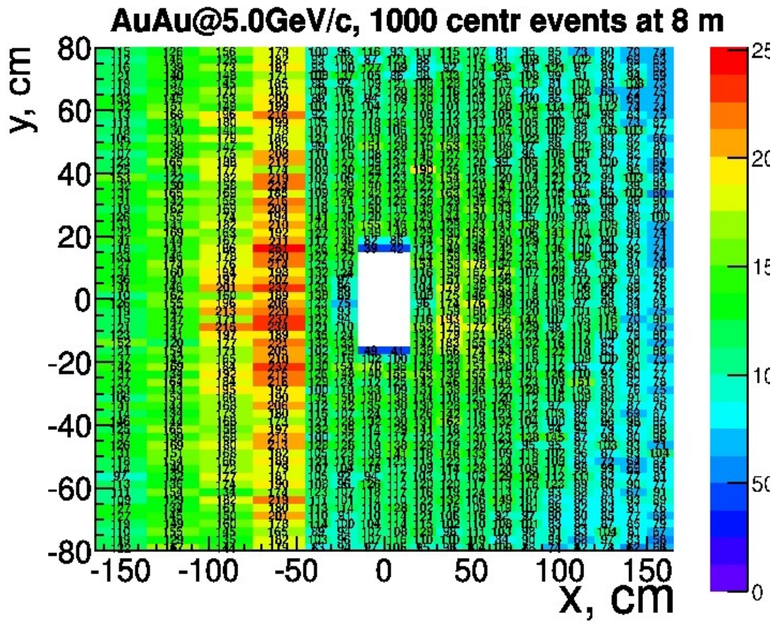


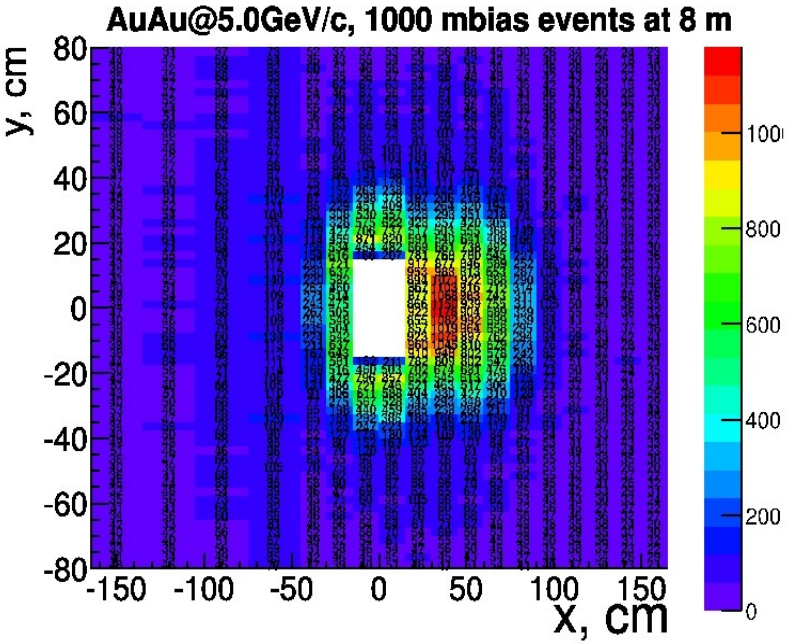
Au+Au @3.5 GeV **Cu+Cu @ 5 GeV**

TOF baseline of 10m and resolution 80 ps provides the good PID

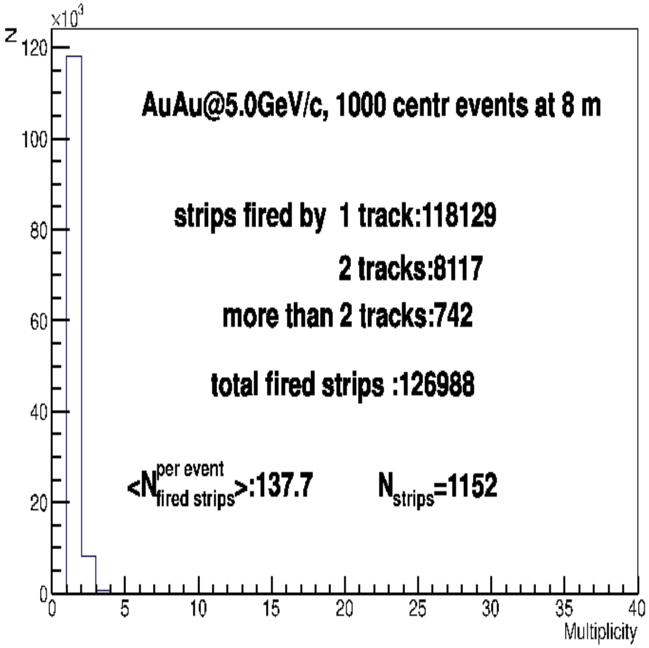
Simulation- T.Vasiliev (LHEP-JINR)

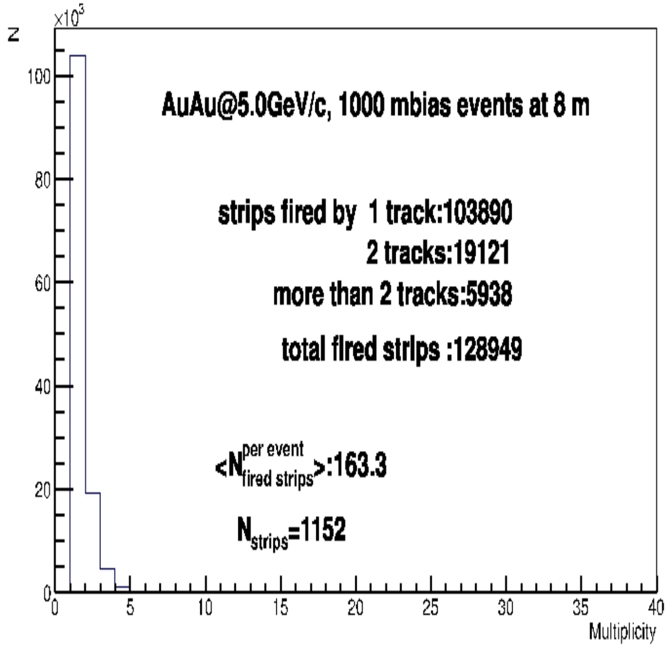
Simulation for TOF





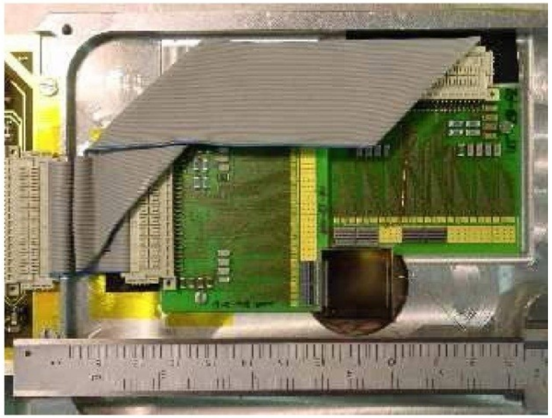
Simulation for TOF

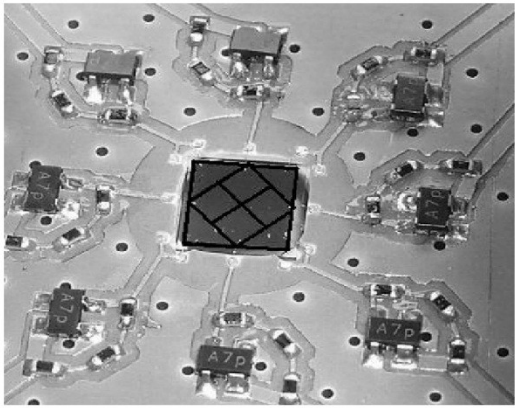




2 options: warm float glass mRPCs
outer part — float glass RPCs

T0 for TOF system

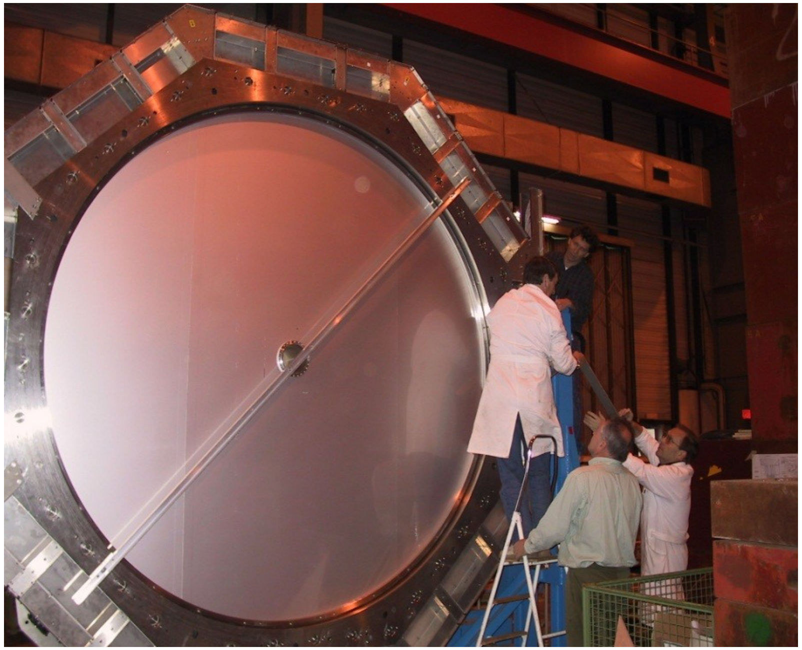


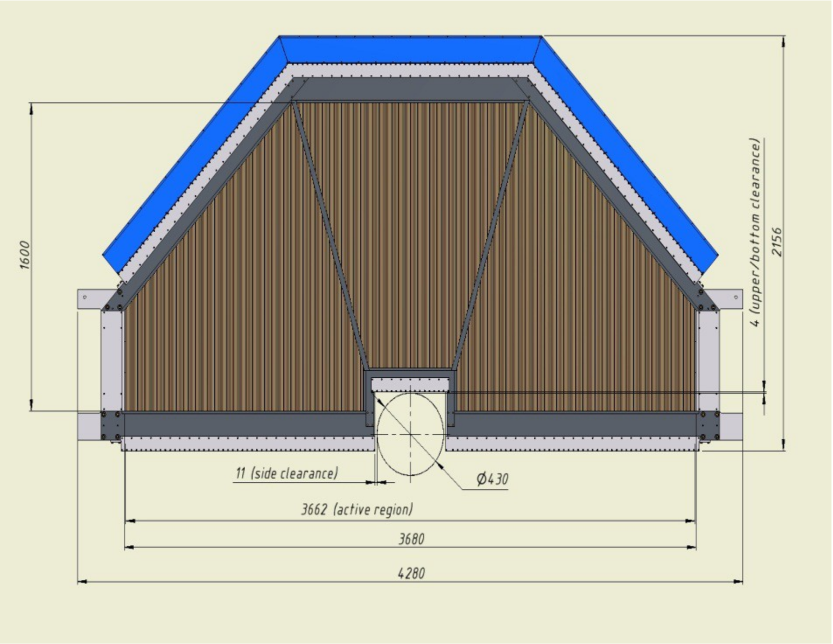


Diamond detector with good timing resolution

SciFi detectors for low intensity (and test) beam

Outer tracker (DC and ST)

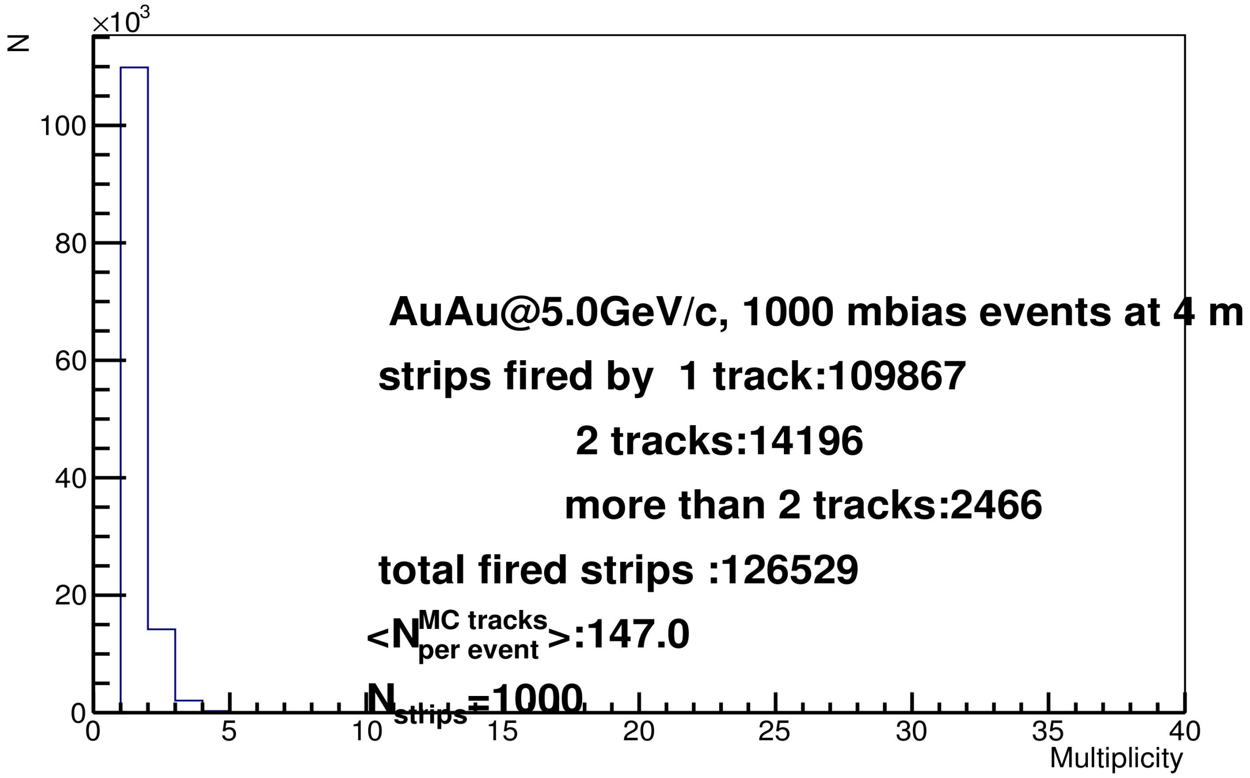




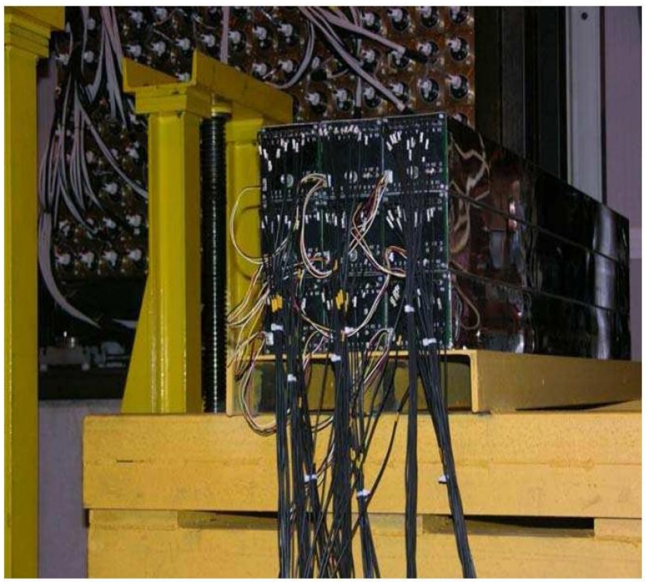
2 Drift Chambers
(NA48 JINR/CERN)

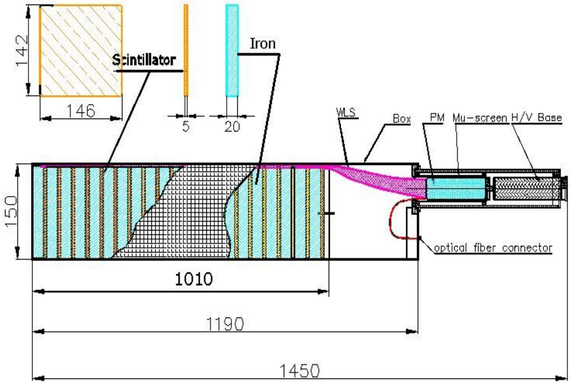
Straw Tubes Station
(CBM GSI, MPD JINR)

4mm straw detector at 4 m



Zero Degree Calorimeter

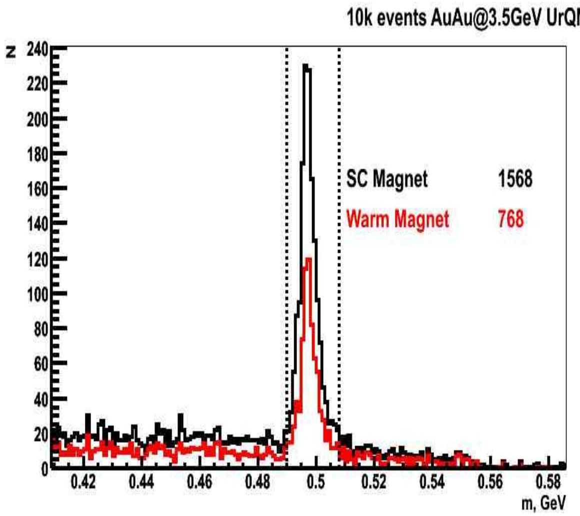


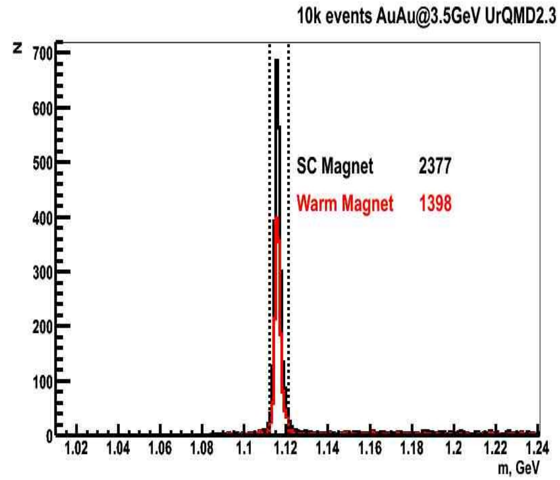


PSD-type (CBM/NA61 INR)

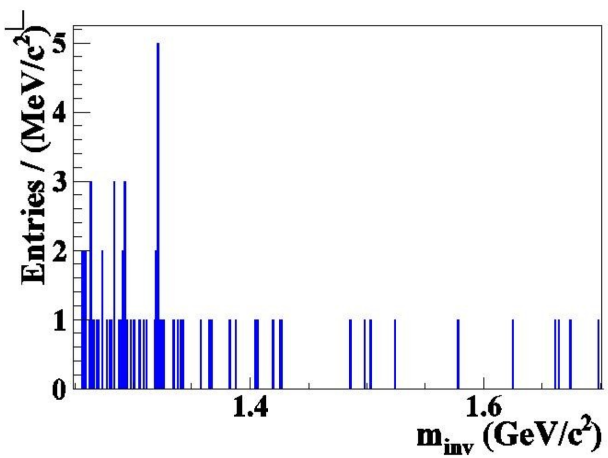
HCAL-type (COMPASS JINR/IHEP)

Feasibility studies for Nuclotron experiment (CBM SC magnet)

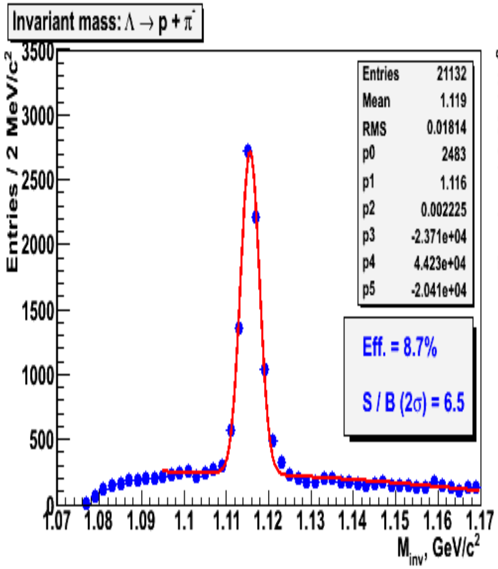


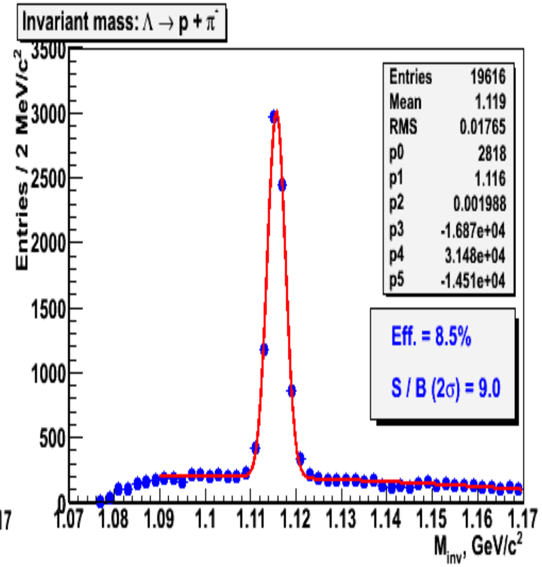


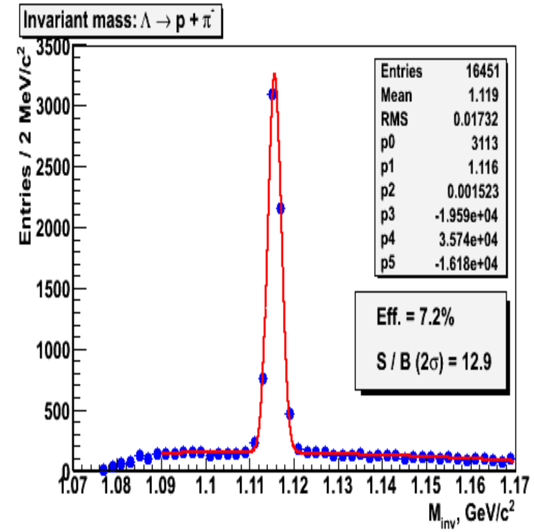
The detection efficiency 2 times less than for CBM (from simulation performed At JINR and GSI)



Simulation: B scale





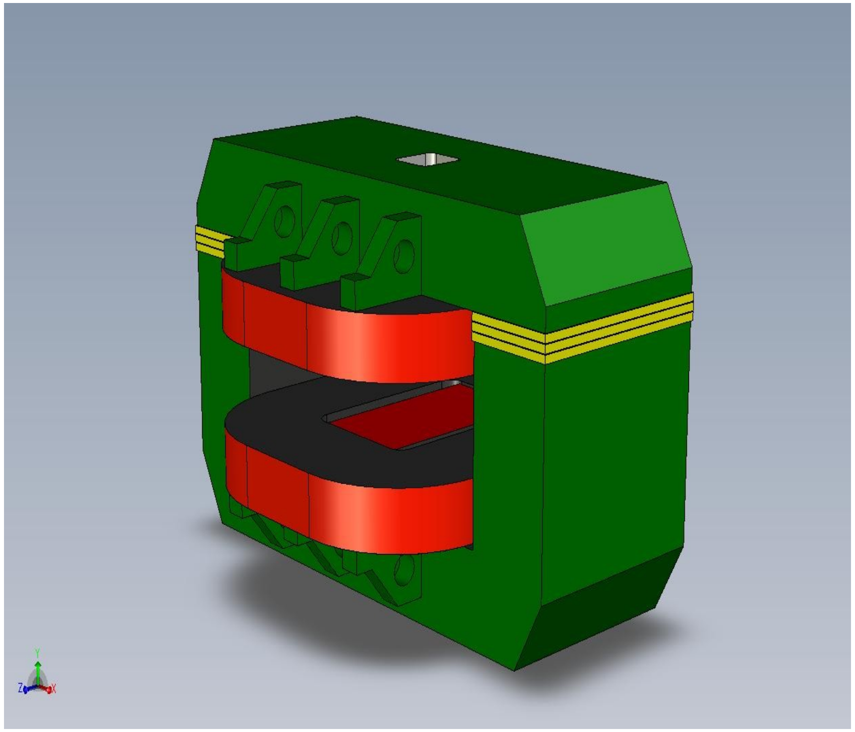


B= 0.5 0.67 1.0 B_{max}

Enlargement of the acceptance

Ω-hyperons reconstruction requires PID by TOF. It is neccessary to increase the acceptance.

Enlarge the distance between the poles of existing WM (upto 1m).



Further simulation is required!

Steps in 2011 (Phase0)

Site preparation

Magnetic elements of 6V beamline reparation

Technical Requirement for the site and the beam

Magnetic optics calculations

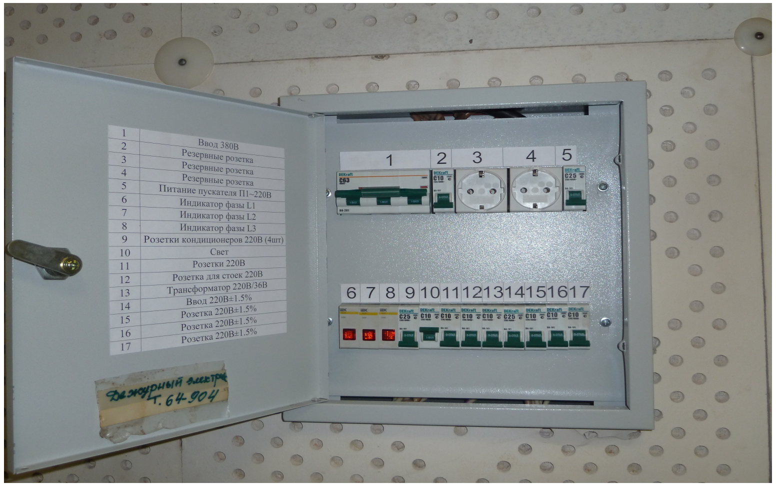
Simulation and setup optimization

Project preparation

Urgent expences (minimal R&D, PMTs etc.)

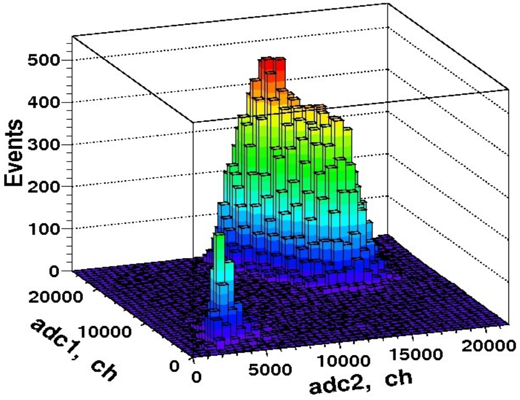
Test beam in the Dec. 2011 Nuclotron run

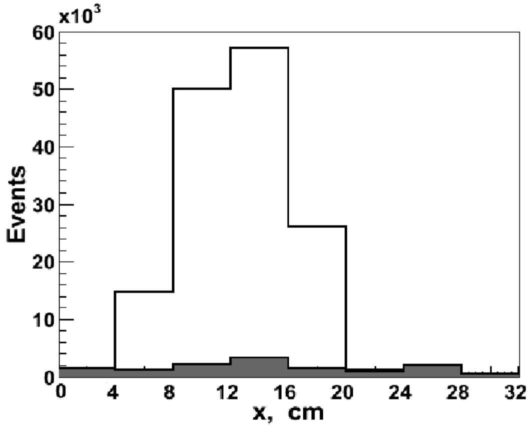
BM@N area in November 2011



Ready for testbeam with carbon at 6V beamline

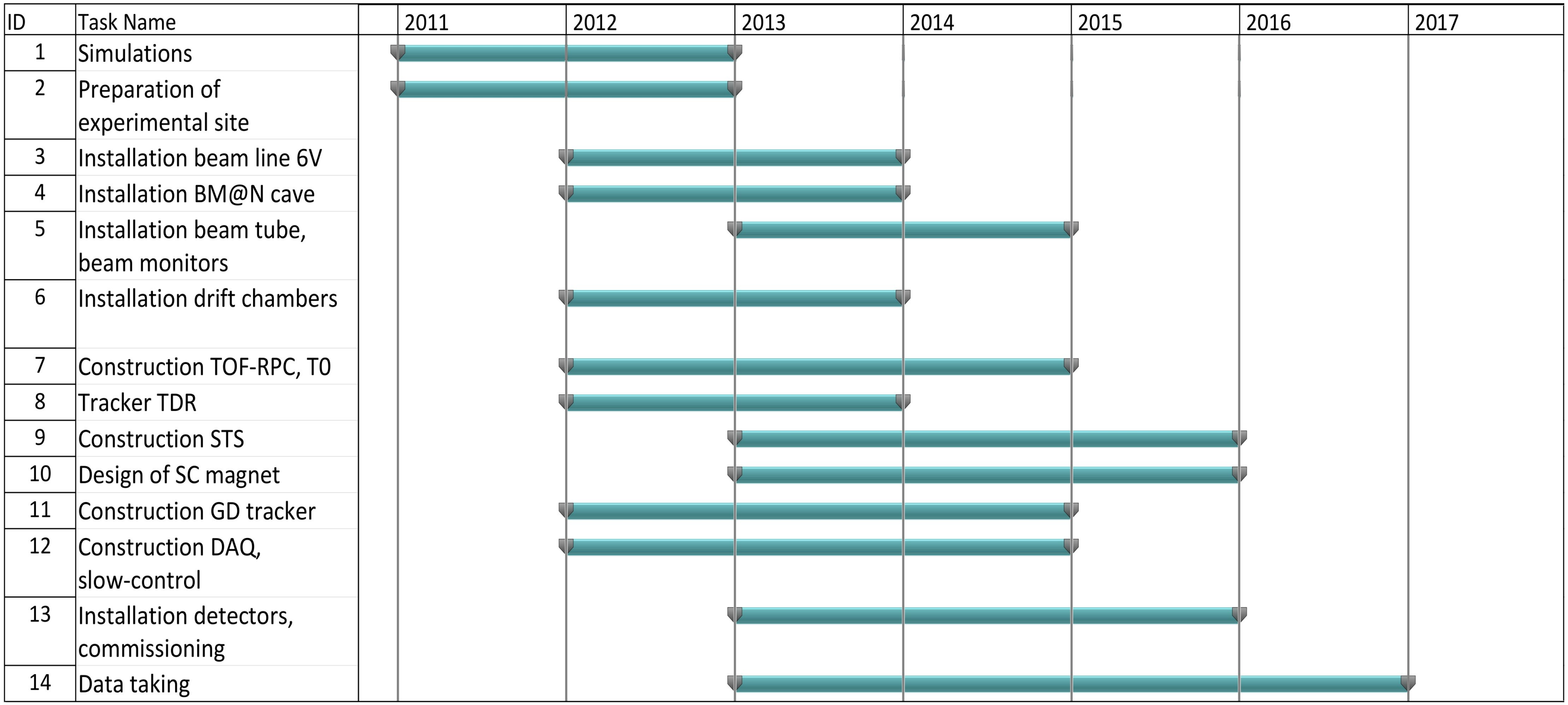
December 2011 carbon test beam results





The measurements at 3.42 A GeV at Nuclotron with carbon beam and the existing beamlines are feasible!

Time table of the experiment



Phase0 (2011) – The site preparation and simulation
Phase1 (2012-2014)–The detector construction and commissioning
Phase2 (2015-.....) - The data taking at 3.5, 4.0 and 4.65 A GeV

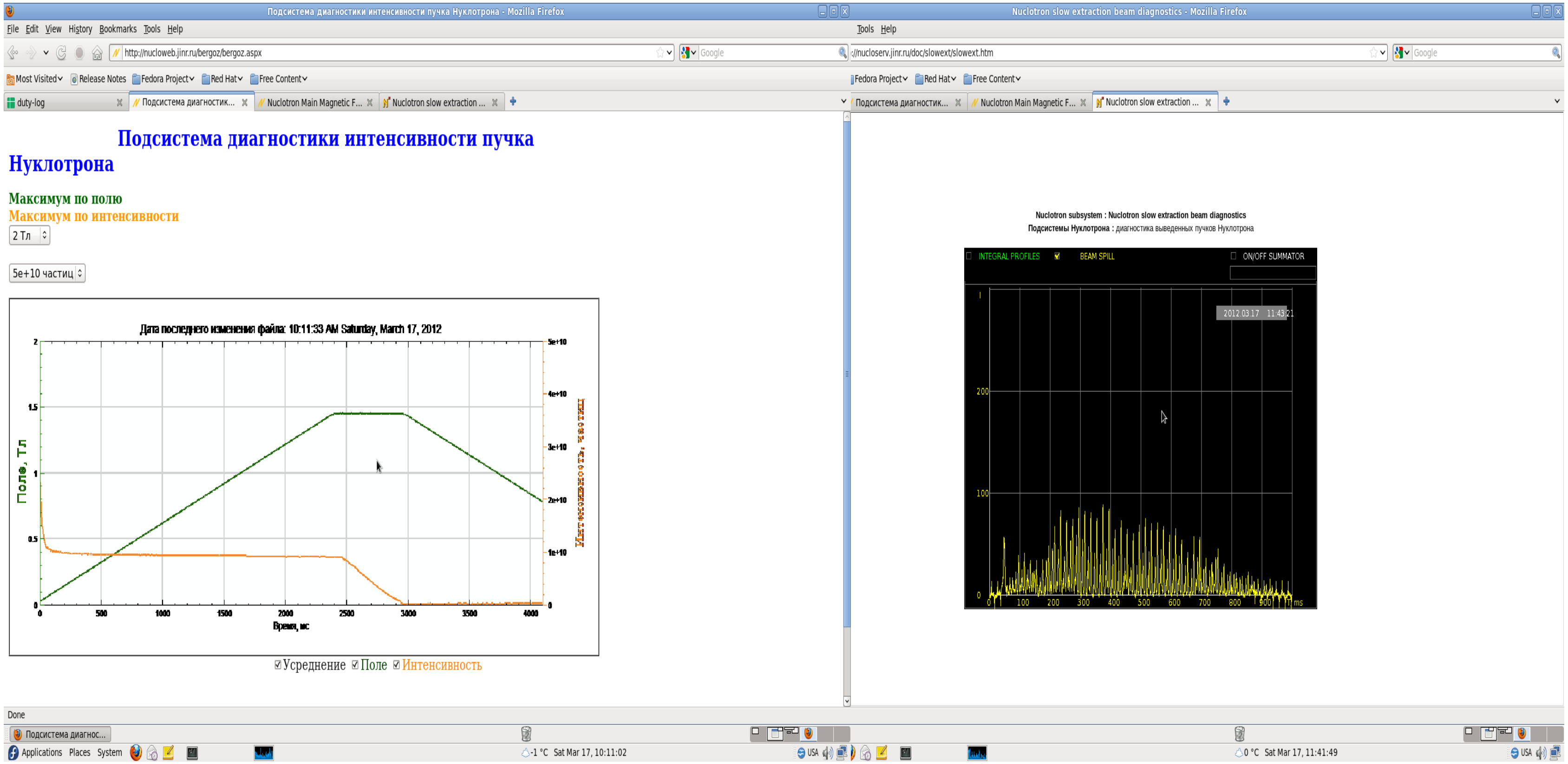
Status of the experiment in 2012

1. The experiment is approved by JINR PAC for 2012 with the first priority for the comprehensive TDR preparation
2. Money for infrastructure and prototypes for 2012 are supplied from JINR budget in full volume

We are forming now the working groups
(InfraStructure, FEE-DAQ, Tracking, Magnet, Centrality Detectors, Silicon Tracker, TOF .....)

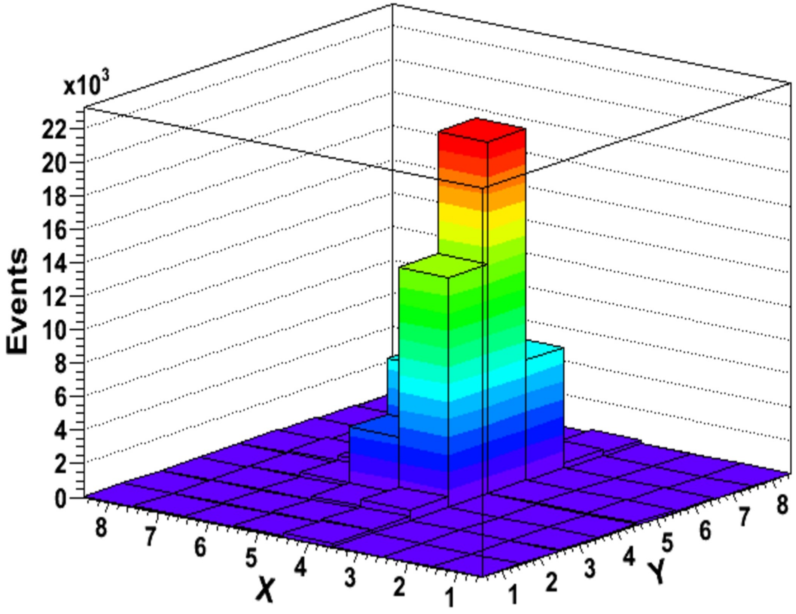
Physics - 31 July 2012
Detectors – 1 August 2012

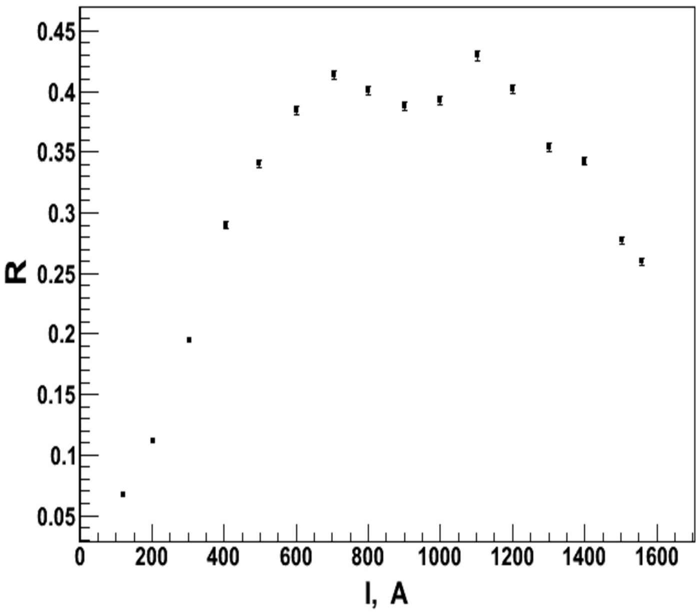
March 2012 deuteron test beam at 4 GeV



Needs to increase the ramp velocity to 6kGs/s and duration of the flattop in order to have duty factor 0.5

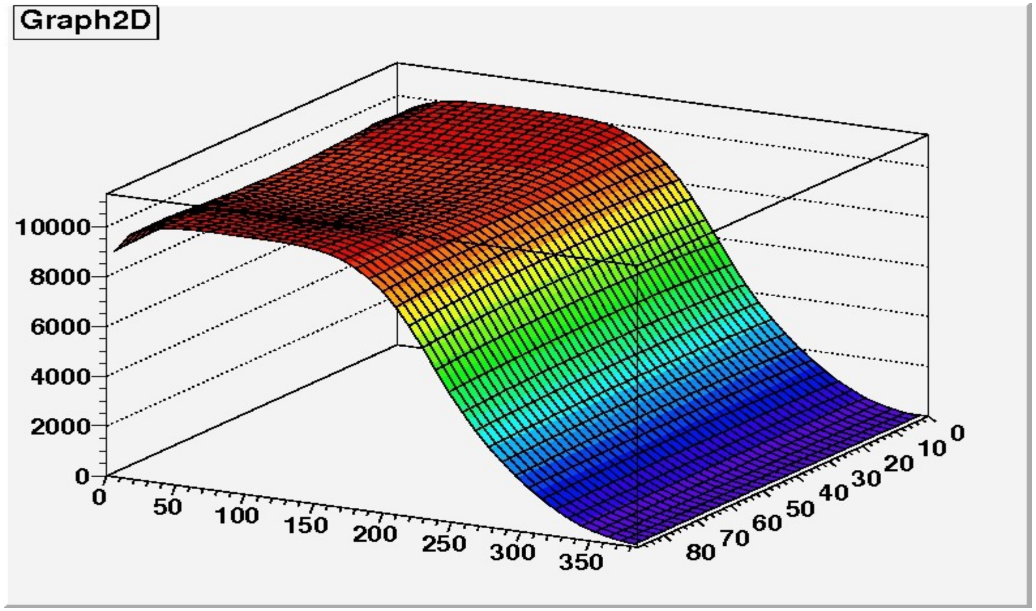
17 March 2012 deuteron test beam results





1. The measurements at 3.5 and 4.0 A GeV at Nuclotron with the existing beamlines are feasible.
2. Test beam (protons and deuterons) can be provided in the energy range 1-4 GeV/nucleon.

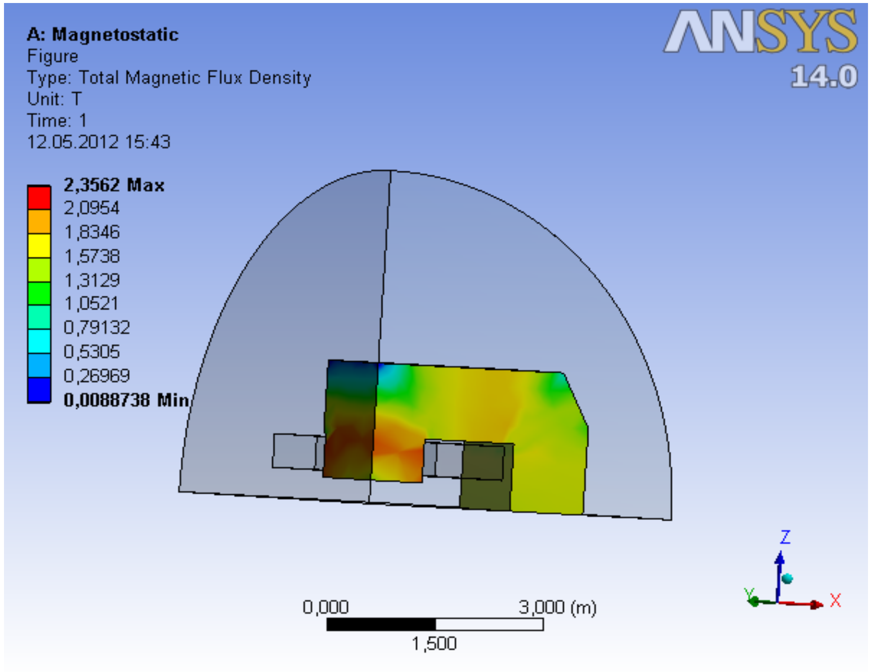
Analyzing magnet SP-41 (warm)

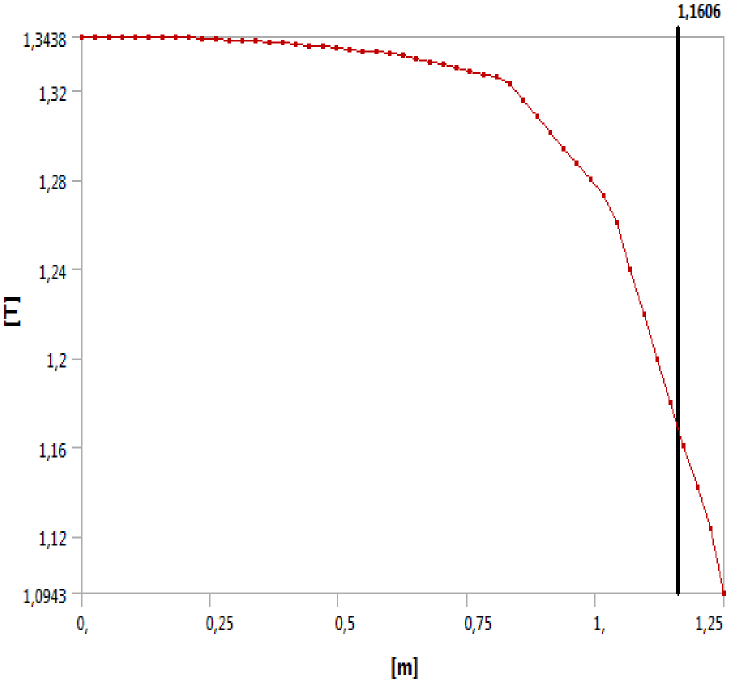


The field integral is 2 T·m at the max. current (1900 A)
In March 2012 run the current up to 1570 A was used.

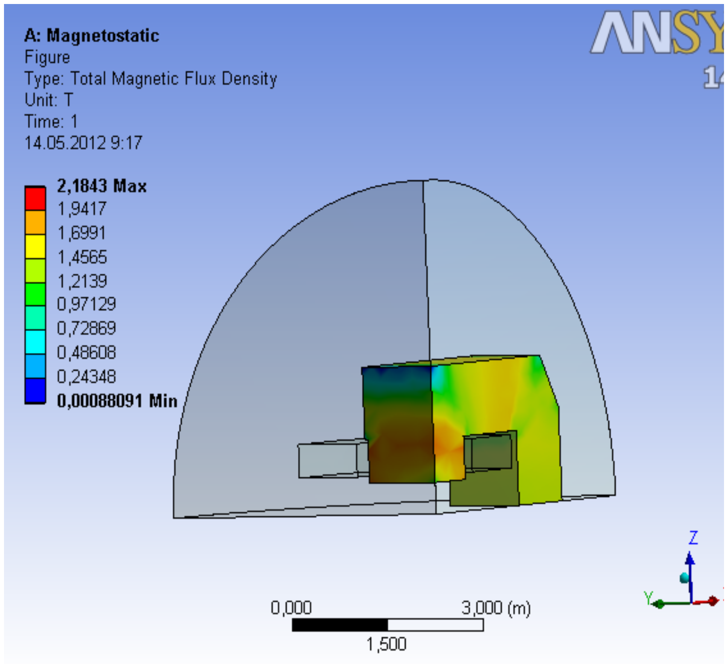
This will allow to perform the measurements up to 4.65 A GeV (maximal energy of Au-beam)

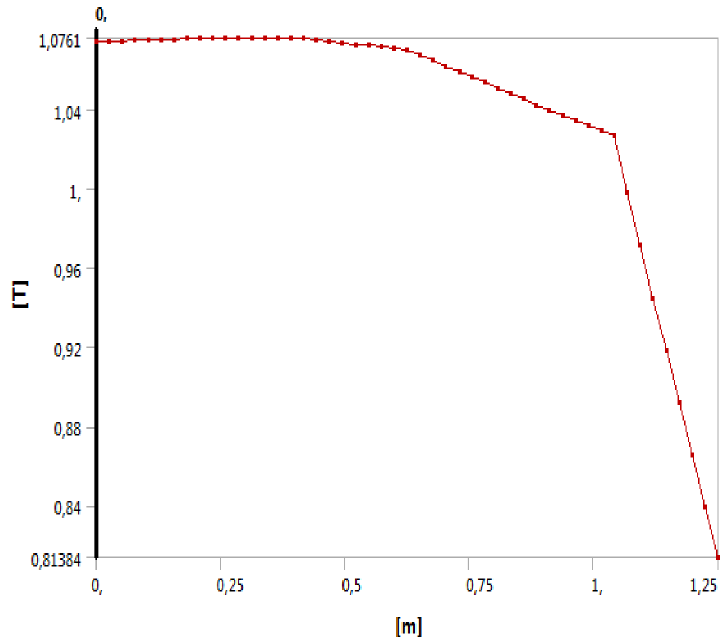
Existing Magnet





Enlarged Magnet (+24 cm)





Field integral is 25% less
(1 cm = 1%)

Further steps in 2012

1. Test beam in February-March with 3.5-4.0 A GeV deuterons (done).

2. Working groups, definition of the minimal configuration for the experiment.

3. Infrastructure for the experiment and detectors manufacture.

4. Test beam in November 2012 – reading of several different detectors.
   Due magnet problem – cosmic run?

2012-2013

1. End of 2012 – LoI, CDR, TDR for the start version

2. End of 2013 – TDR (STS+ GD-tracker)

3. Hopefully, end 2013 - first stage of the setup (magnetic spectrometer option and test beam area) will be ready.

4. 2012-2013 – agreements, fundings.

Life after 2016

Assuming that there will be a life after 21.12.2012,
the following question arises:
If there will a room for BM@N during
CBM&HADES at SIS100 and MPD at NICA ?

Answer: Yes, but we have to find the unique branch

Options: large aperture, fine electromagnetic calorimetry,
wide scientific program (including spin effects)

Strong theoretical support is required!

Conclusions

- High discovery potential,
 new insight of the problem
- Frontier for the large scale
 experiments (CBM, MPD,
 SPD etc.)
- New detector technologies
 for JINR home experiments

- Inevitable step in the collider experiments
 (MPD and SPD) realization
- Young JINR scientists perspectives

Backup slides

JINR budget request

Form №29

Estimate of the JINR budget expences for the project: **Study of the strange matter production in the heavy ion collisions at Nuclotron (BM@N project).**

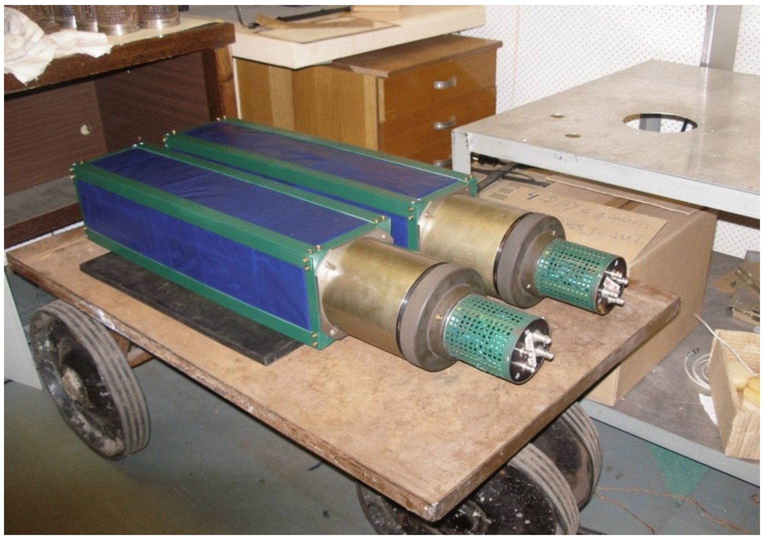
№	Title of the expences	Total cost , k$	1 year	2 year	3 year	4 year	5 year
	Direct expences	3300	700	900	700	500	500
1.	Accelerator Nuclotron (hours)	2500	100	300	500	500	600
2.	Computing						
3.	Computer network						
4.	Design office (n.hours)	5000	1500	1300	1000	500	500
5.	Model shop (n.hours))	5500	1200	1200	1200	1000	900
6.	Matherials	1100	250	300	230	160	160
7.	Equipment	1400	300	440	310	180	170
8.	Payment of SEW, made on the agreements	500	100	100	100	100	100
9.	Travel expences, including	300	50	60	60	60	70
	a) countries of the non-rouble zone	250	40	50	50	50	60
	b) rouble zone	50	10	10	10	10	10
	c) travels on the contracts						

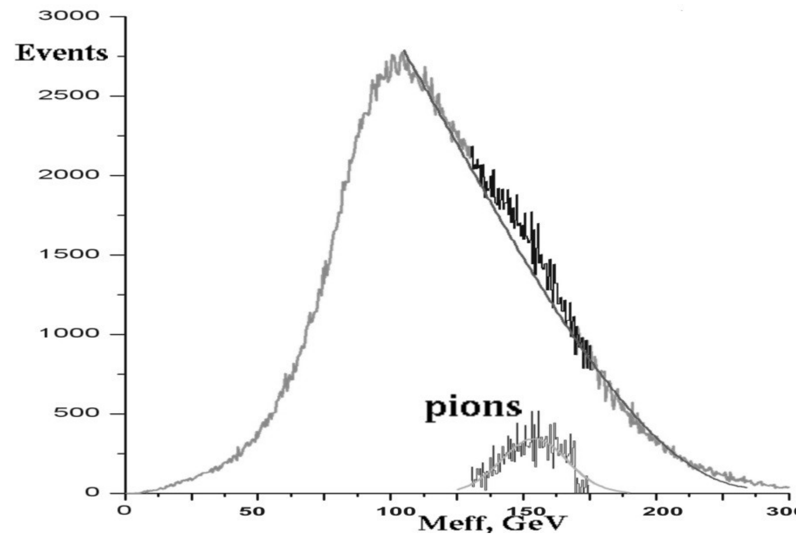
Project leader Ladygin V.P.

LHEP Director Kekelidze V.D.

Leading economist of LHEP Volkova G.G.

Detector of Transverse Energy





(INR/JINR)

DTE is 30 blocks of 15x15 cm^2 and 14 X_0 scintillating glass SGS1 (from PINOT spectrometer).

Test beam with 2 blocks at ITS at Nuclotron

Total request

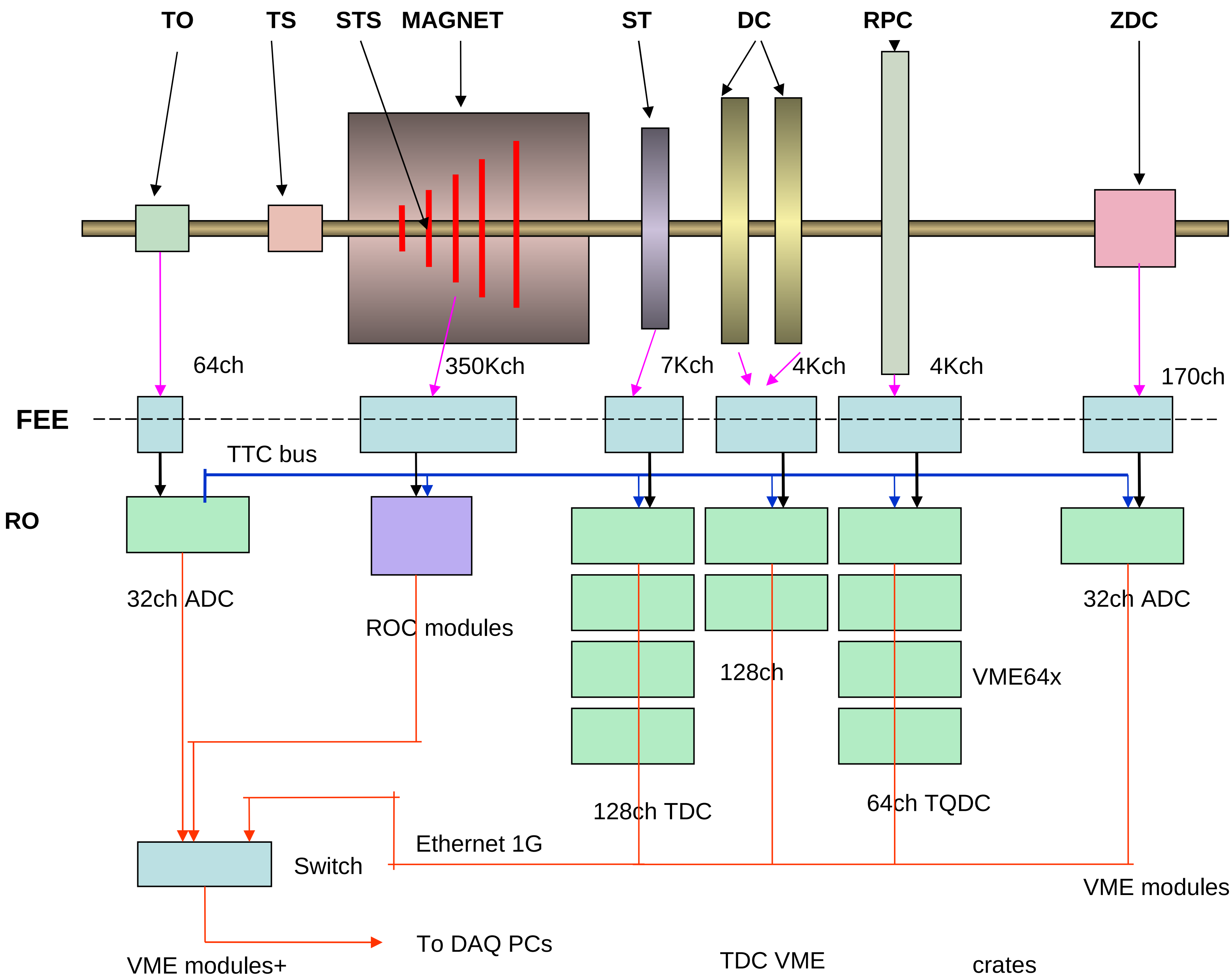
Form № 26

Suggested time-table and wherewithal for realization of project:

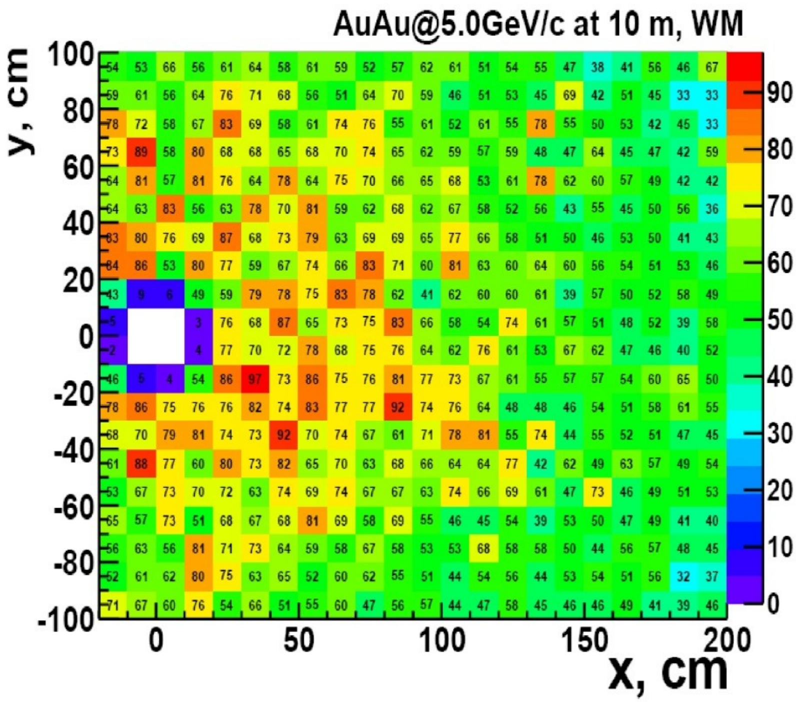
Study of the strange matter production in the heavy ion collisions at Nuclotron (BM@N project).

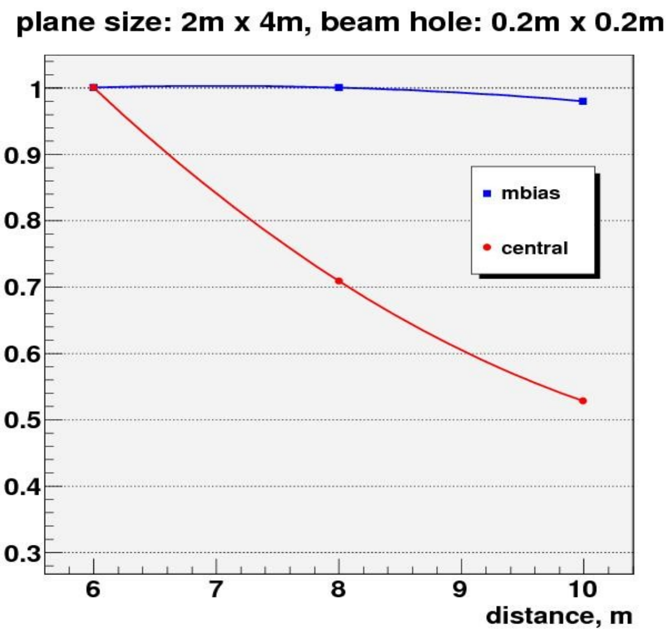
Name of components and systems of plants, resources, funding sources			Cost of components (k$) of plant. Resources requirements	Proposals of laboratories on financing and resources				
				1 y.	2 y.	3 y.	4 y.	5 y.
equipment and matherials		Detectors	4500	300	500	2000	1200	500
		Registration electronics	3500	300	500	1500	1100	100
		Prototypes	500	100	150	150	50	50
		Infrastructure	1200	100	300	400	200	200
		DAQ/ELES	500	50	50	150	200	50
Other resources	Hours	JINR model shop						
		Design office	5000 hours	1500	1500	1000	500	500
		LHEP model shop	5500 hours	1200	1200	1200	1000	900
	Hous	Accelerator Nuclotron Reactor Computing	2500 hours	100	300	500	500	600
		Operating costs						
Sources and fundings	Budget	Budget cost including	3300	700	900	700	500	500
		currency amount	300	50	60	60	60	70
	Out budget	Collaboration holding	500	100	100	100	100	100
		Grants						
		Sponsors Contracts						
		Other sources	6700	100	560	3460	2210	370

PROJECT LEADER Ladygin V.P.

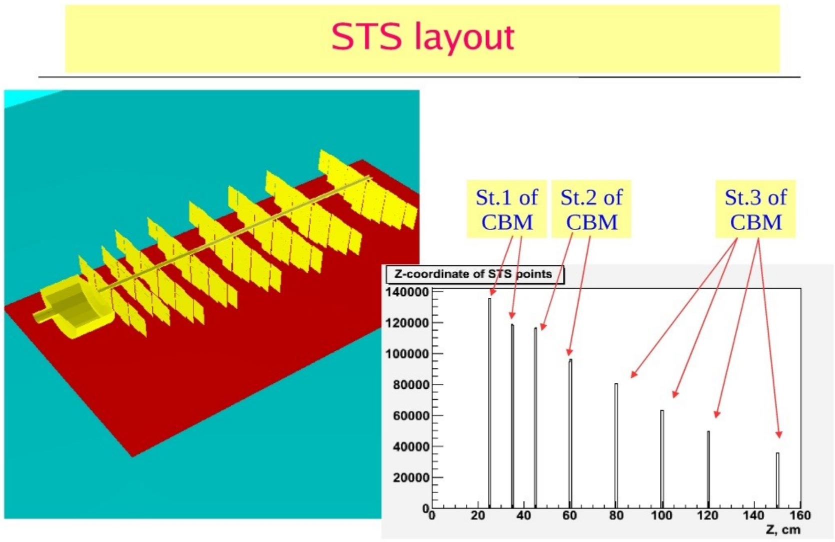

TO
TS
STS
MAGNET
ST
DC
RPC
ZDC
64ch
350Kch
7Kch
4Kch
4Kch
170ch
FEE
TTC bus
RO
32ch ADC
ROC modules
128ch
VME64x
32ch ADC
128ch TDC
64ch TQDC
Ethernet 1G
Switch
VME modules
To DAQ PCs
VME modules+
TDC VME
crates

TOF acceptance



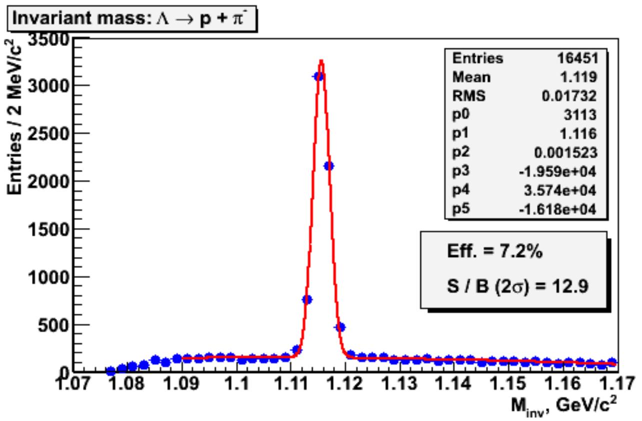


Feasibility studies with existing warm magnet



3 times less efficiency

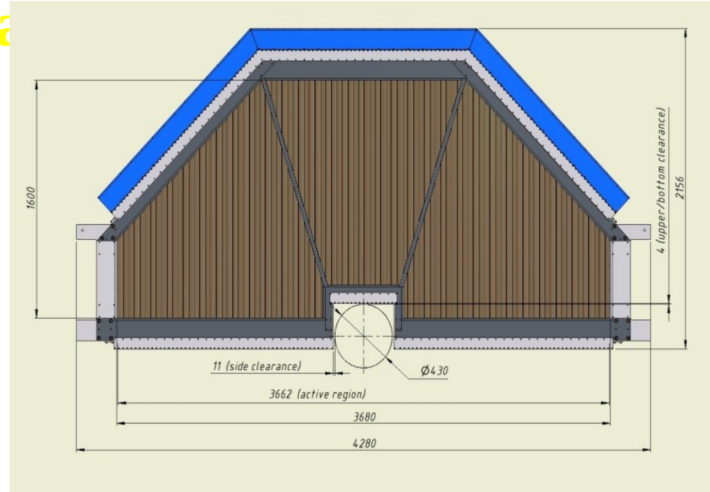
After minor optimization- good agreement with previous simulations.



A.Zinchenko (LHEP JINR)

Further optimization is required!

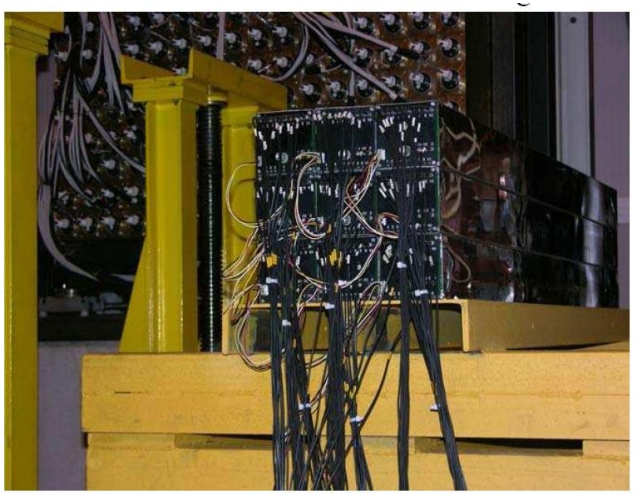
Main subdetectors (tracking, particle ID & centrality
ea

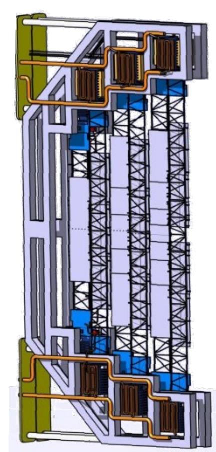


(CBM

Outer Tracker: NA48 drift chambers

RPC TOF

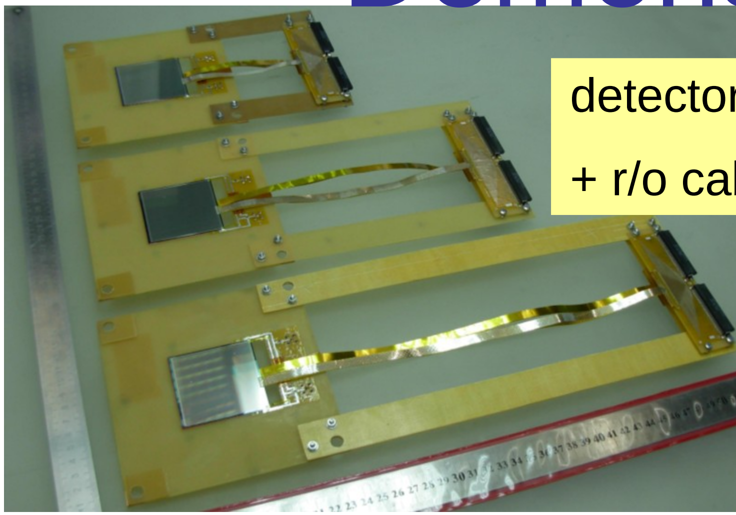




Silicon Tracker System (CBM-GSI)

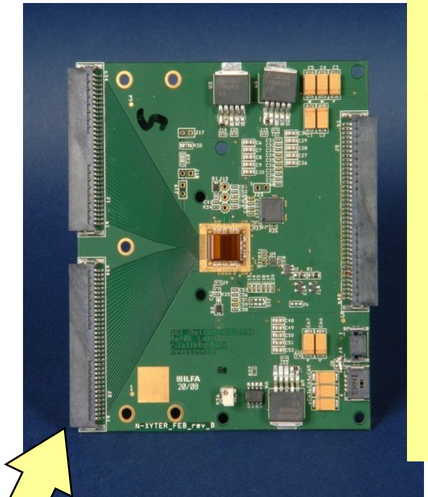
CBM/ INR

Demonstrator module

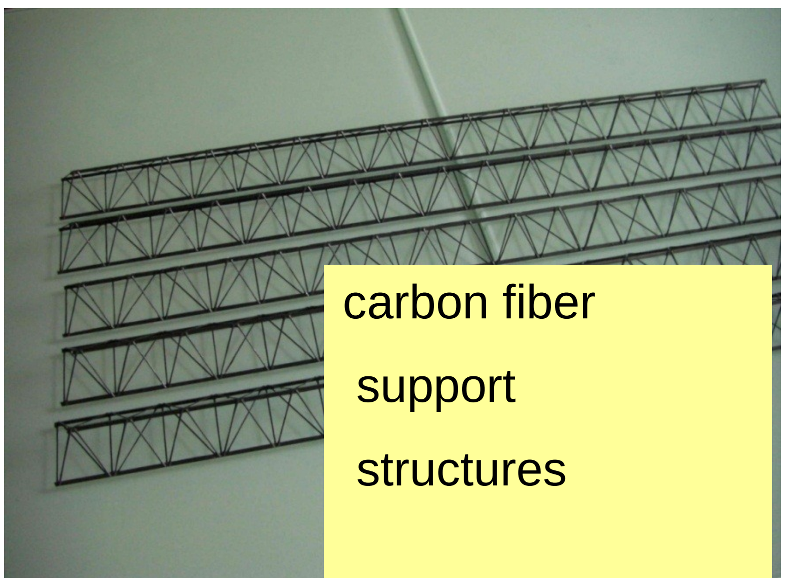


detectors

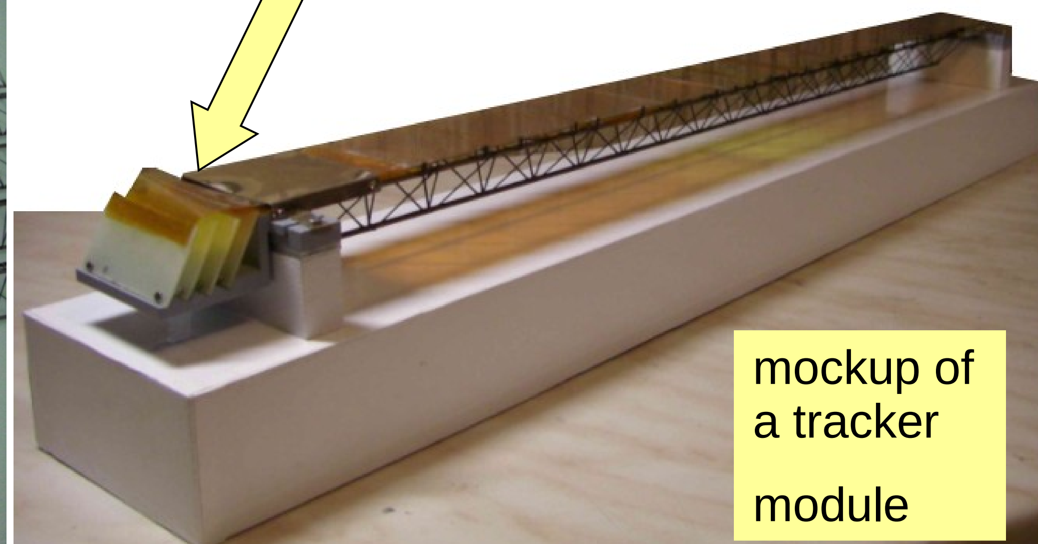
+ r/o cable



Front-end electronics board based on n-XYTER chip

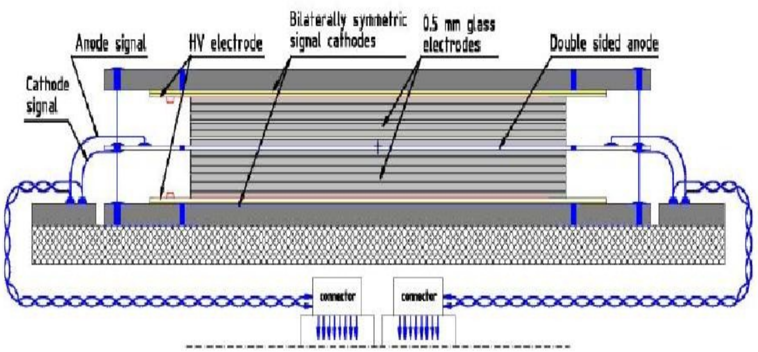


carbon fiber support structures

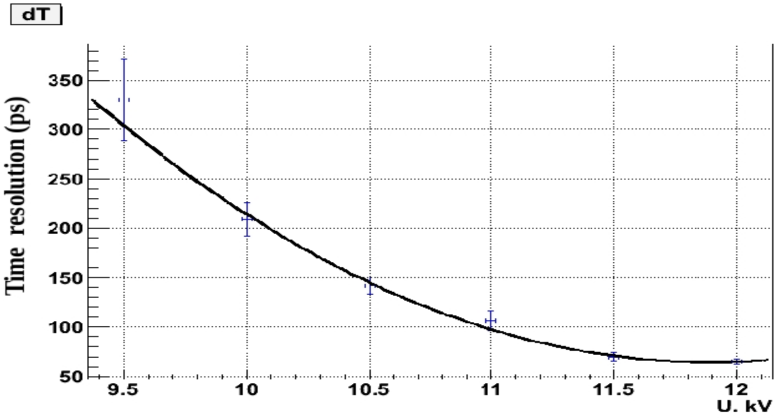


mockup of a tracker module

TOF system (mRPC)



Symmetrical structure, differential readout



MPD-TOF JINR