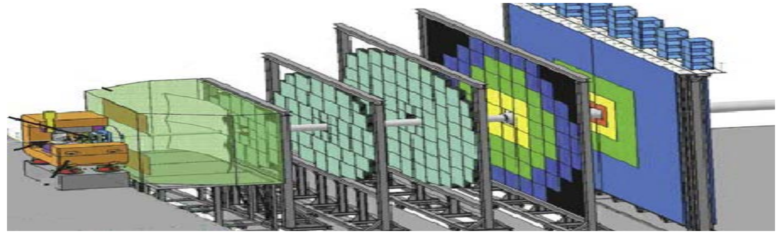
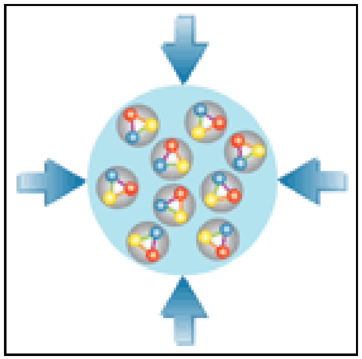




# Study of Compressed Baryonic Matter at FAIR:JINR participation

*O. Derenovskaya on behalf of CBM JINR group*

*LIT, JINR*

**ISCSNP of PSD RAS, April 12- 15, 2016**

# *Outline*

*Introduction:*

*CBM physics case and observables.*

*Experimental requirements.*

*JINR participation in CBM experiment:*

- *SC dipole magnet.*
- *Muon detection system.*
- *Development of STS.*
- *Methods, algorithms and software for fast event reconstruction*
- *Study of multiparticle dynamics at CBM.*

*Conclusion.*

# The CBM Collaboration

**Croatia:**
RBI, Zagreb
Split Univ.

**China:**
CCNU Wuhan
Tsinghua Univ.
USTC Hefei

**Czech Republic:**
CAS, Rez
Techn. Univ.Prague

**France:**
IPHC Strasbourg

**Hungaria:**
KFKI Budapest
Budapest Univ.

**Norway:**
Univ. Bergen

**India:**
Aligarh Muslim Univ.
Panjab Univ.
Rajasthan Univ.
Univ. of Jammu
Univ. of Kashmir
Univ. of Calcutta
B.H. Univ. Varanasi
VECC Kolkata
SAHA Kolkata
IOP Bhubaneswar
IIT Kharagpur
Gauhati Univ.

**Korea:**
Korea Univ. Seoul
Pusan Nat. Univ.

**Germany:**
Univ. Heidelberg, P.I.
Univ. Heidelberg, KIP
Univ. Heidelberg, ZITI
Univ. Frankfurt IKF
Univ. Frankfurt, FIAS
Univ. Münster
FZ Dresden
GSI Darmstadt
Univ. Wuppertal

**Poland:**
Jag. Univ. Krakow
Warsaw Univ.
Silesia Univ. Katowice
AGH Krakow

**Portugal:**
LIP Coimbra

**Romania:**
NIPNE Bucharest
Univ. Bucharest

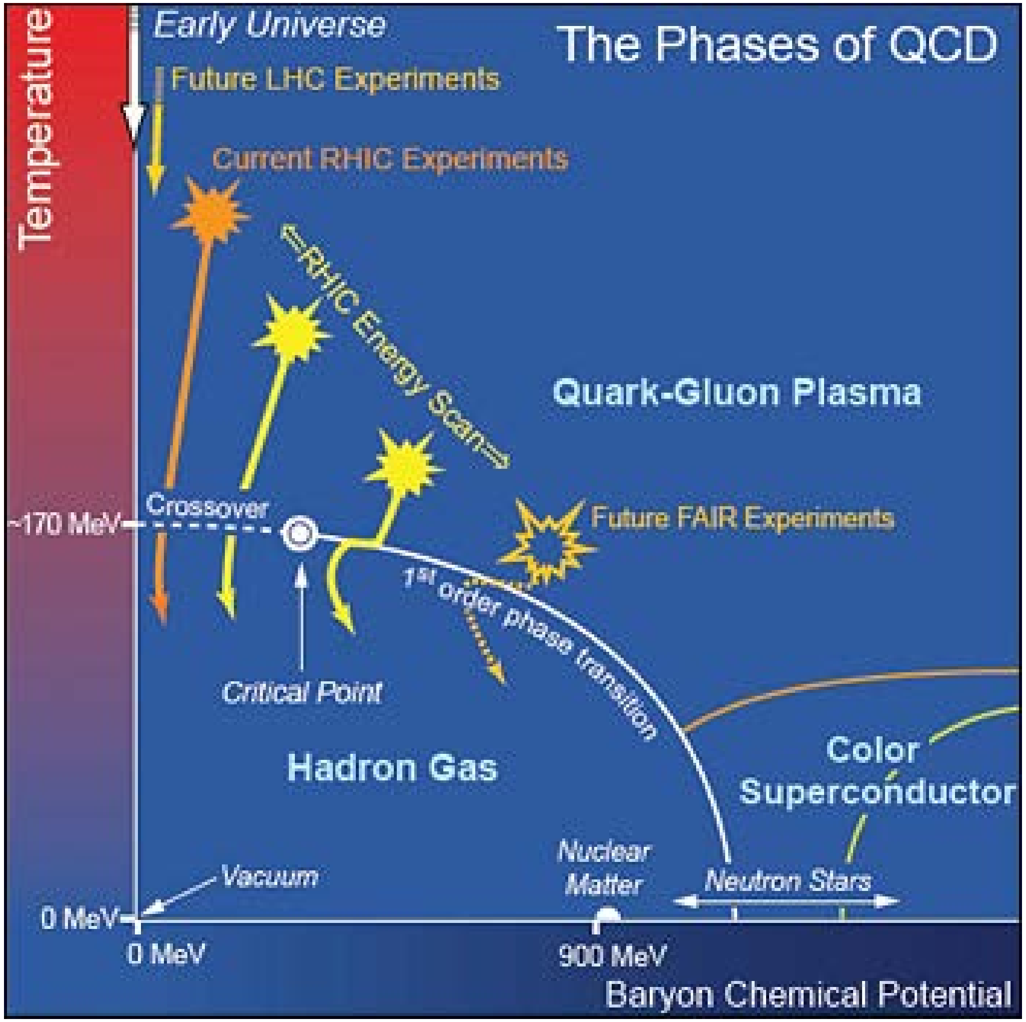
**Russia:**
IHEP Protvino
INR Troitzk
ITEP Moscow
KRI, St. Petersburg
Kurchatov Inst., Moscow
LHEP, JINR Dubna
LIT, JINR Dubna
MEPHI Moscow
Obninsk State Univ.
PNPI Gatchina
SINP MSU, Moscow
St. Petersburg P. Univ.

**Ukraine:**
T. Shevchenko Univ. Kiev
Kiev Inst. Nucl. Research

# The 22-nd CBM Collaboration Meeting
# 23-27 September 2013, JINR, Dubna

**150 participants**

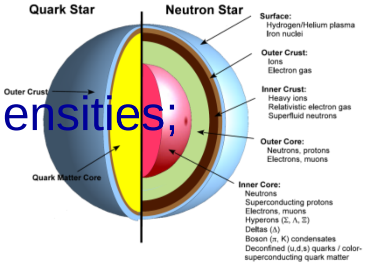
# Exploring the QCD phase diagram




<u>At high baryon density:</u>

- N of particles >> N of anti-particles
  Densities like in neutron star cores
- L-QCD not (yet) applicable
- Models predict first order phase transition with mixed or exotic phases
- Experiments: BES at RHIC,
  NA61 at CERN SPS,
  CBM at FAIR,
  NICA at JINR

# CBM physics case and observables



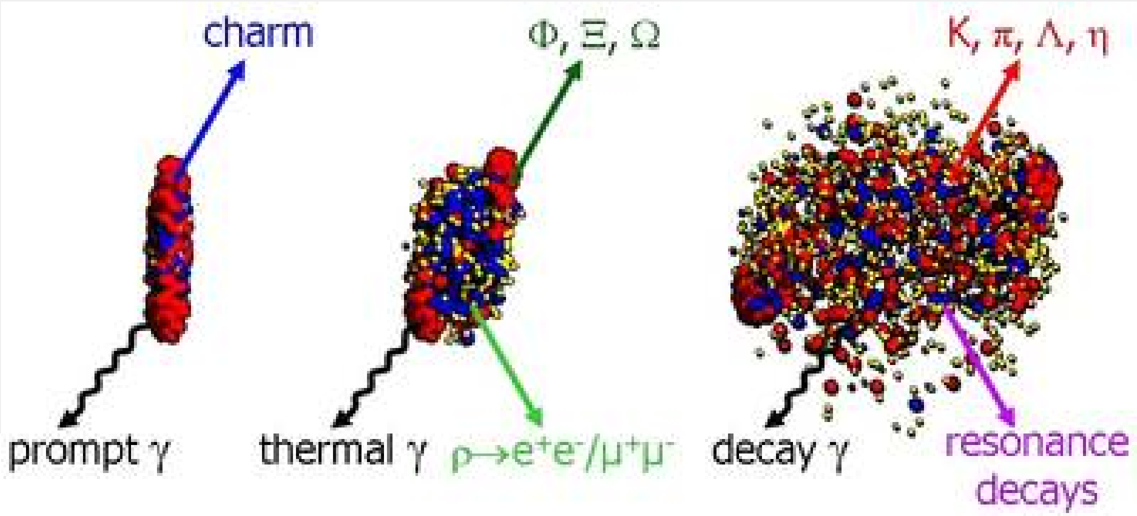

- in-medium modifications of hadrons in dense matter;
- indications of the deconfinement phase transition at high baryon densities;
- the critical point providing direct evidence for a phase boundary;
- exotic states of matter such as condensates of strange particles

✓ short-lived light vector mesons (e.g. the ρ-meson) which decay into electron-positron pairs. These penetrating probes carry undistorted information from the dense fireball;

✓ strange particles, in particular baryons (anti-baryons) containing more than one strange (anti-strange) quark, so called multistrange hyperons (Λ, Ξ, Ω);

✓ mesons containing charm or anti-charm quarks (D, J/Ψ);

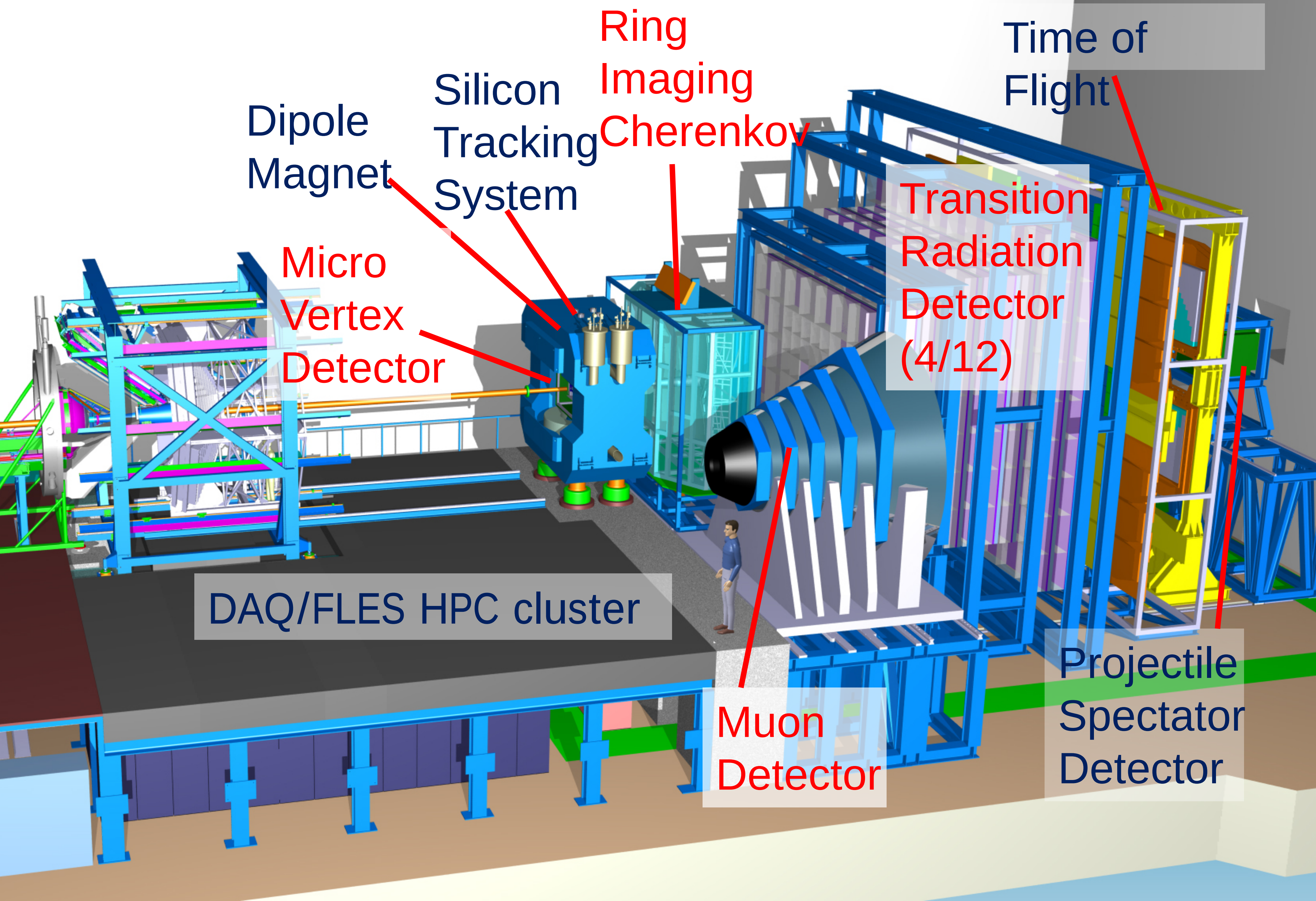
✓ collective flow of all observed particles.
event-by-event fluctuations



# Experimental requirements

- $10^5$ - $10^7$ Au+Au reactions/sec
- determination of displaced vertices ($\sigma \approx 50$ μm)
- identification of leptons and hadrons
- fast and radiation hard detectors
- free-streaming readout electronics
- high speed data acquisition and high performance computer farm for online event selection
- 4-D event reconstruction

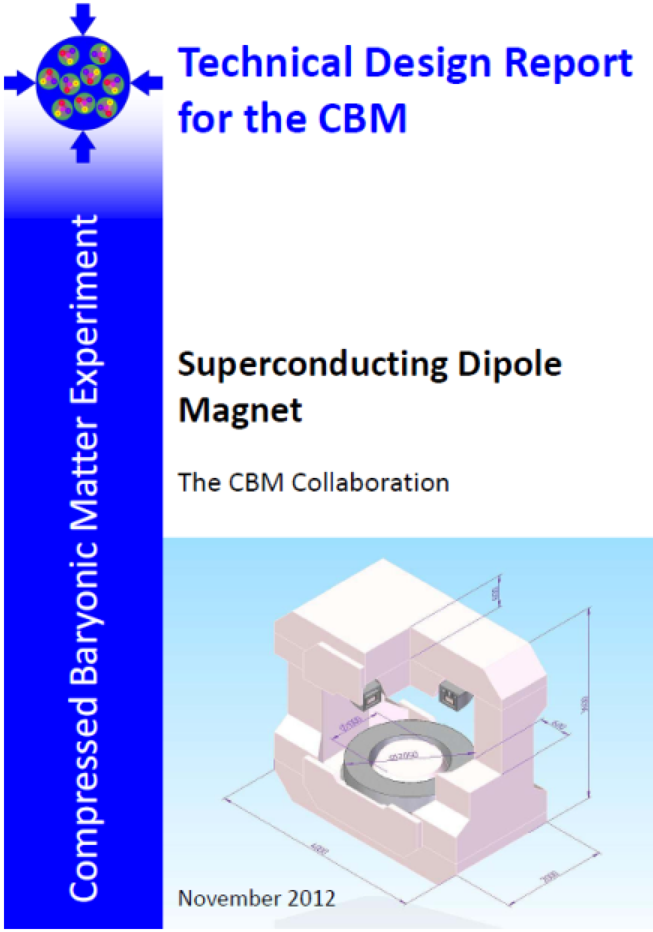
# CBM detector



# JINR participation in CBM

- Design of SC dipole magnet
- Development, design and production of a straw tube tracker prototype
- Methods, algorithms and software for fast event reconstruction
- Vector finding approach to track reconstruction in MUCH
- Study of multi-particle dynamics in heavy ion collisions at CBM
- R&D, beam tests

# CBM Superconducting Dipole Magnet




**Technical Design Report for CBM superconducting dipole magnet was approved in the final form in 2014 year.**

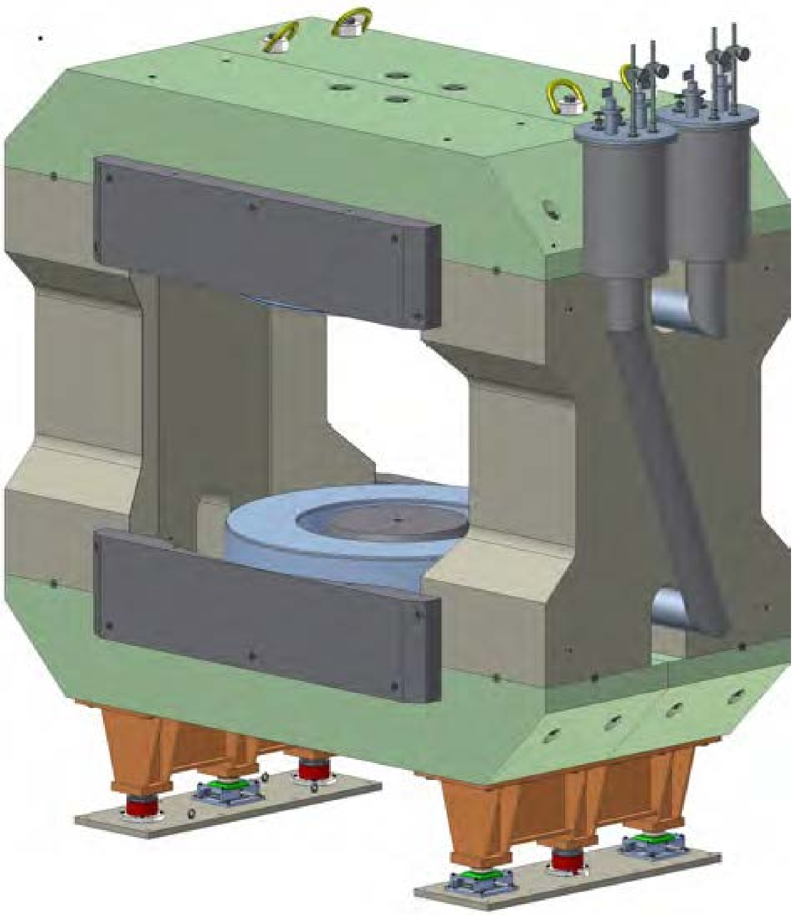
**1.** VNITEP Company and JINR design team prepared the drawings in two standards (ESKD for Russia and ISO for Europe).

**2.** The following drawings are done: yoke, support, coil cryostat (superconducting coil, heat shield, vacuum vessel, support strut and tie rod)

**3.** Seach for the potential manufactors of the different CBM magnet parts: coils, cryostats and magnet yoke was very active**.**

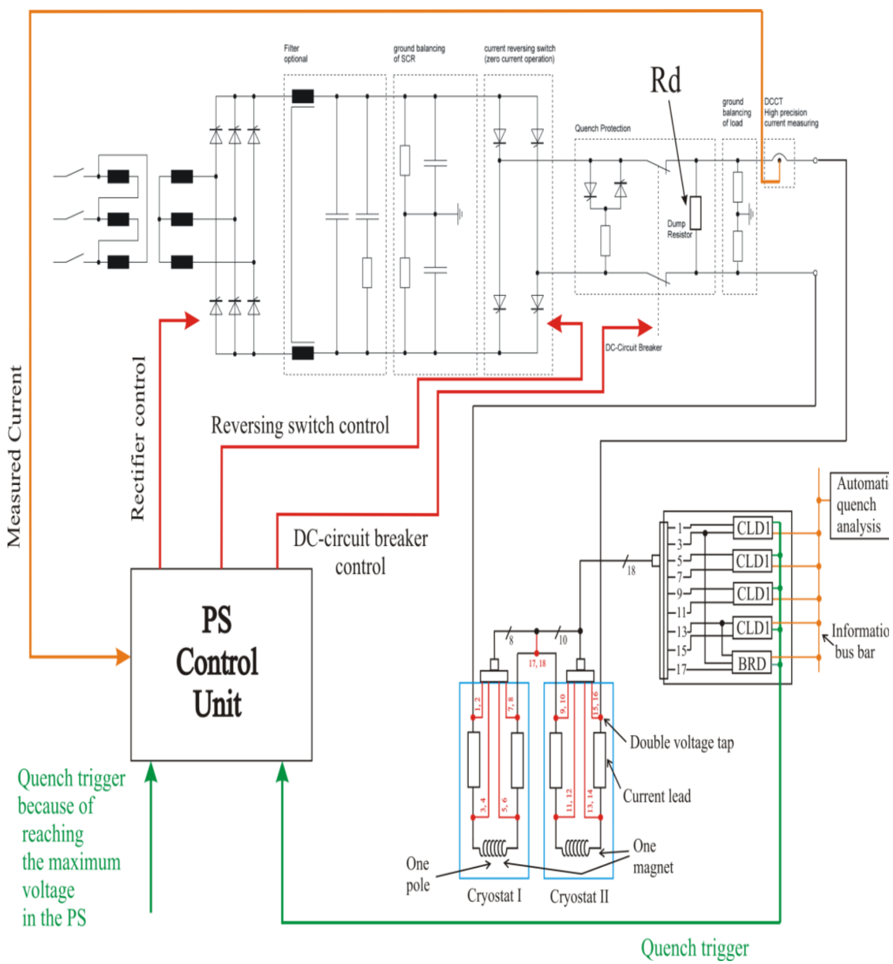
**4.** Works on the further design of the magnet, cryostat, support as well as on quench and magnetic field calculations are continued at JINR and GSI.

# CBM Superconducting Dipole Magnet

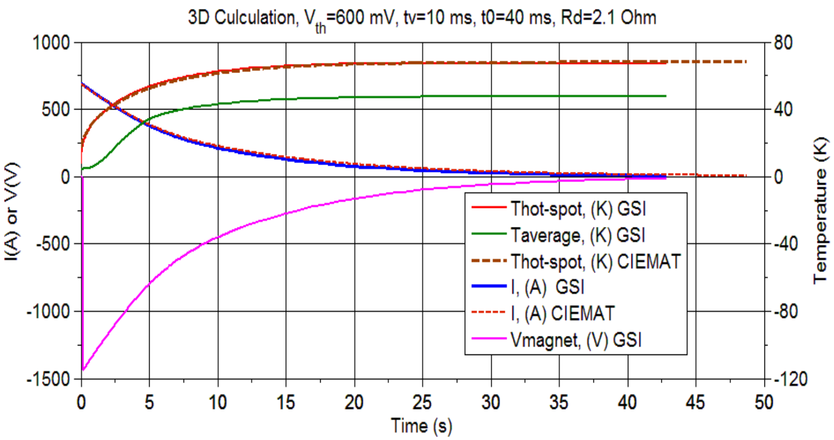


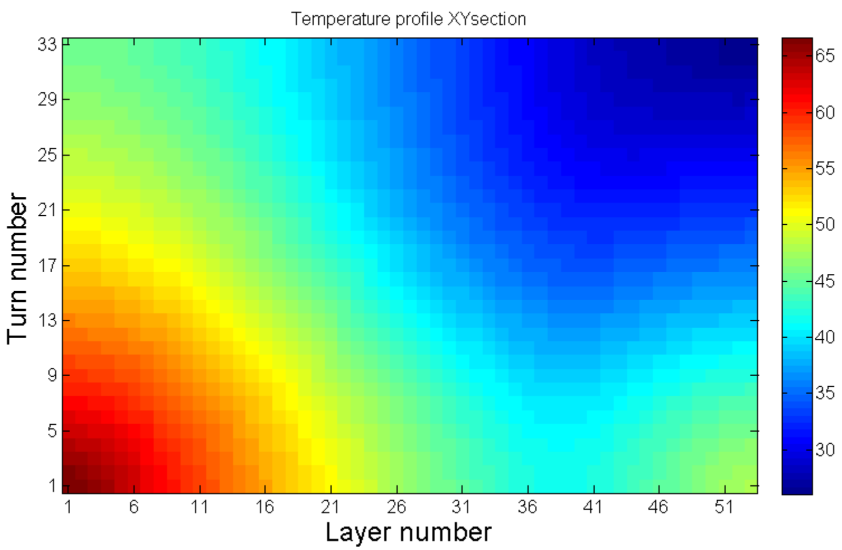
| Specifications of the superconducting dipole magnet | |
|---|---|
| Type | **H-type**, circular coils |
| Number of turns | 1749 /coil |
| Number of layers | 53 /coil |
| Windings of coil | Orderly |
| Coil cross section | V131mm x H158.8 mm |
| Outer diameter of coil | 1.724 m |
| Inner diameter of coil | 1.426 m |
| Nominal current | **686 A** |
| Magnetomotive force | 1.2 MAT/coil |
| Current density | 58.8 A/mm$^2$ |
| Central field | **1.08 T** |
| Maximum field at coil | **3.25 T** |
| Field integral | **1.0 Tm** |
| Inductance | 21,9H |
| Stored energy | **5,15 MJ** @686 |

# Quench protection and detection scheme



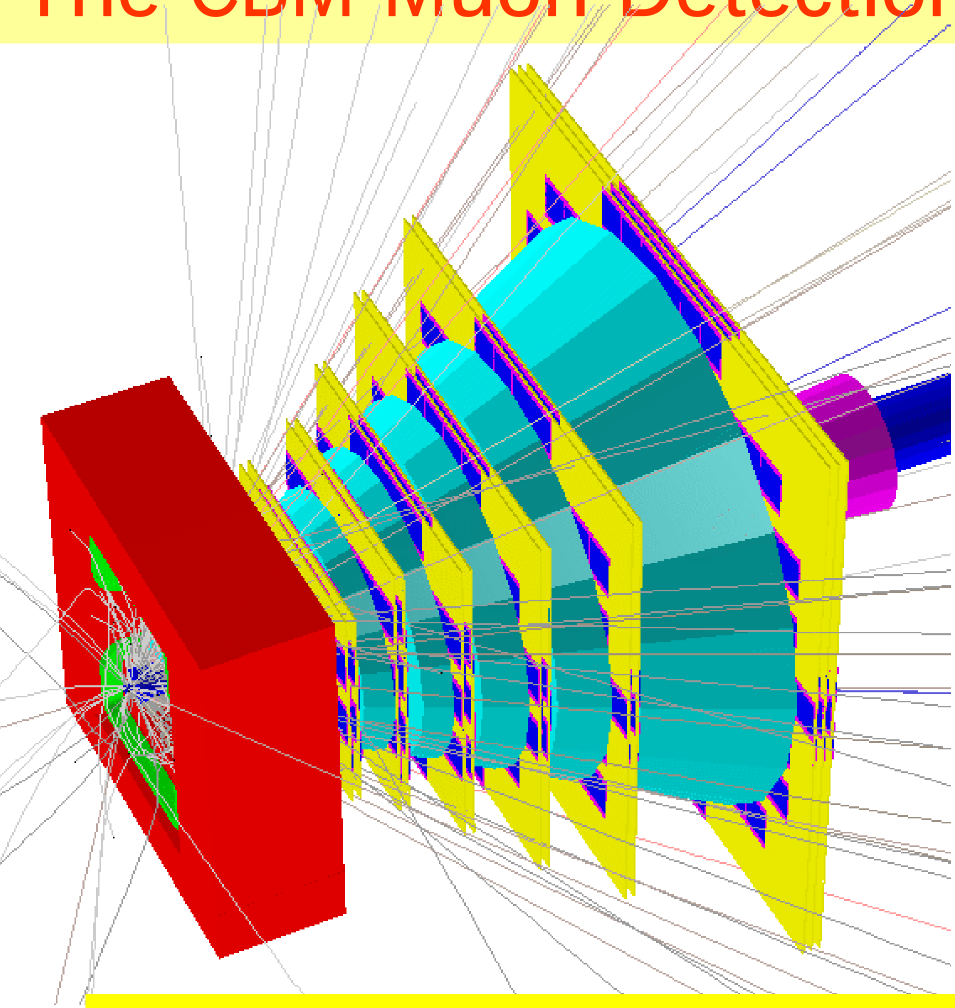

H. Ramakers and E. Floch.

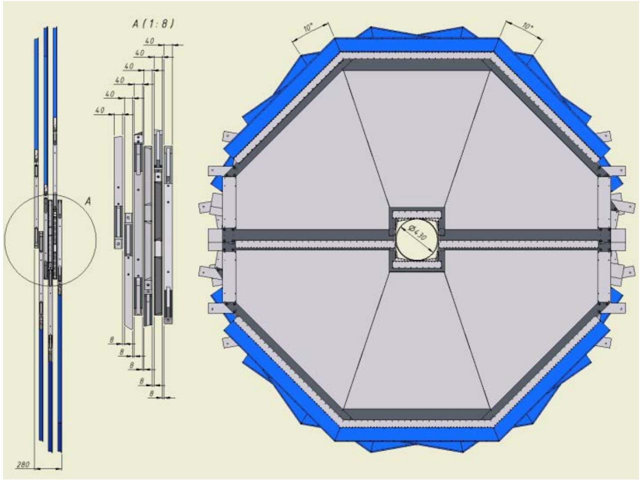



The result of 3D calculation with Rd=2.1 Ohm

# The CBM Muon Detection System

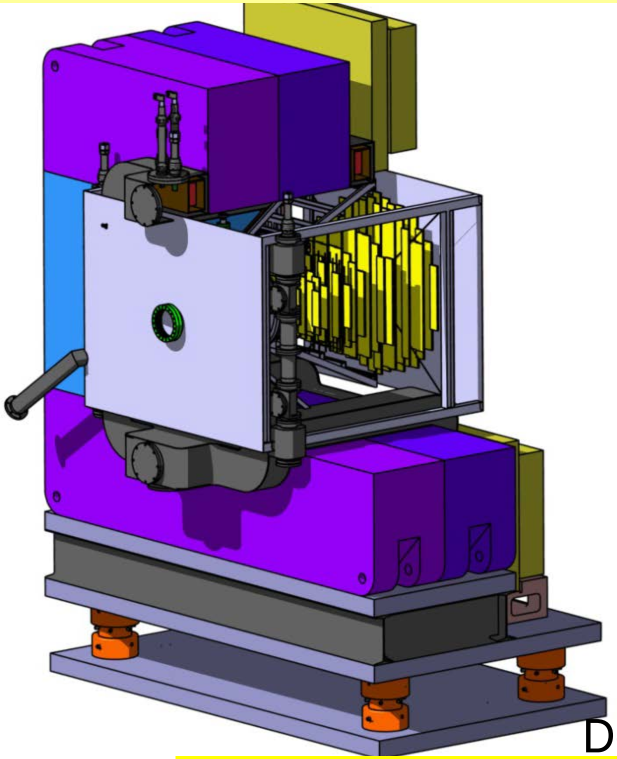


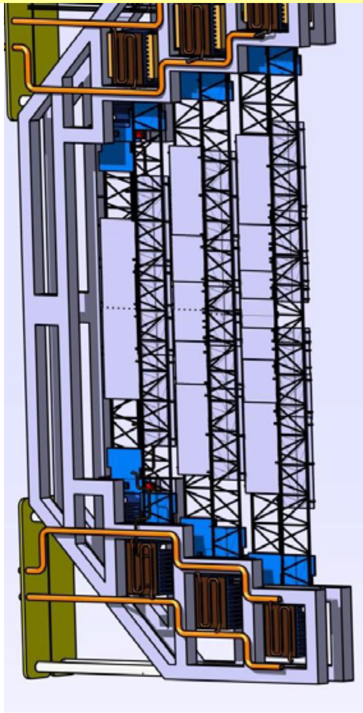


straw-tube tracker

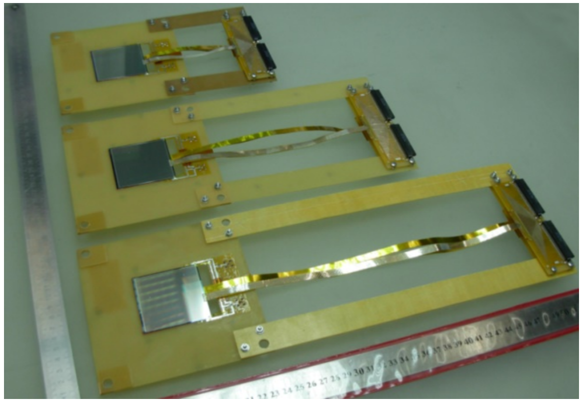
Institutions: Indian muon consortium (12 Univ. and labs),
PNPI Gatchina, JINR Dubna
Funding: FAIR contributions (India, Russia)
TDR is approved in 2015

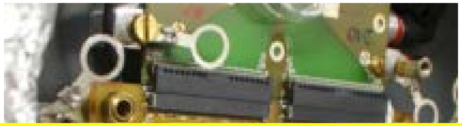
# Development of the Silicon Tracking System for CBM





Sensor development:
Double-sided microstrips
60 μm pitch, 300 μm thick, read-out via ultra-thin micro-cables





Detector layers:

STS in
enclos

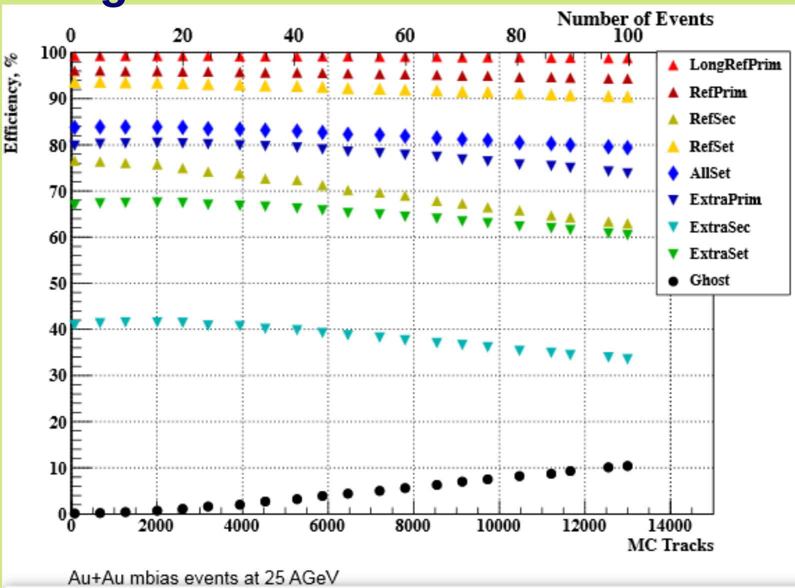
Institutions: GSI, JINR, KRI SPb, SPbSPU, AGH Krakow, JU Krakow, Moscow St. U, KINR, U Tübingen, industrial partners (Erfurt, Kharkov, Minsk, …)

Funding: FAIR contributions (Germany, Russia, Poland), German BMBF Univ. funds,

TDR is approved. Many FAIR – Institutes Contracts

# Methods, algorithms & software for fast event reconstruction

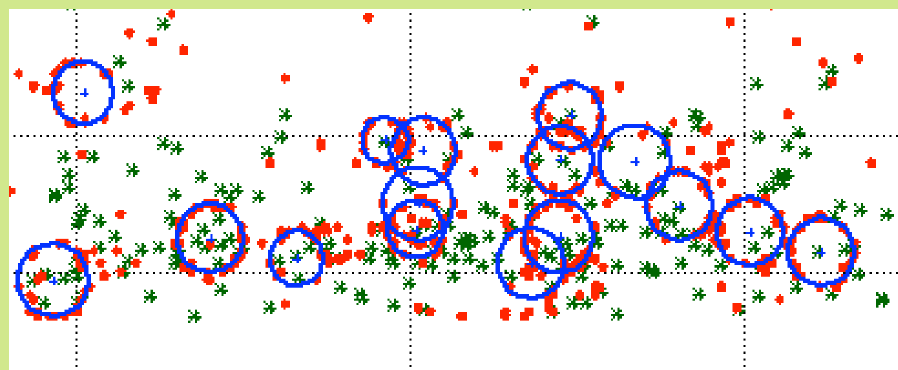
• global track reconstruction




V. Akishina, A. Lebedev

• Development of the algorithms and software for track and ring reconstruction in MUCH, TRD, RICH, MVD detectors as well as global track reconstruction. Track reconstruction method is based on the track following and Kalman filter procedures. Ring reconstruction is based on the Hough Transform method.

• event reconstruction in RICH

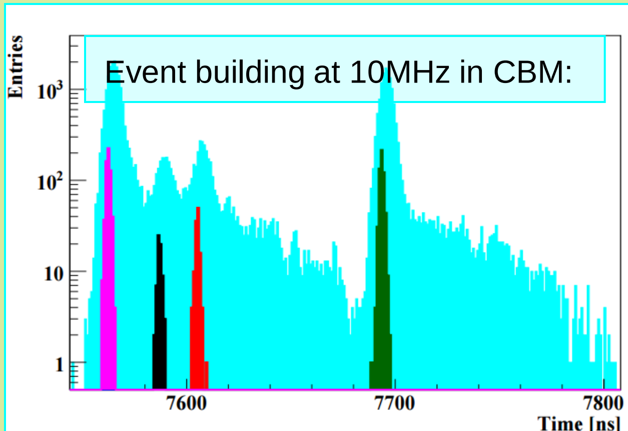


S. Lebedev

• magnetic field calculations;
• beam time data analysis of the RICH and TRD prototypes;
• contribution to the CBMROOT development;
• development of the Concept of CBM Databases;

# *Methods, algorithms & software for fast event reconstruction*

## • 4D event reconstruction (with time slices information)

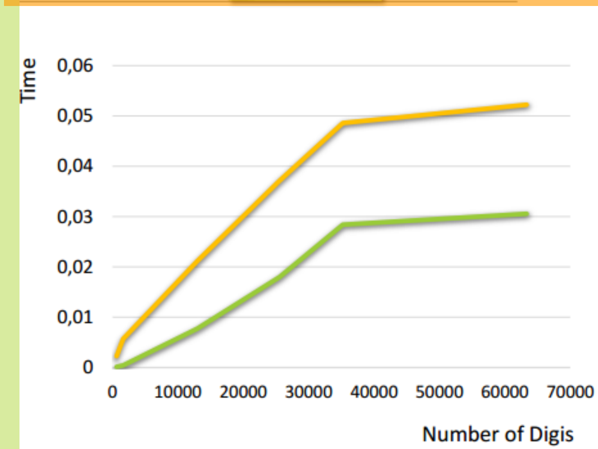



tracks, reconstructed with 4D CA Track Finder, represent well resolved physical events on the blue background of overlapped initial hits

V. Akishina, I. Kisel

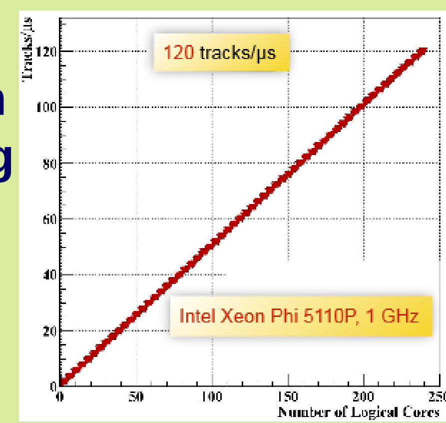
## • clustering in MVD, STS, MUCH

Time-based cluster finder for the STS



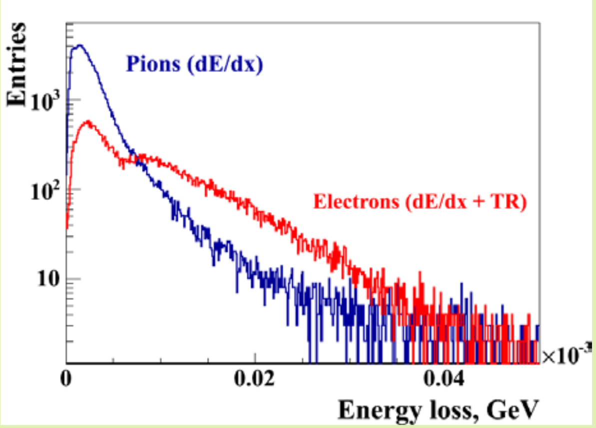

G. Kozlov

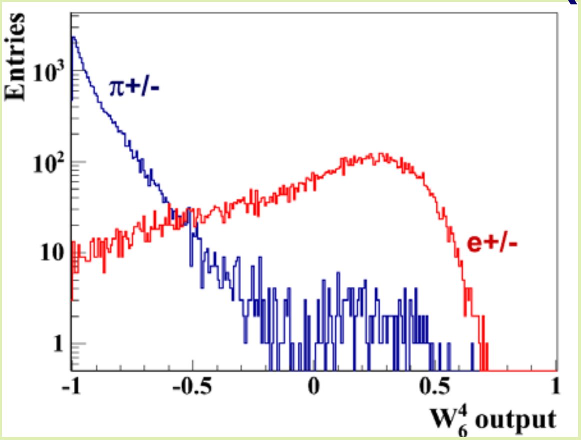
## • First Level Event Selection software development using different manycore CPUs and GPUs platforms



# *Methods, algorithms & software for fast event reconstruction*

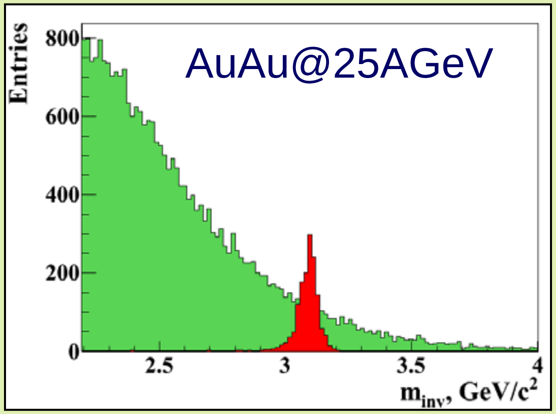
- **electron identification in TRD (Artificial Neuron Network and w(k,n) criterion)**




O. Derenovskaya, V. Ivanov

- **feasibility study of the J/ψ→e$^+$e$^-$ and J/ψ→μ$^+$μ$^-$ reconstruction using developed software**

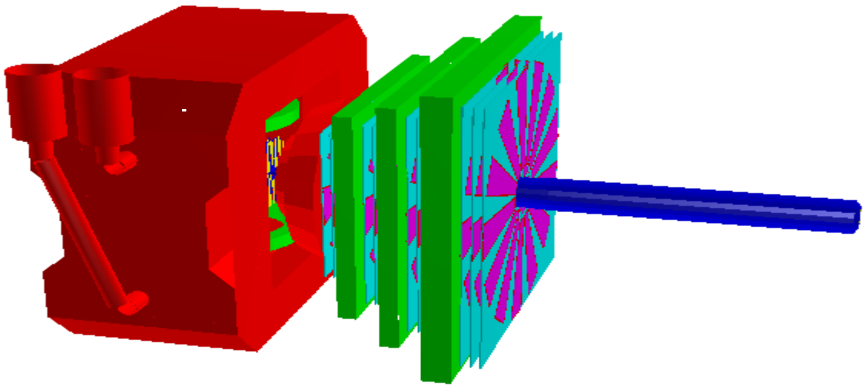


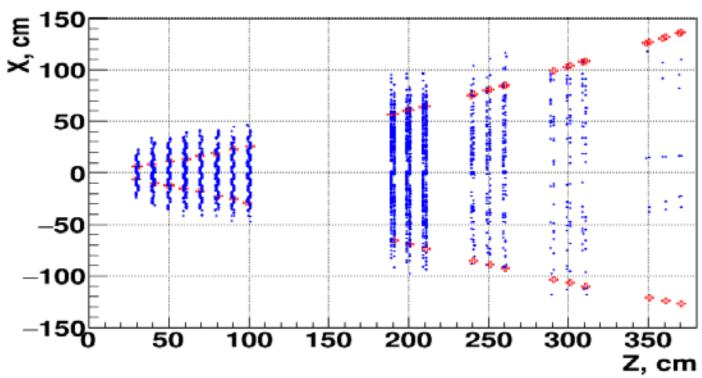

| | a | b | c |
|---|---|---|---|
| pC@30GeV | 14 | 22 | 11 |
| pAu@30GeV | 18 | 22 | 27 |
| AuAu@10AGeV | 0.18 | 18 | 64 |
| AuAu@25AGeV | 7.5 | 13.5 | 5250 |

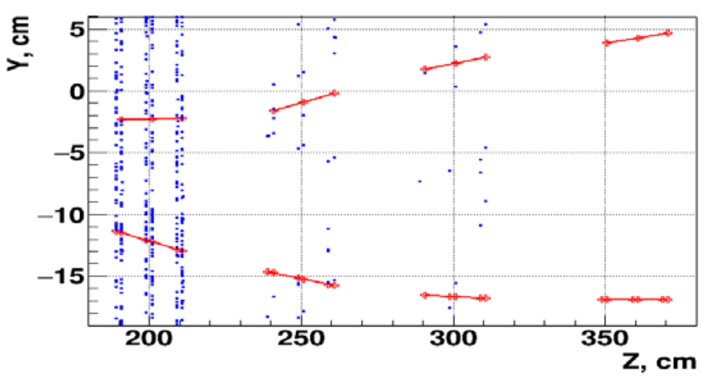
a: S/Bg$_{2\sigma}$,
b: Efficiency (%),
c: J/ψ per hour (10 Mhz)

O. Derenovskaya

# A vector finding approach to track reconstruction in CBM-MUCH





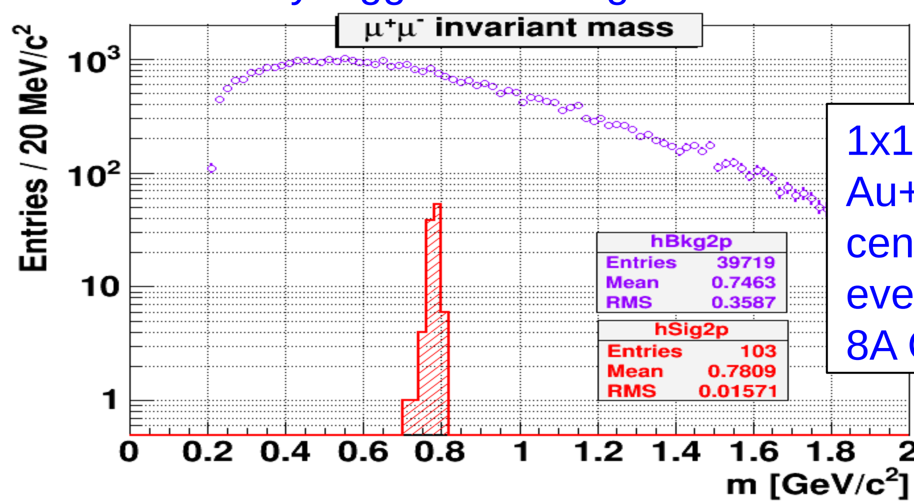




Low-mass vector meson decays: $\omega \rightarrow \mu^+\mu^-$

- very low yield of signal di-muon pairs
- background: false (ghost) tracks + hadron decays

Build vectors for each station to:

- better handle different MUCH detectors (GEMs and Straws)
- facilitate parallel processing
- unify trigger / tracking tasks

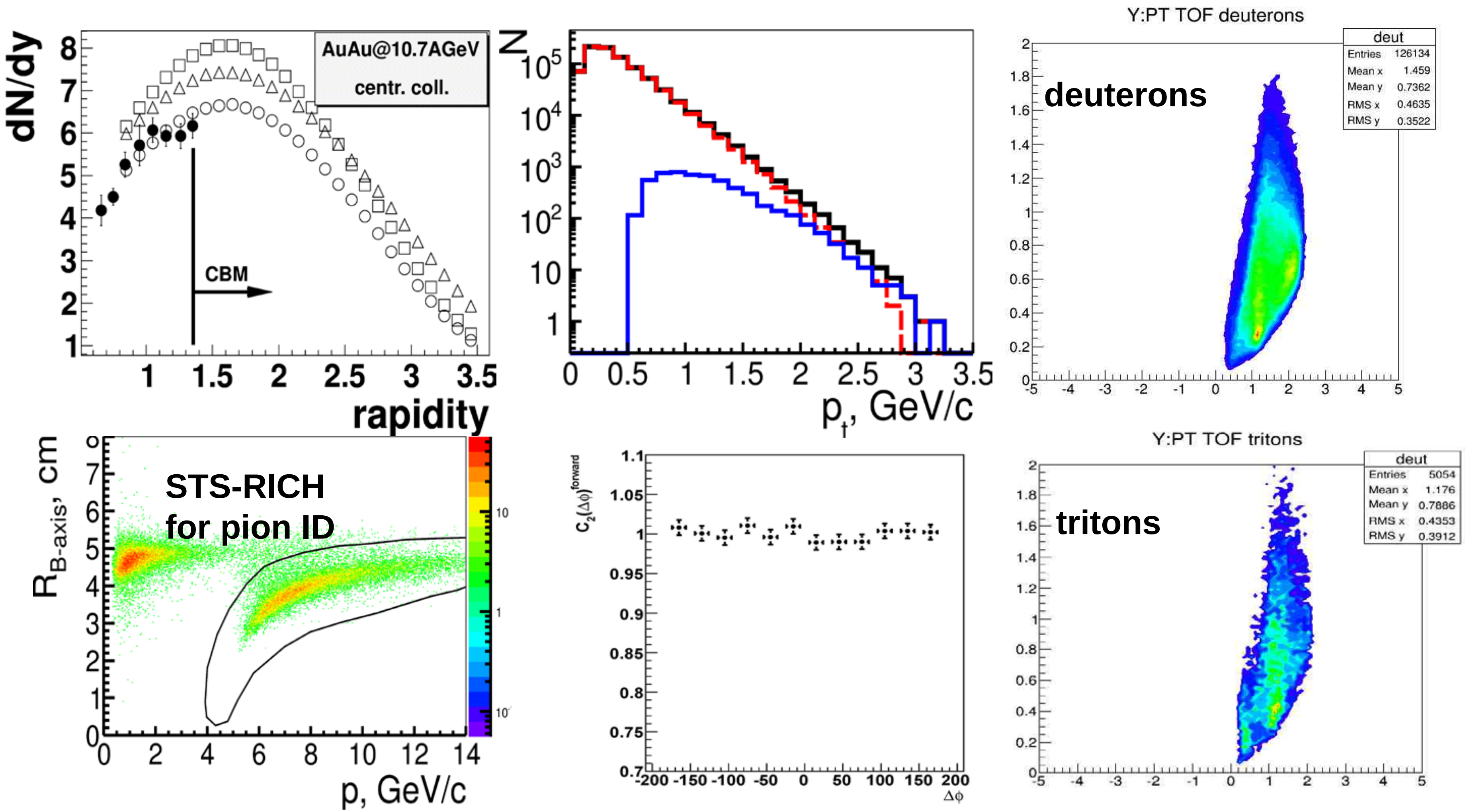



$1\times10^7$ Au+Au central events @ 8A GeV

Future developments:

- fine tuning of the tracking algorithm to better reject ghost combinations
- use TOF information to suppress hadron contribution

# Study of multiparticle dynamics at CBM at SIS100



# *Conclusions*

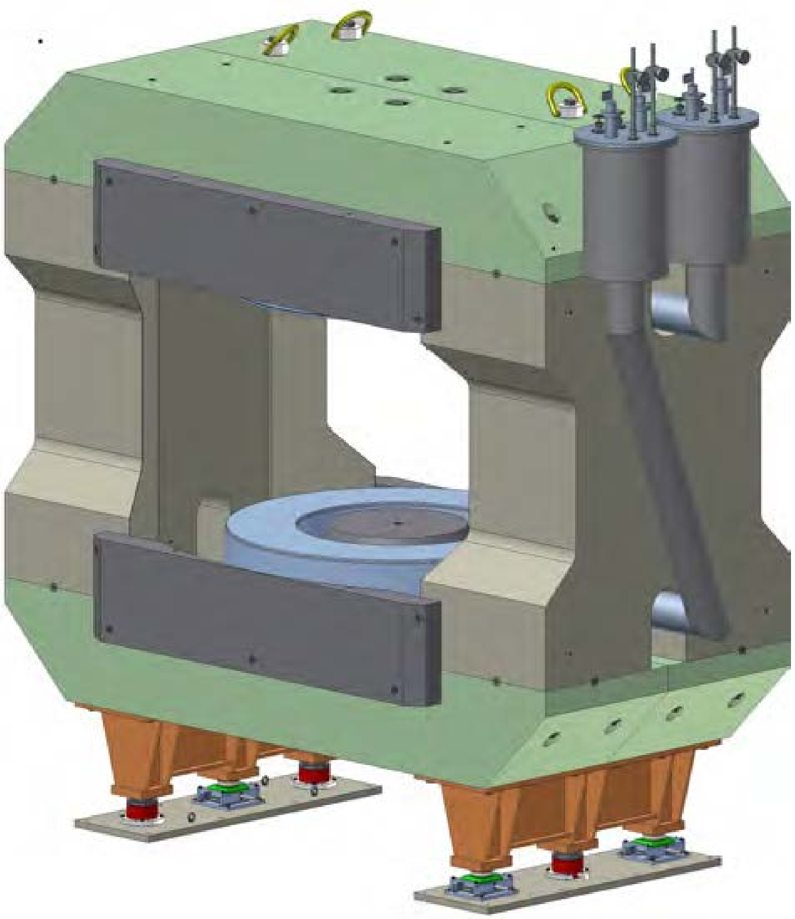
- The CBM research program aims at the exploration of the structure of high density matter. For these purpose the advanced experimental setup will be build for high counting rate conditions expected at FAIR.
- JINR participated in the CBM project very actively and its contribution is large.
- The ultimative goal for 2016-2020 is to construct CBM detector to be ready for data taking  at SIS100.
- Experience of the design and construction of many elements of the CBM (the Superconductive Dipole Magnet, MUCH,STS ) is used for the BM@N  at the external Nuclotron beams and MPD (NICA).

***Thank you for the attention!***

**T.O.Ablyazimov, E.P.Akishina, P.G.Akishin, T.P.Akishina, V.P.Akishina, E.I.Alexandrov, I.N.Alexandrov, Yu.S.Anisimov, S.P.Avdeev, D.Blaschke, I.V.Boguslavsky, S.G.Bondarenko, V.V.Burov, A.V.Bychkov, O.Yu.Derenovskaja, O.V.Fateev, I.A.Filozova, V.M.Golovatyuk, N.Grigalashvili, Yu.V.Gusakov, E.-M.Ilgenfritz, V.V.Ivanov, V.V.Ivanov (junior), A.P.Ierusalimov, W.Karcz, V.A.Karnaukhov, G.D.Kekelidze, V.V.Kirakosyan, P.I. Kisel, G.E. Kozlov, V.A.Kramarenko, S.N.Kuznetsov, A.K.Kurilkin, P.K.Kurilkin, V.P.Ladygin, A.A.Lebedev, S.A.Lebedev, V.M.Lysan, A.I.Malakhov, Yu.A.Murin, G.A.Ososkov, E.V.Ovcharenko, D.V.Peshekhonov, V.D.Peshekhonov, S.V.Rabtsun, A.M.Raportirenko, O.V.Rogachevsky, E.P.Rogochaya, A.A.Savenkov, A.V.Shabunov, V.D.Toneev, E.V.Vasilieva, B.S.Yuldashev, Yu.V.Zanevsky, A.I.Zinchenko, P.V.Zrelov, V.N.Zryuev**

***Joint Institute for Nuclear Research (57)***
***LHEP, LIT, LNP, BLTP***

# CBM Superconducting Dipole Magnet

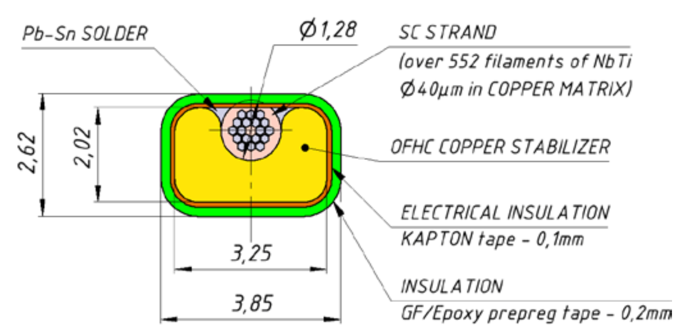


| Required parameters: | |
|---|---|
| Geometry | |
| Opening angle:<br>Vertically from the target<br>Horizontally from the target | <br>±25º<br>±30º |
| Free aperture:<br>vertically<br>horizontally | <br>1.4 m<br>1.8 m |
| Distance target-magnet core end | 1.0 m |
| Total length | 1.5 m |
| Field: | |
| Field integral within STS | 1 Tm |
| Field integral variation | ≤ 20% (± 10%) |
| Operation conditions: | |
| Operates at both polarities | |
| 100% duty circle, 3 months/year, 20 years | |
| No real time restriction on the ramp: 1 hour up ramp | |

# Main parameters of CBM magnet

| Specifications of the superconducting dipole magnet | |
|---|---|
| Type | **H-type**, circular coils |
| Number of turns | 1749 /coil |
| Number of layers | 53 /coil |
| Windings of coil | Orderly |
| Coil cross section | V131mm x H158.8 mm |
| Outer diameter of coil | 1.724 m |
| Inner diameter of coil | 1.426 m |
| Nominal current | **686 A** |
| Magnetomotive force | 1.2 MAT/coil |
| Current density | 58.8 A/mm$^2$ |
| Central field | **1.08 T** |
| Maximum field at coil | **3.25 T** |
| Field integral | **1.0 Tm** |
| Inductance | 21,9H |
| Stored energy | **5,15 MJ** @686 |

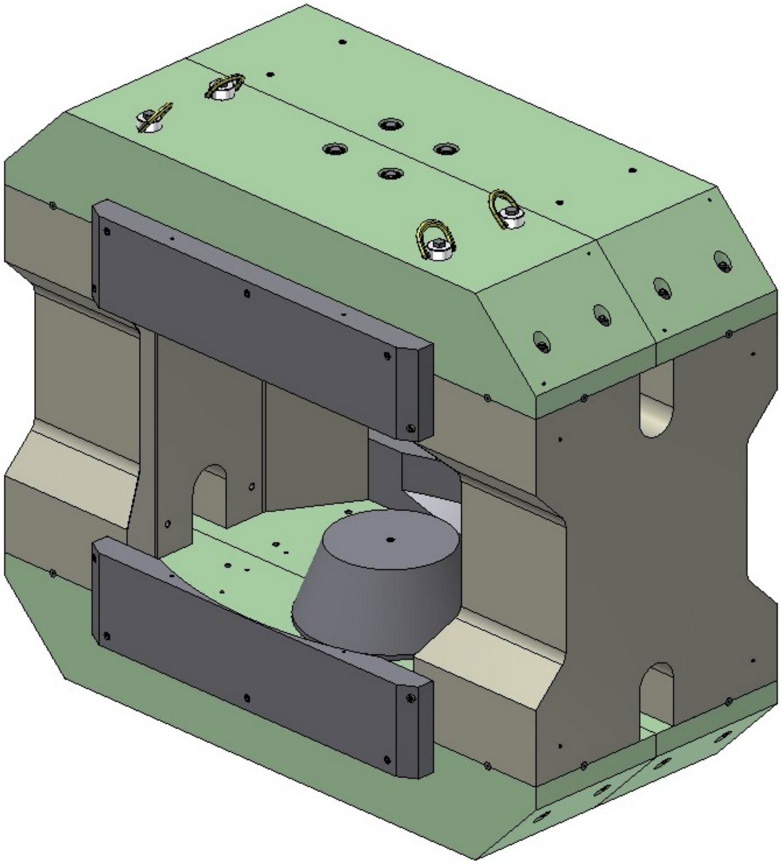
| Specifications of the superconducting wire | |
|---|---|
| Material of SC cable | **NbTi/Cu** |
| Dimension of conductor | 2,02x3.25 mm |
| Cu/S.C. ratio | **9.1** |
| Insulation | Kapton + GF tape |
| Filament diameter | < 40 mm |
| Number of filaments | ~ 552 |
| Twist pitch | 45 mm |
| RRR | >100 |
| Critical current @ 4.2K | 1330 A @5 T |
| Load factor | **~0.52** |




B. Blau, et al., **The CMS Conductor**, **IEEE Transactions on Applied Superconductivity**, Date of Publication: March 2002, Volume: 12 , Issue: 1 Page(s): 345 – 348

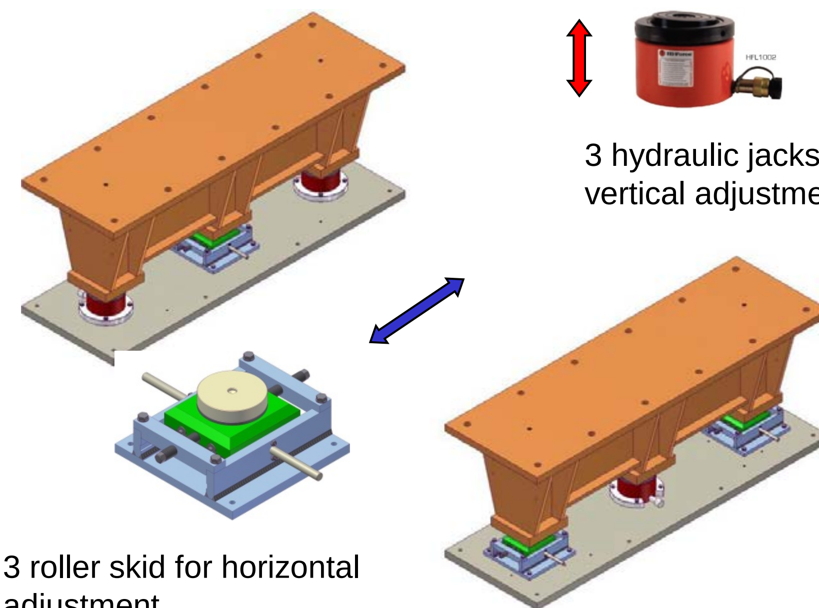
# CBM Superconducting Dipole Magnet

### *The magnet yoke*



| | |
|---|---|
| The magnet weigth | - 150 t |
| The beam axis from the floor | - 2600 mm |
| The height of the support | - 750±20 mm |
| The support points | - 3 |
| The maximal load on point | - 85 t |
| The vertical adjustment | - ±20 mm |
| The horizontal adjustment | - ±20 mm |

### *The magnet support*

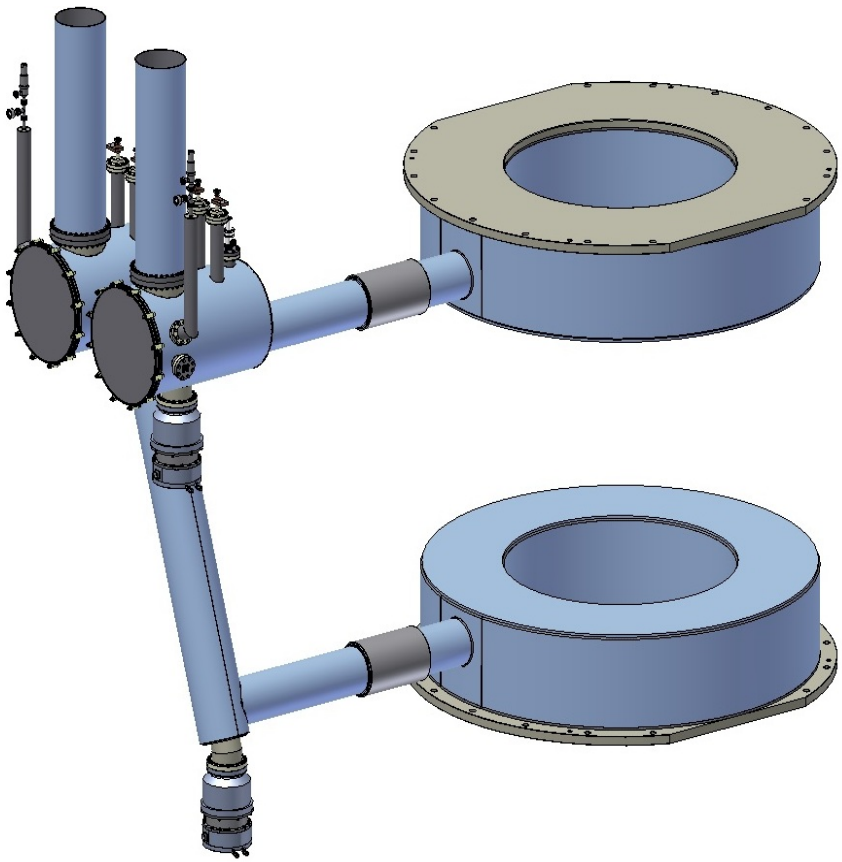


3 hydraulic jacks for vertical adjustment

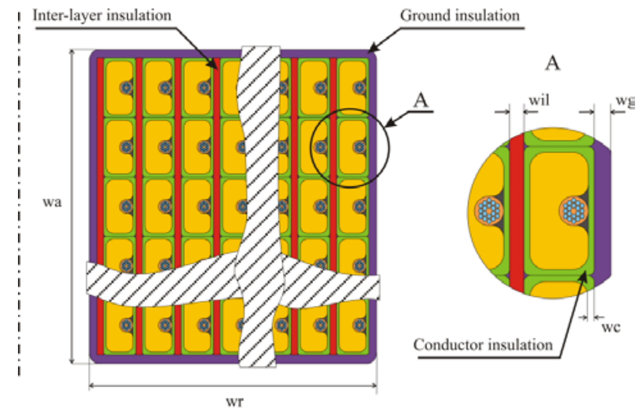
3 roller skid for horizontal adjustment

# CBM Superconducting Dipole Magnet

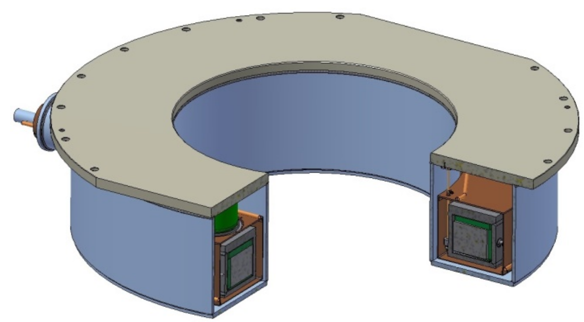
*Top and bottom coils with feed boxes*



*Cross section of the coil winding*




*Cryostat of superconducting coil*



# CBM Superconducting Dipole Magnet

## (quench calculations)

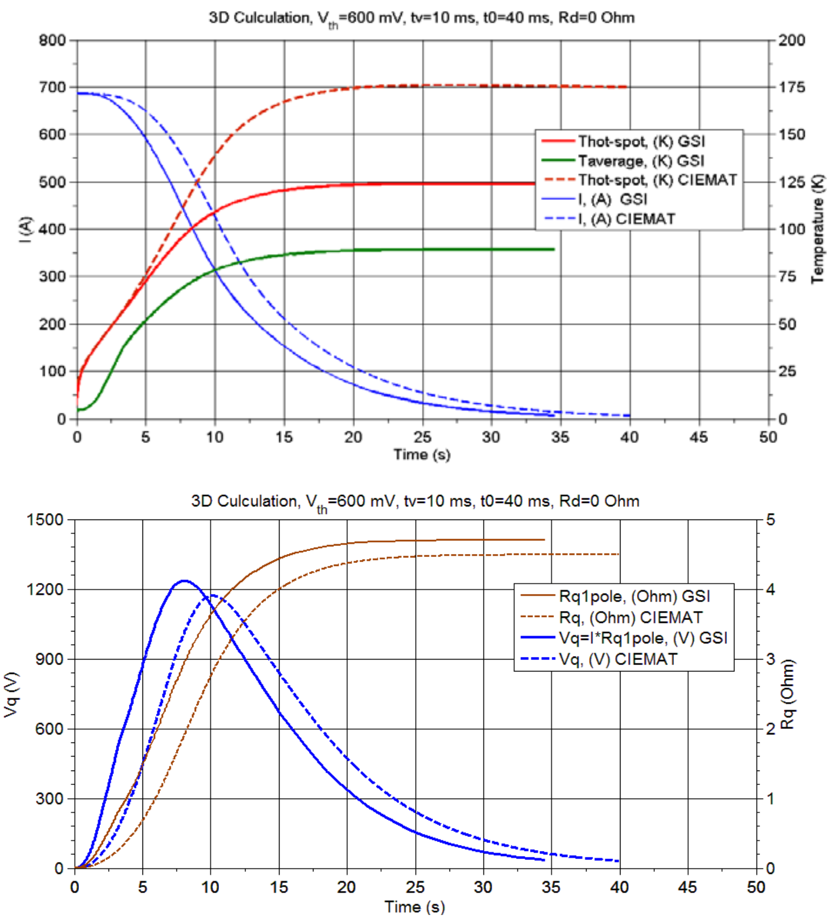



Fig.1 3D quench calculation results.

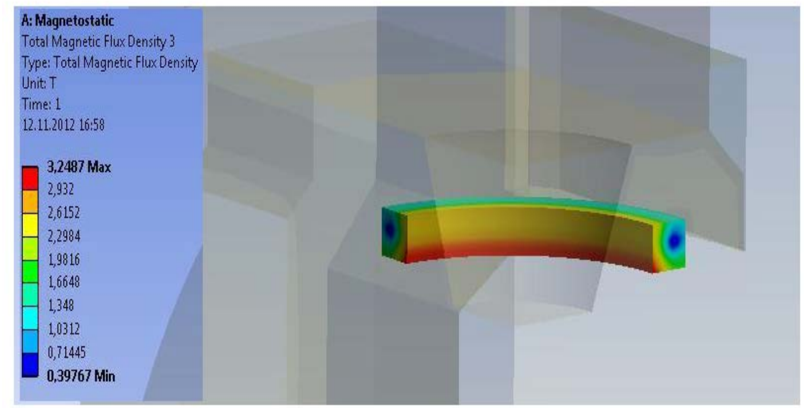



Fig.2 Magnetic field in the coil.

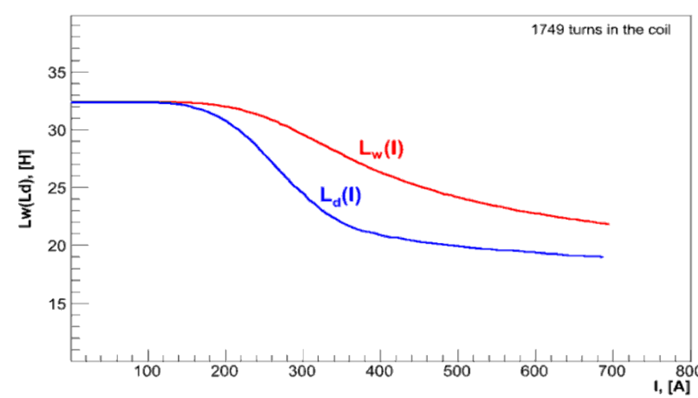
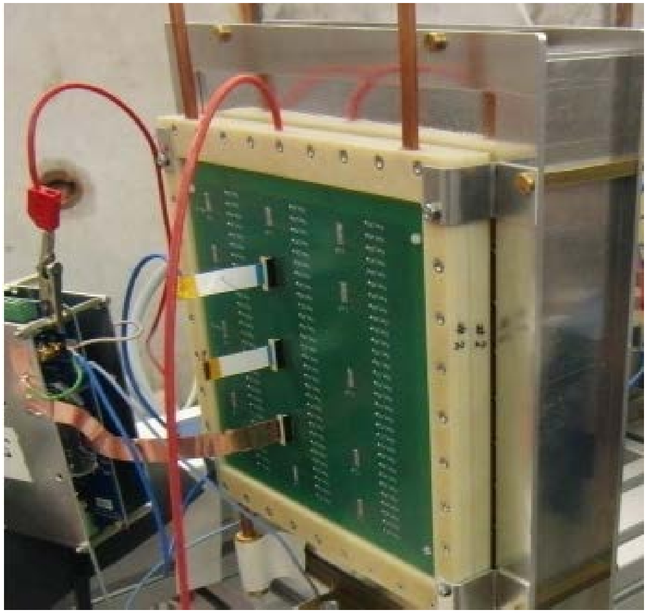


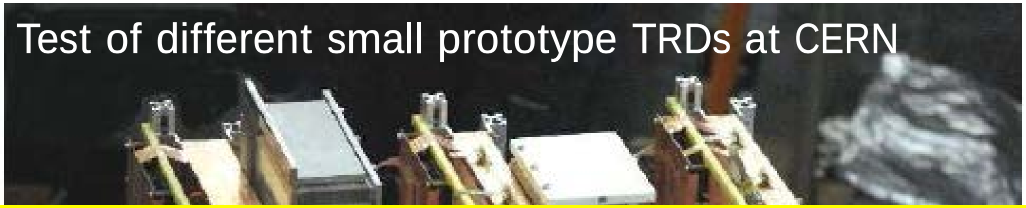

Fig.3 Inductances $L_w$ and $L_d$ vs the current.

# The CBM TRD (R&D for SIS300)

Requirements:
- e/π discrimination of > 100 (p > 1.0 GeV/c)
- active area ~1000 $m^2$ (12 stations)
- rate capability up to 100 $kHz/cm^2$
- position resolution about 200 μm



Prototype detectors:
- no drift region
- thickness of gas volume ~1 cm

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TDR: internal report in progress