Статус проекта MPD

В.Кекелидзе

- *Вступление*
- *Физические задачи*
- *MPD концептуальный проект*

  – магнит
  -Barrel Tracker (TPC, Straw)
  - TOF
  - BBC
  - ZDC
- *Организационные аспекты*
- *Заключение*

Introduction

- **NICA / MPD project**
  to study hot & dense strongly interacting QCD matter
  & to search for possible manifestation of the mixed phase formation
  & critical endpoint in heavy ion collisions
  has started for preparation

- **NICA / MPD** is a leading **LHE** project in both
  *– **research program** & development of **basic facility***
  *in **2008-2015***

- it is expected that this ***flagship*** project provides:
  - frontier researches in the relativistic heavy ion physics
  - attraction of young physicists & worldwide cooperation
  - development of new technologies (incl. nanotechnologies)
  - attraction of extra funding

New Basic Facility

- *Preparation of the project of new JINR facility*
  – Heavy Ion Collider **NICA** (**N**uclotron-based **I**on **C**ollider f**A**cility)
  has started

- *This project foresees the design & construction of*

  Injection complex including the new Krion source & linac

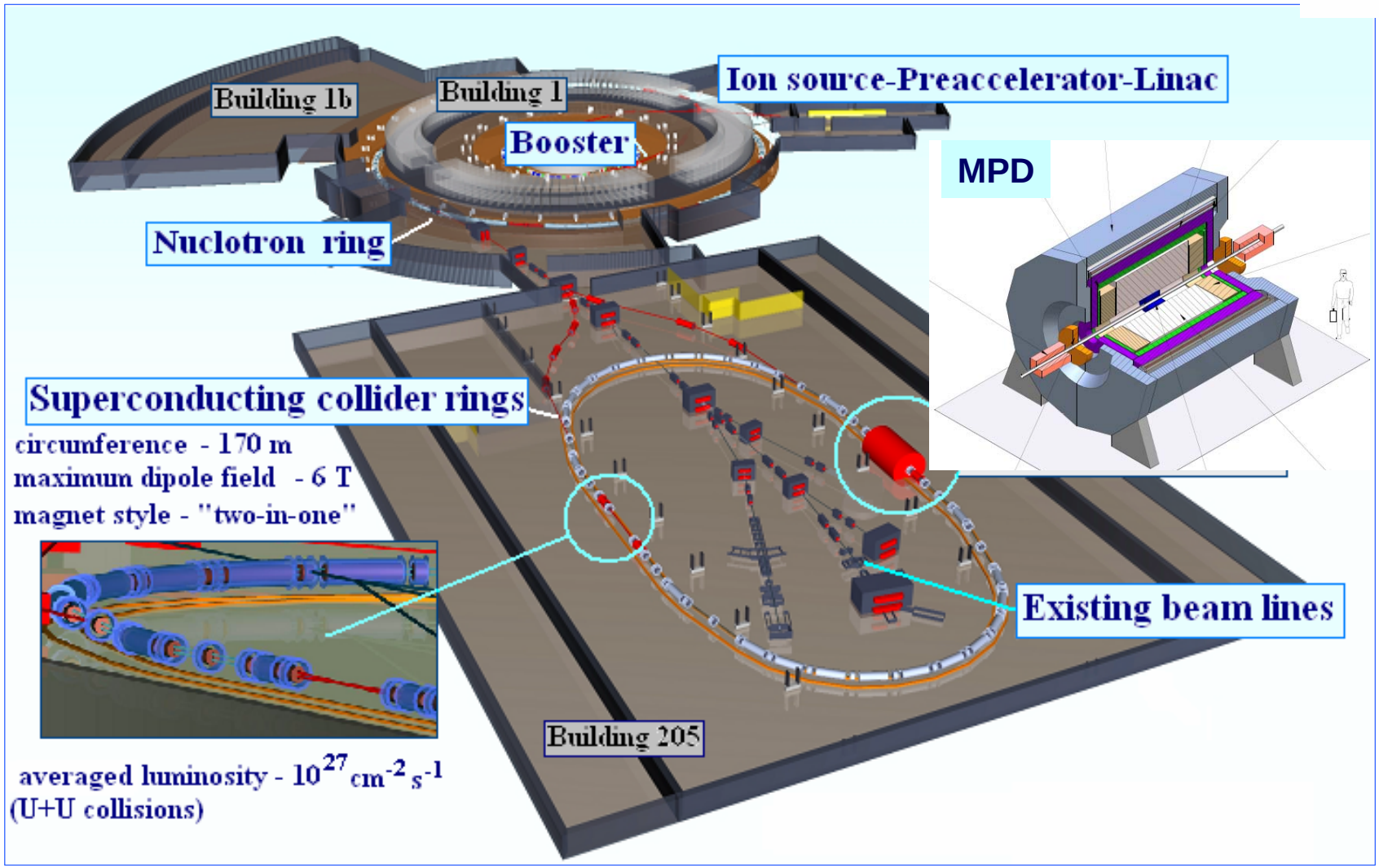
  Booster & upgraded Nuclotron (Nuclotron-M)

  Ion Storage Rings with two intersection points

  & MultiPurpose Detector (MPD)

- *The conceptual design – close to completion*

Collider NICA complex allocation



Collider NICA characteristics

Ring circumference, m	251.2
Ion kinetic energy, E [GeV/u], min/max	1/3.5
Particle number per bunch, $N_{ion/bunch}$	$2.0 \cdot 10^9$
Bunch number, n_{bunch}	20
Horizontal emittance, ε [π mm mrad]	0.7
Momentum spread, $\Delta p/p$	0.001
IBS life time [sec]	≥ 100
Beta function at interaction points, β^*	0.5
RF voltage, U_{RF} [kV]	200
Laslett tune shift, ΔQ	0.0044
Beam-beam parameter	0.009
Luminosity, L [$cm^{-2}s^{-1}$], peak/average	$2/ (1 \div 1.5) \cdot 10^{27}$

Major milestones

- **Stage 0**
  Jan 2008 — ***Letter of Intent***
- **Stage I**
  (2007-2009) — *upgrade of the **Nuclotron facility***
  wide program of R&D
  preparation of Technical Design Report
- **Stage II**
  (2008-2012) — *design & construction*
  production lines for magnets
  & other parts & systems
  booster completion
  infrastructure development
- **Stage III**
  (2010-2012) — *+ assembling*
- **Stage IV**
  (2013) — *commissioning*
  & putting in operation

Experimental Tasks – *the first stage*

the following effects will be studied
(on energy & centrality scanning):

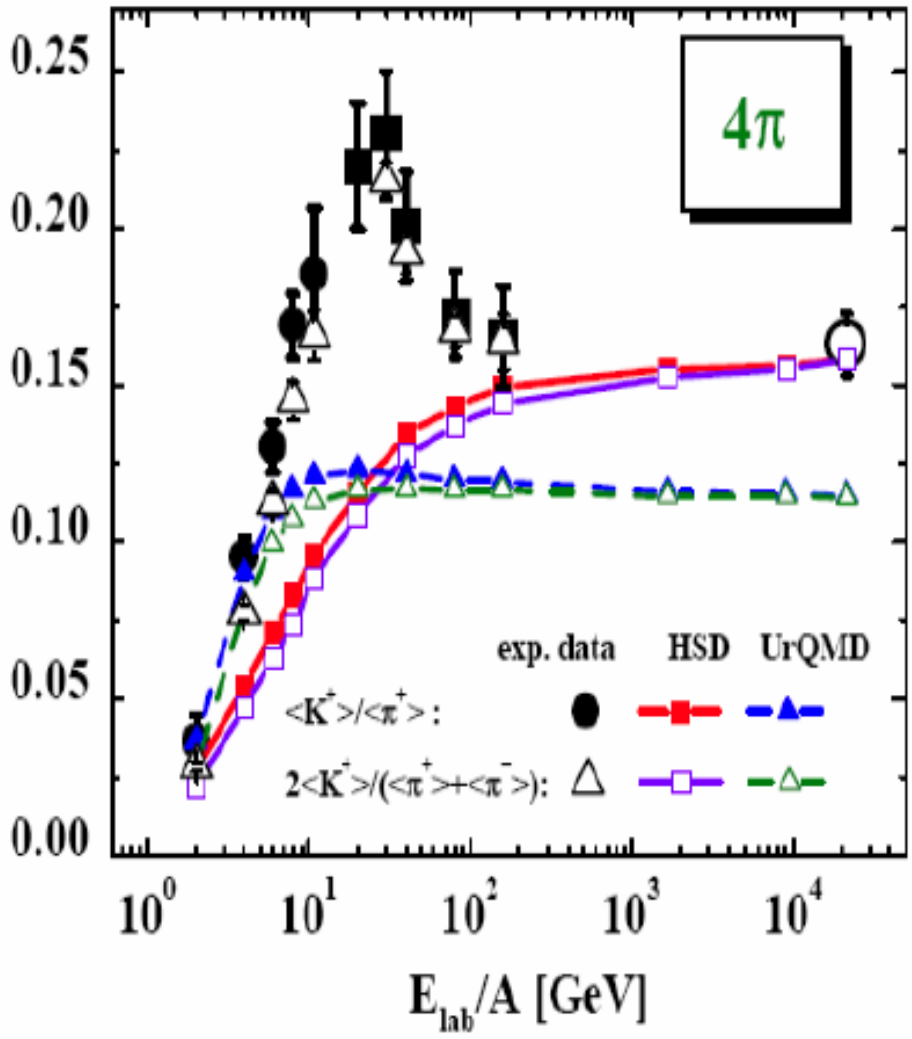
- ***Event-by-event fluctuation in hadron productions***
  (multiplicity, Pt etc.)

- ***HBT correlations indicating the space-time size of the systems involving*** π, **K, p,** Λ
  (possible changes close to the de-confinement point)

- ***Directed & elliptic flows for various hadrons***

- ***Multi-strange hyperon production:***
  yield & spectra *(the probes of nuclear media phases)*

Possible indication on phase transition



measurements of related yields for charged kaons & pions

Some enhancement is indicated in the energy region around
~ $E_{лаб}$ = 30 А ГэВ

MPD – conceptual design

Basic principles of experimental approach:

- ***Technical solutions should be as simple as possible***
- ***Detailed simulation of expected parameters & corresponding cross-checks by available data***
- ***The experiment should fulfill the major requirement: physical observables must be clearly (qualitatively) distinguished from possible apparatus effects***

MPD – conceptual design

Basic principles of organization

- ***At first approximation***
  - all sub-detectors could be designed & constructed at JINR based on the existing expertise & infrastructure

- ***some sub-detectors*** *could have* ***alternative*** *designs in order to provide possibility for potential collaborators to substitute/accomplish corresponding groups in future*

- *The first* ***realistic draft of the Letter of Intent*** *should be ready by* ***January 2008***

- ***The rough cost*** *estimation should be done by that time as well*

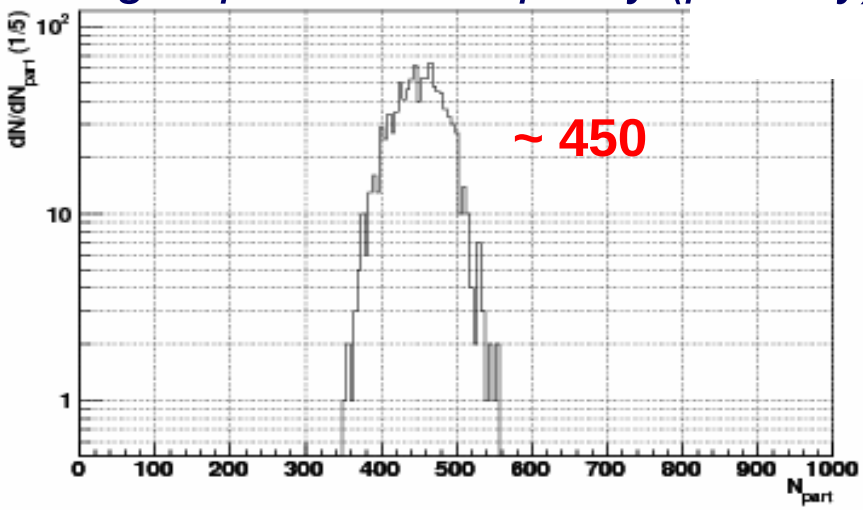
MPD – conceptual design

First stage of simulation based on UrQMD & GEANT4
in the framework of MPD-Root shell:

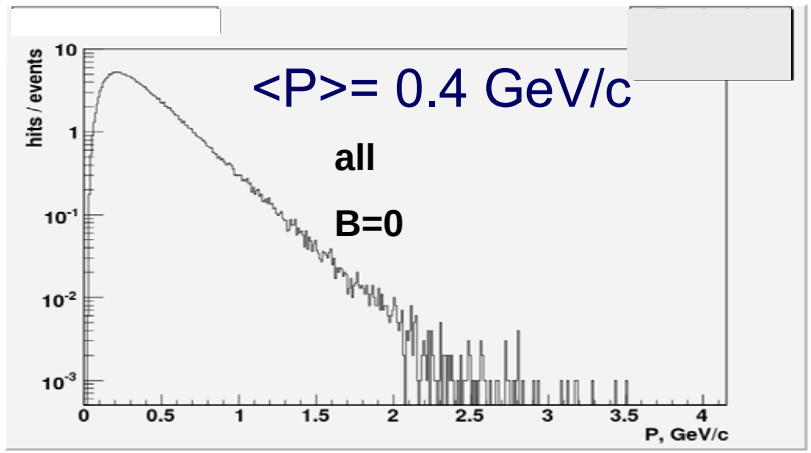
- *Au+Au collisions with total energy of 4.5 + 4.5 AGeV*
- *Central interaction within b: 0 – 3 fm*
- *Minimum bias within b: 0 – 15.8 fm*
- *Collision rate at $L=10^{27}$ $cm^{-2}s^{-1}$: ~ 6 kHz*

*central collision | η | < 1, **p** >100 MeV/c*

charged particle multiplicity (primary)

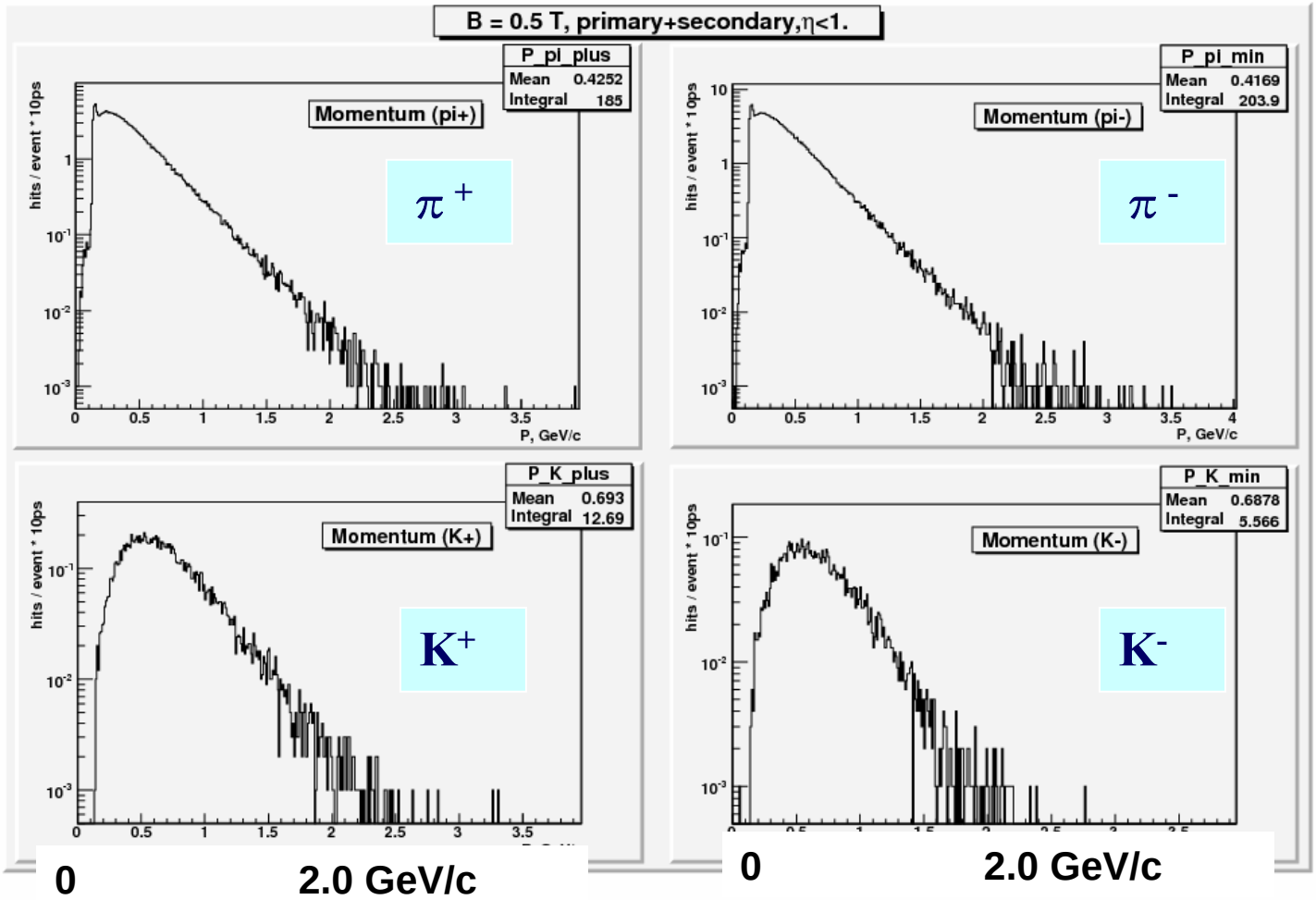


momentum spectrum



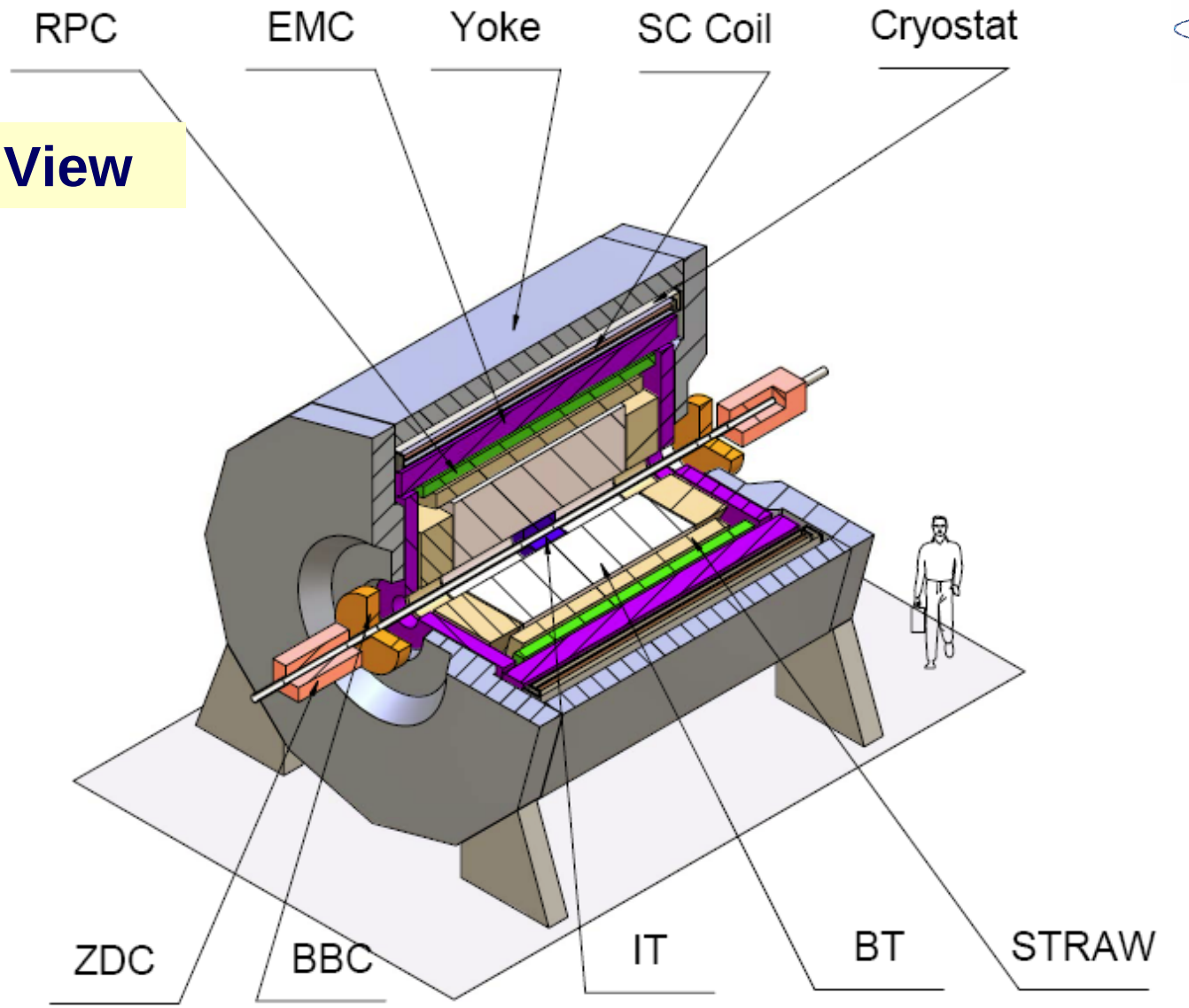
MPD – conceptual design

momentum spectra for various particles



MPD – conceptual design

General View



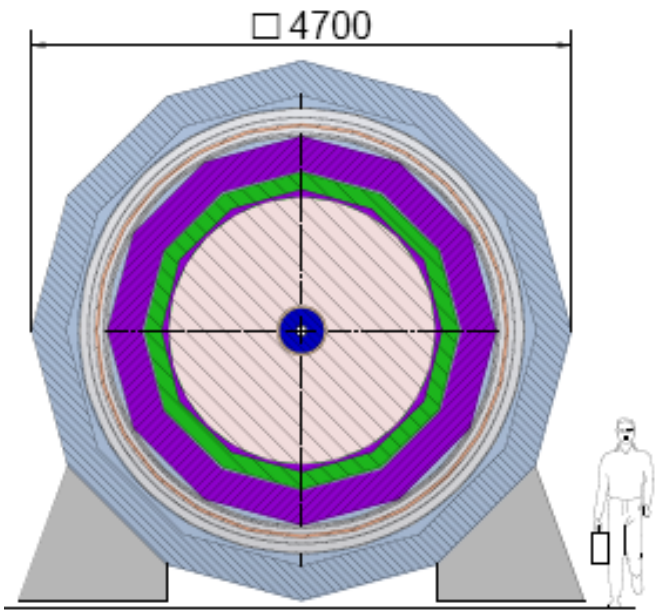
MPD – conceptual design

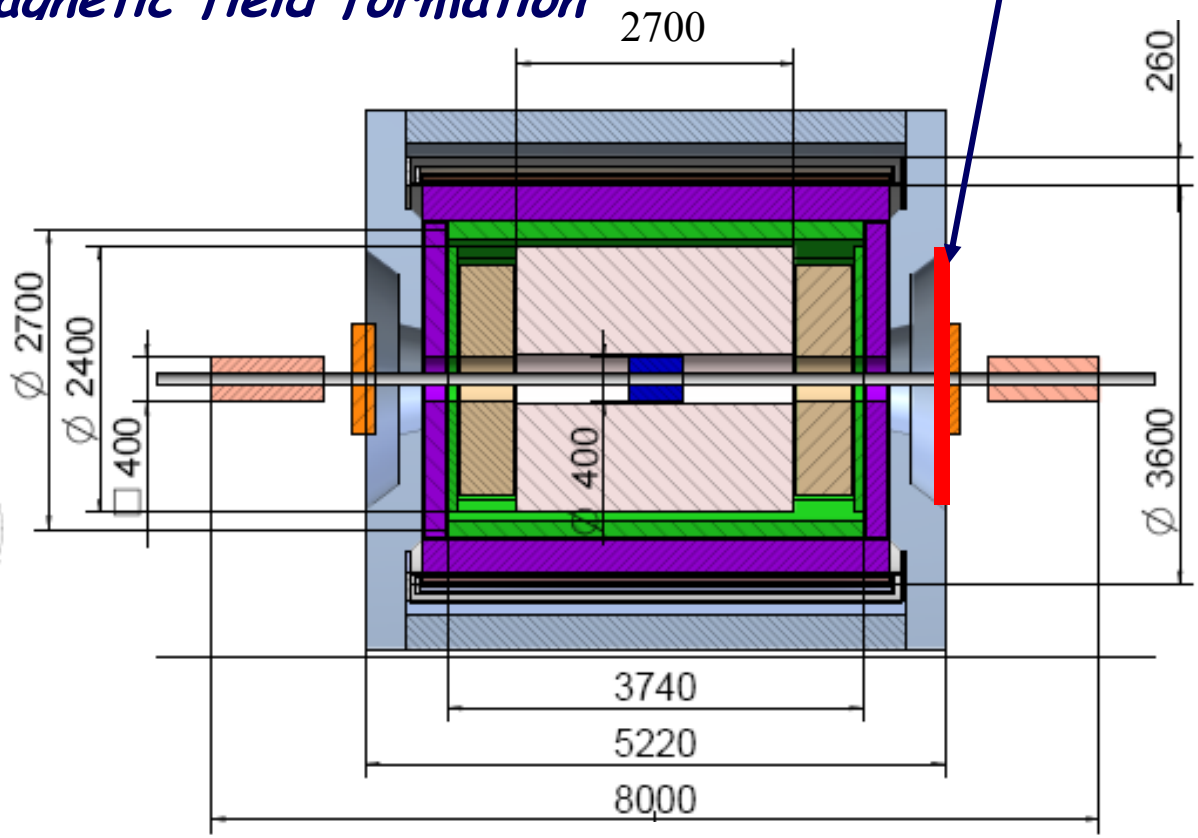
basic geometry

preliminary

Defined as a compromise bet...

- ***TOF requirement***
- ***tracker resolution***
- ***magnetic field formation***



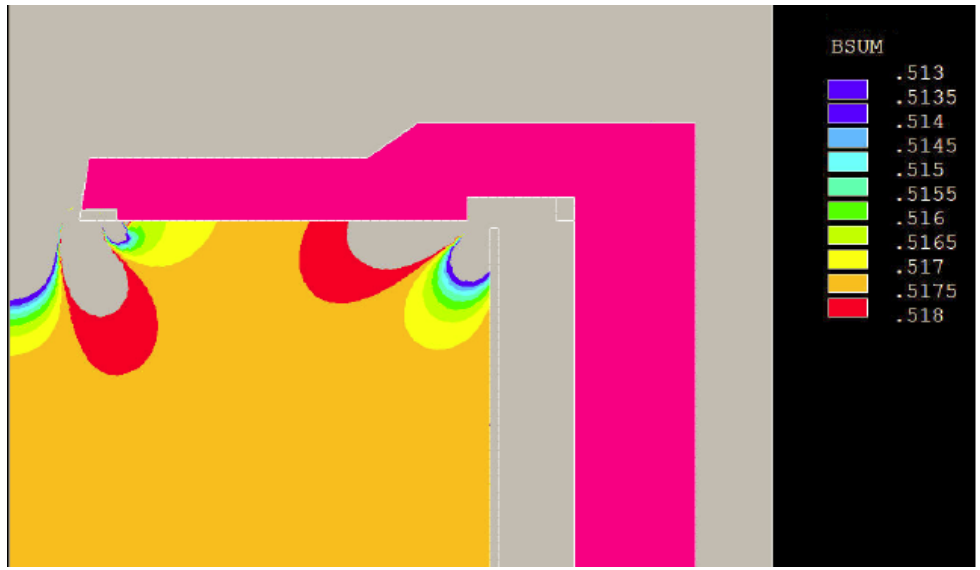


limited by collider optics

MPD – conceptual design

Magnet:

- *superconducting* ***solenoidal*** *magnet*
- *magnetic field* ***0.5 T***
- *cryostat* ***inner radius*** *(region available for the detector)* ***~ 1.5*** *m*
- ***iron yoke*** *is used to form a* ***homogeneous*** *magnetic field*
- *color step* ***5*** *Gauss (~1 pm)*
  - ***good homogeneity***
  feasible for ***TPC***



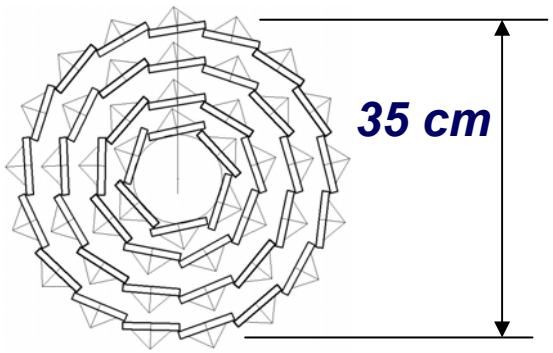
MPD major sub-detectors

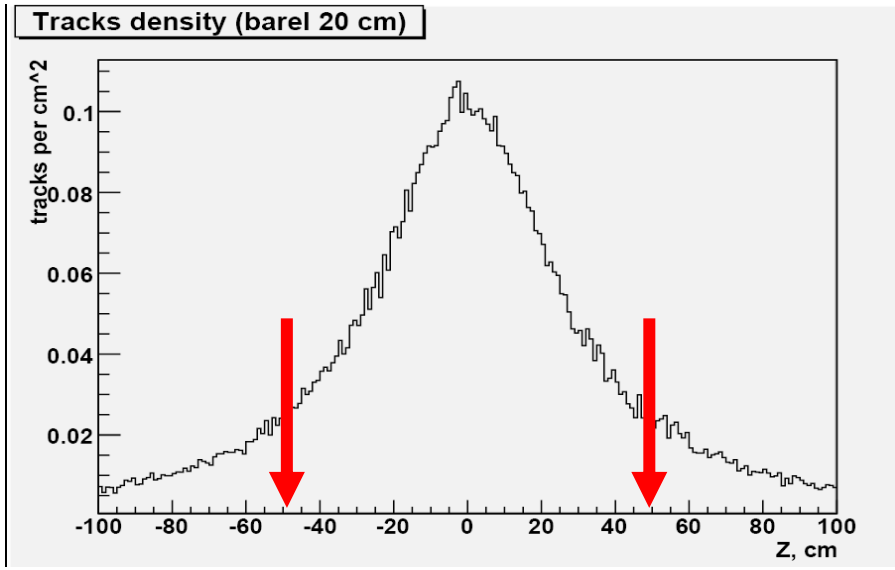
- **Inner Tracker (IT)** - *silicon strip detector / gem chamber for tracking close to the interaction region*
- **Barrel Tracker (BT)** - ***TPC*** *and* ***Straw*** *(for tagging) for tracking & **precise** momentum measurement in the region* $-1 < \eta < 1$
- **End Cap Tracker (ECT)** – ***Straw*** *(radial) for tracking & momentum measurement at* $|\eta| > 1$ *(+ reaction plane)*
- **Time of Flight (RPC)** *to measure Time of Flight for charged particle identification in the region* $-1 < \eta < 1$
- **Electromagnetic Calorimeter (ECAL)** *for* π^0 *reconstruction & electron/positron identification*
- **Beam-Beam Counters (BBC)** *to define centrality & interaction point, **ToF** starting time*
- **Zero Degree Calorimeter (ZDC)** *for centrality definition*

MPD – conceptual design

Inner Tracker:

- *Complementary detector for track precise reconstruction in the region close to the interaction piont*
- *Cylindrical geometry (4 layers) covering the interaction region ~ 50 cm along the beam axis*
- *Possible contribution to dE/dx measurements for charged particles*



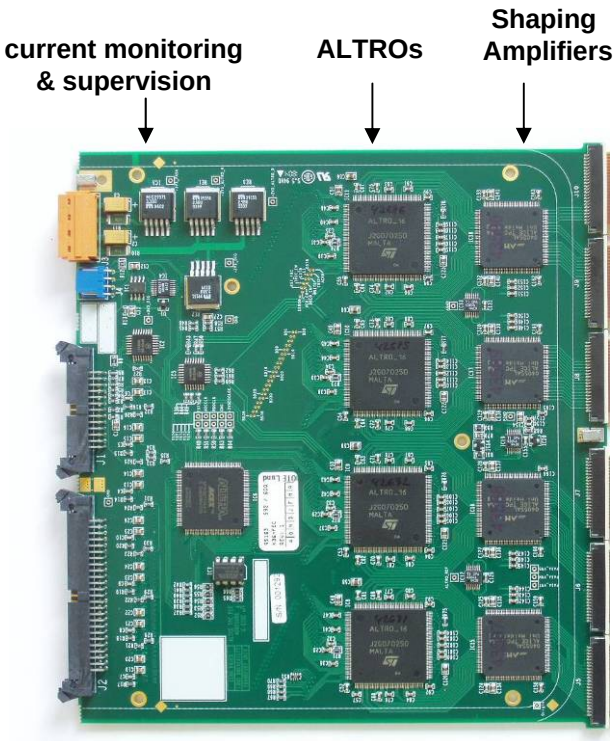


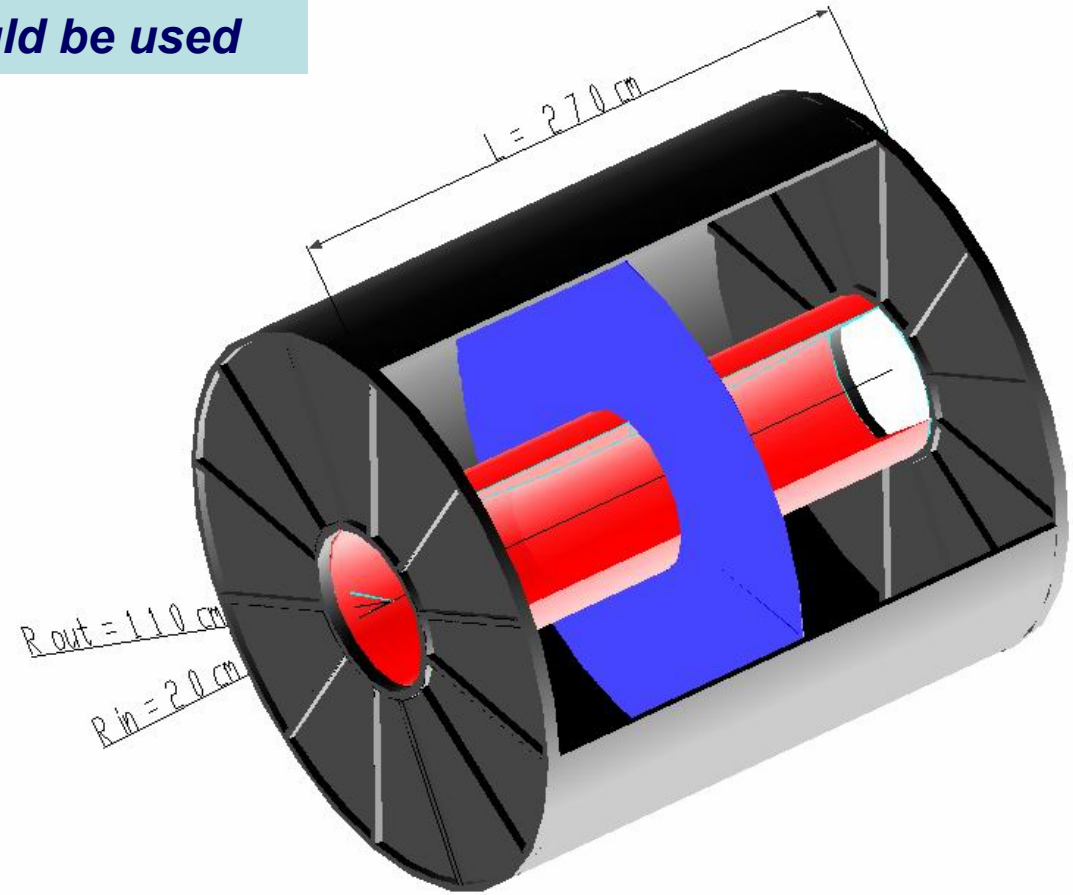
TPC option for the Tracker

specification (preliminary)	
Outer radius	~ 110 cm
Inner radius	20 cm
Drift length	~135 cm
Number of sections (each side)	12
Total number of readout chambers	24 (12 – each side)
Drift time	~ 20-30 μs
Multiplicity for charged particles (central collision)	~ 500
Total pad/channels number	~ 70000
Two track resolution	2cm
Special resolution (σ_φ x σ_R x σ_z)	3 x 0.4 x 3 mm
Maximal rate	6 kHz

TPC design & readout

FEE and Readout electronics from ALICE TPC (ALTROs and PASAs) could be used





TPC: charged particle identification

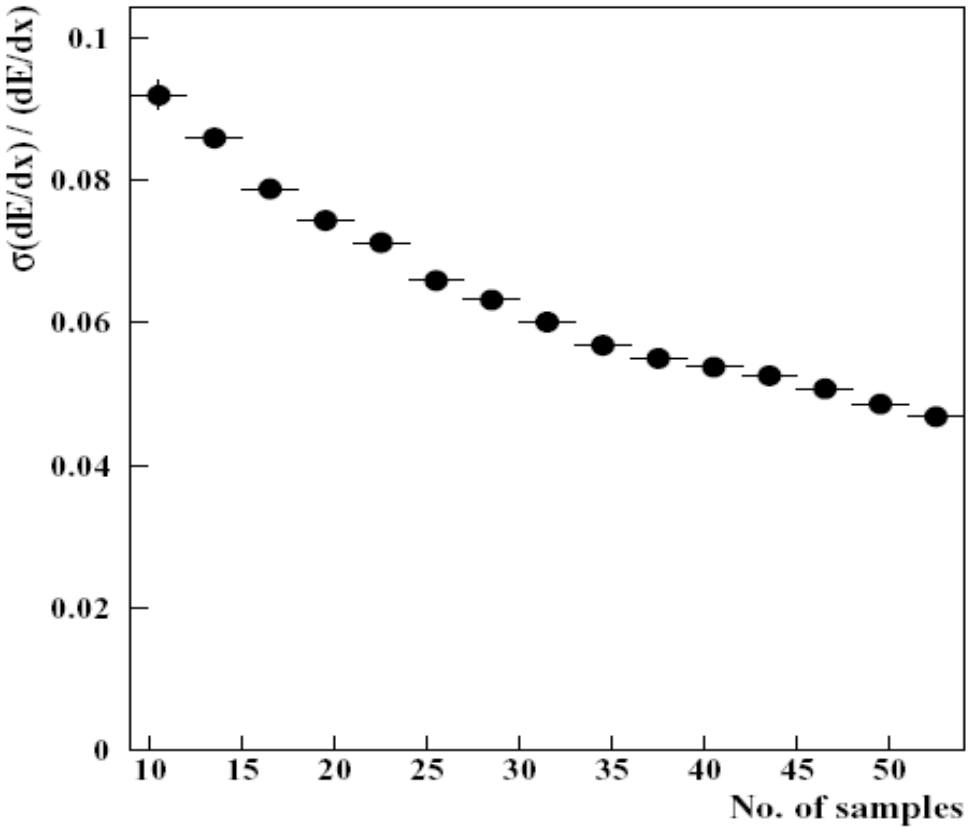


Figure 3.35: dE/dx resolution as a function of the number of samples in the NA35 TPC. Sample length 4 cm, gas Ar/CH_4 (91/9).

Gas mixture - Ar/CH4 (90/10)

~ 6% of dE/dX resolution is expected

π/K separation to 0,7 GeV/c

(π+K)/p to p = 1,2 GeV/c

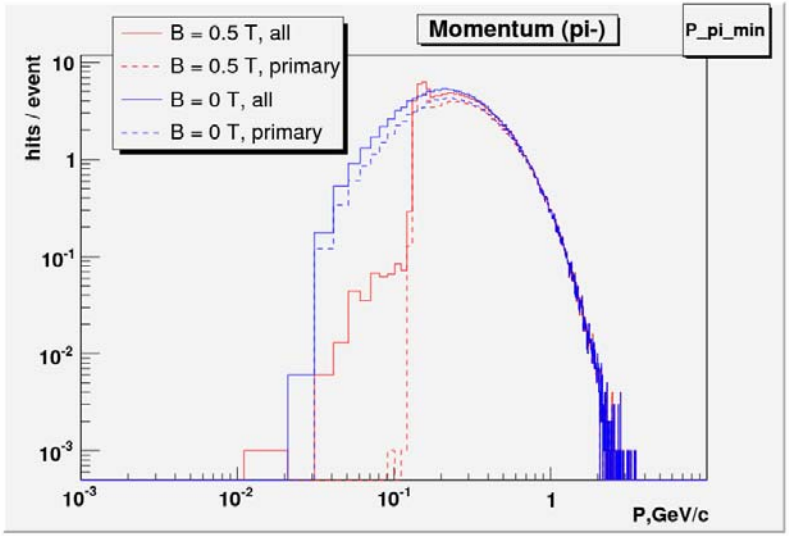
Time of Flight

- **RPC** – *the major detector for particle identification*
- *separation should be provided*
  for pion / kaon in the momentum range **0-1,5 GeV/c**
  for proton / kaon in the momentum range **0-2,5 GeV/c**
- *2 stations of scintillation counters (BBC) situated symmetrically from the interaction region near the beam pipe give the start signal*
- *RPC detectors on the radius* **1,3 m** *provides the TOF measurement*
- *RPS provides additional targeting for track reconstruction in BT*

ToF specification

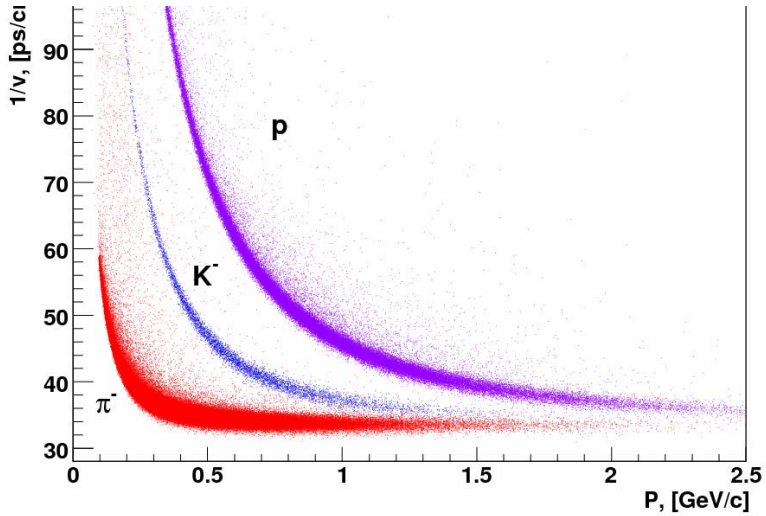
- *the RPC TOF system looks like barrel with the length 4 m and radius of 1,3 m.*
- *the barrel surface is about 33 m2*
- *the dimensions of one RPC counter is 7 cm x 100 cm it has 150 pads with size 2,3cm x 2 cm.*
- *the full barrel is covered by 160 counters*
- *the total number of readout channels is 24000*
- *Time resolution ~ 100 ps*

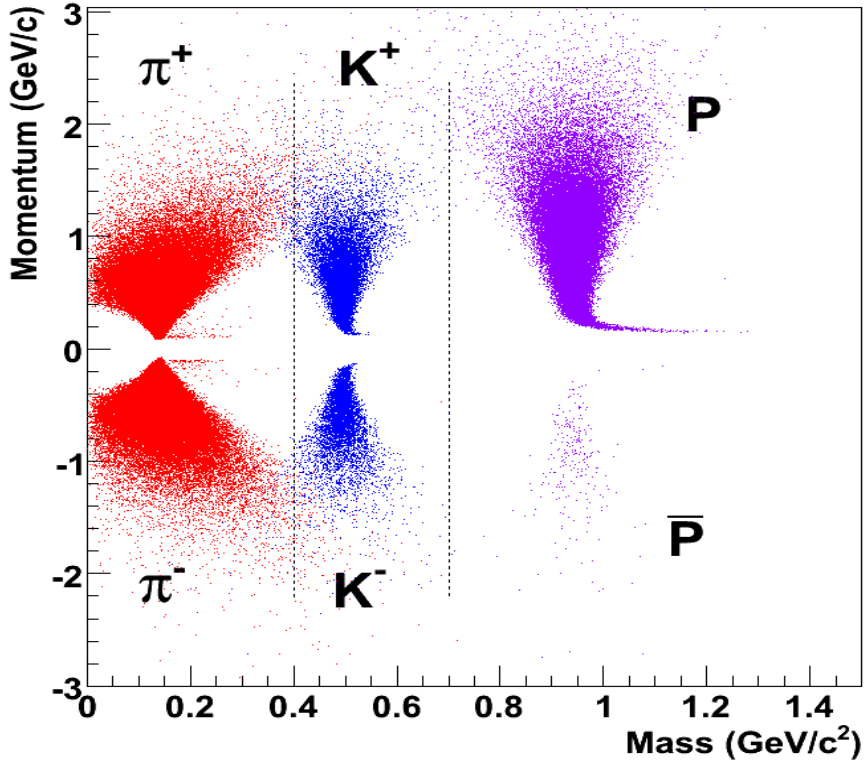
ToF features



track momenta

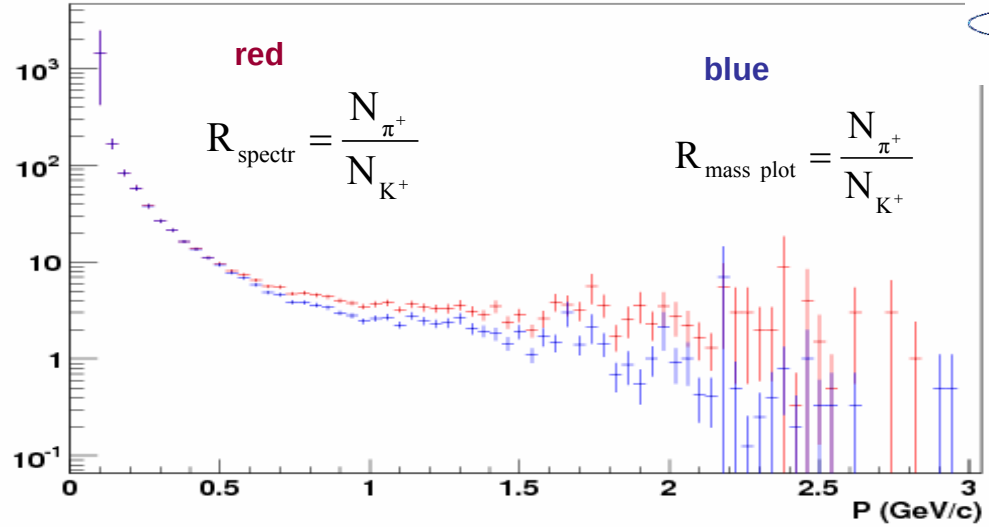
separation of primary particles for central events



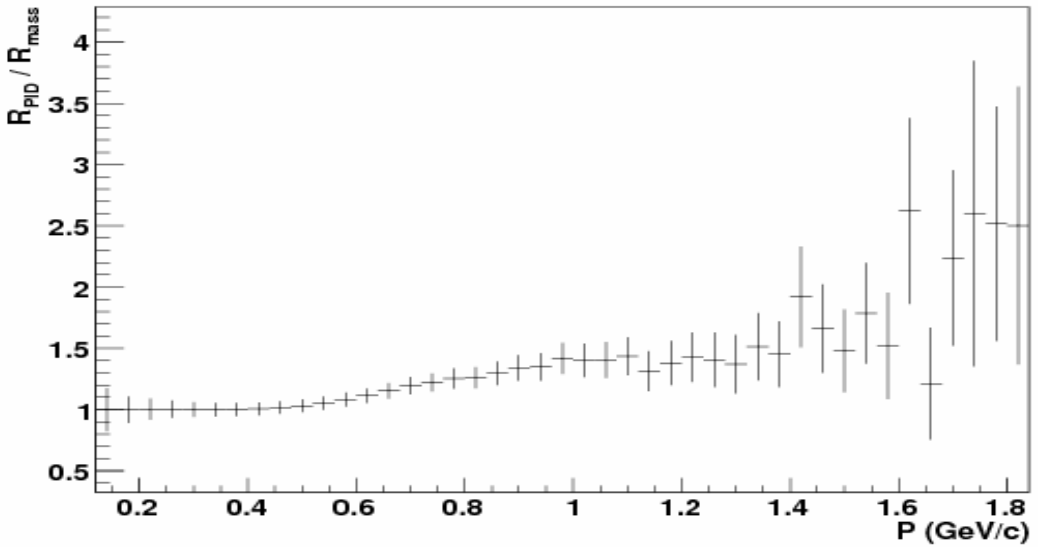


ToF features

momentum spectra ratios for primary **K / π** *particles*



no essential bias on momentum for the separation

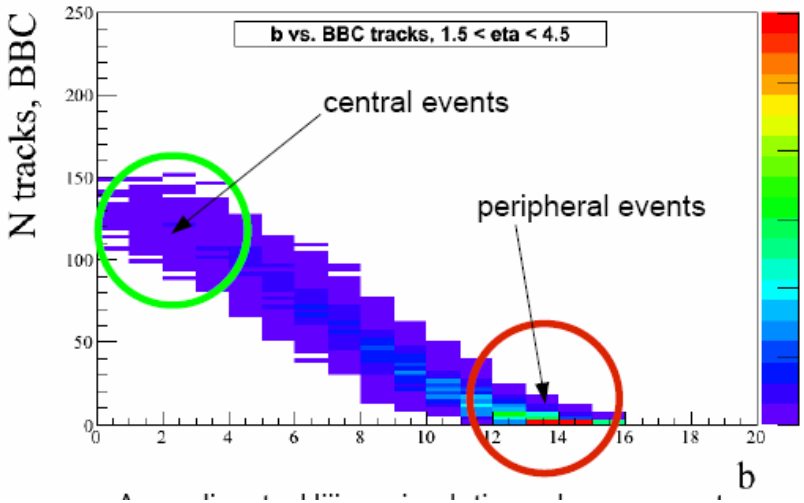


BBC design

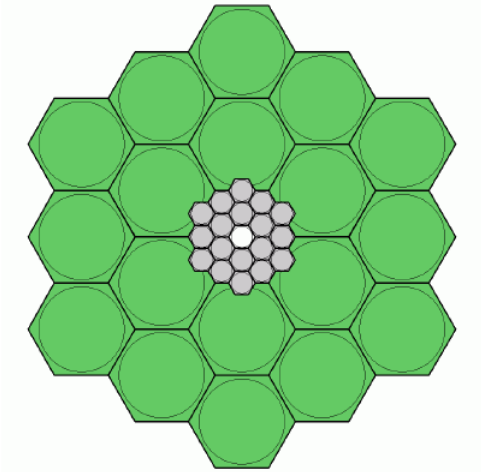
Centrality definition (trigger level)

MinBias trigger

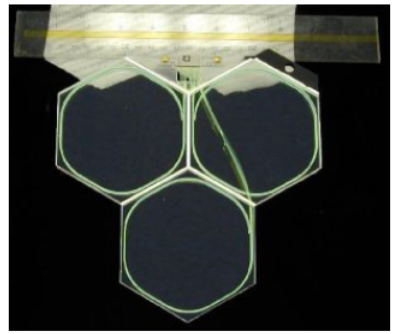
Au+Au @ 9 GeV



Tech. details

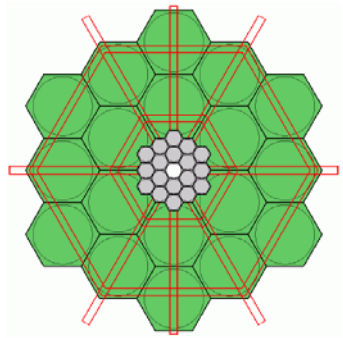


Small tile can be inscribed in circle with **12 cm** diameter, large tiles are four times bigger.
Exact inner radius: **5.2 cm**
Exact outer radius: **104.0 cm**



- The BBC scintillators are from 1-cm thick Kuraray SCSN-81.
- Scintillation light produced within a tile was collected by four 0.83-mm diameter Y-11 doped optical fibers.

Support

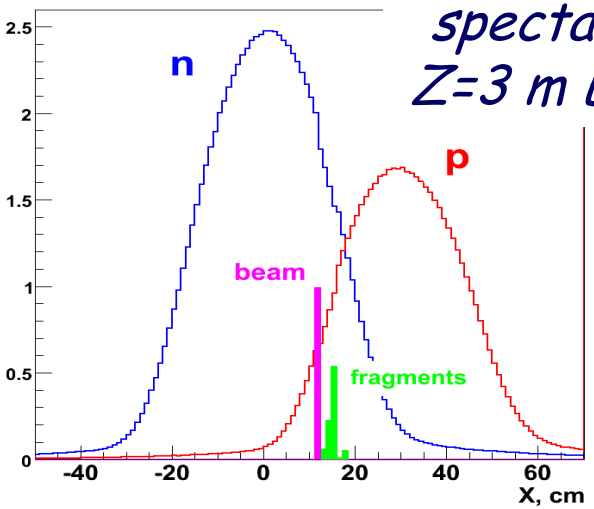


ex.: STAR BBC support frame

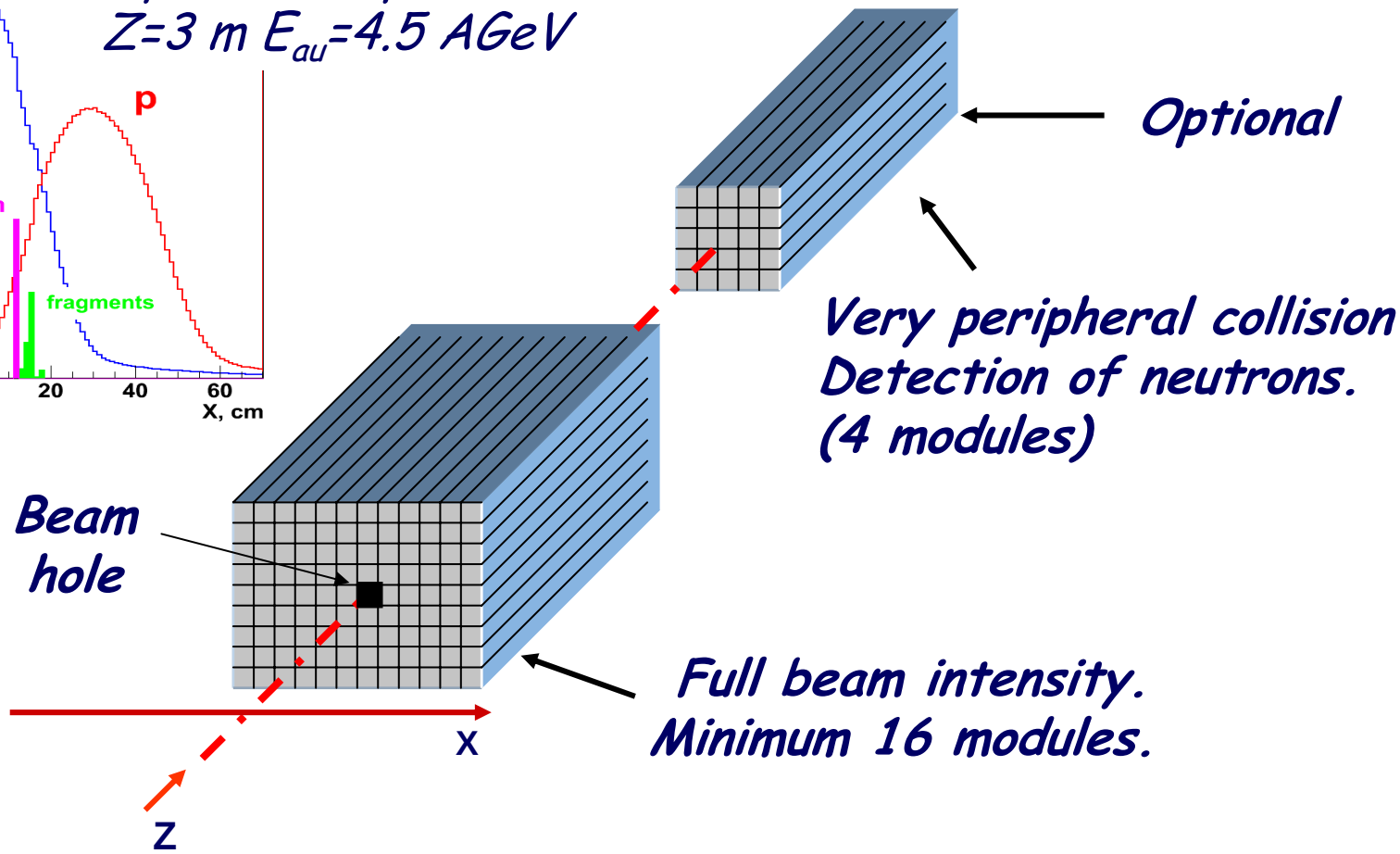
Zero Degree Calorimeter *(INR RAN)*

- *measurement of centrality: b ~ A - Nspect*
  selection of centrality at trigger level
- *measurement of event-by-event fluctuations*
  to exclude the fluctuation of participants
- *monitor of beam intensity by detecting*
  the neutrons from electromagnetic dissociation
- $\varepsilon_e / \varepsilon_h = 1$ - *compensated calorimeter*
- *Lead / Scintillator sandwich*

Schematic view of ZDC configuration



spectator spots at
Z=3 m E_{au}=4.5 AGeV



Organization – *sub-detector groups*

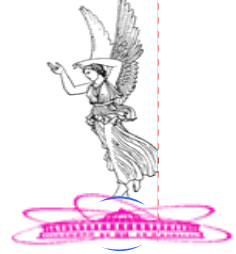
- Magnet — *V.V.Borisov*
- IT — *V.A.Nikitin*
- BT
  - TPC — *Yu.V.Zanevsky*
  - STRAW — *V.D.Peshekhonov*
- ECT *(STRAW wheels)* — *V.D.Peshekhonov*
- TOF *(RPC)* — *V.M.Golovatyuk*
- ECAL — *I.A.Tyapkin*, *H.Abramyan*
- BBC *(+ trigger)* — *D.Arkhipkin*
- ZDC — *A.B.Kurepin*

Summary

- *The work on the MPD project is well progressing*
- *Many experts are involved*
- *Many new ideas & suggestions have been considered*
- *The major milestones are fixed*

the Letter of Intent should be ready by January 2008

Thanks to the MPD working group

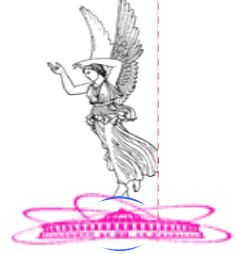


NICA center group:

Afanasiev S.V.
Nikitin V.A.
Borisov V.V.
Peshekhonov V.D.
Pavlyuk A.V.
Golovatyuk V.M.
Kurepin A.B.

+ volunteers

Shabunov A.V.
Potrebenikov Yu.K.
Zanevskij Yu.V.
Kiryushin Yu.T.
Murin Yu.A.
Tyapkin I.A.
Arkhipkin D.
Abramyan H.
Avdejchikov V.V.
……
…..



Spare

Organization - center NICA

is organized in the ***Laboratory of High Energy***
for the project preparation: *Director -* ***A.S.Sorin***

Four groups *started active works in:*

Theory development *(led by - V.D.Toneev)*

Accelerator complex design *(- A.D.Kovalenko, I.N.Meshkov)*

MPD project preparation *(- V.D.Kekelidze)*

Software development *(- O.V.Rogachevsky)*

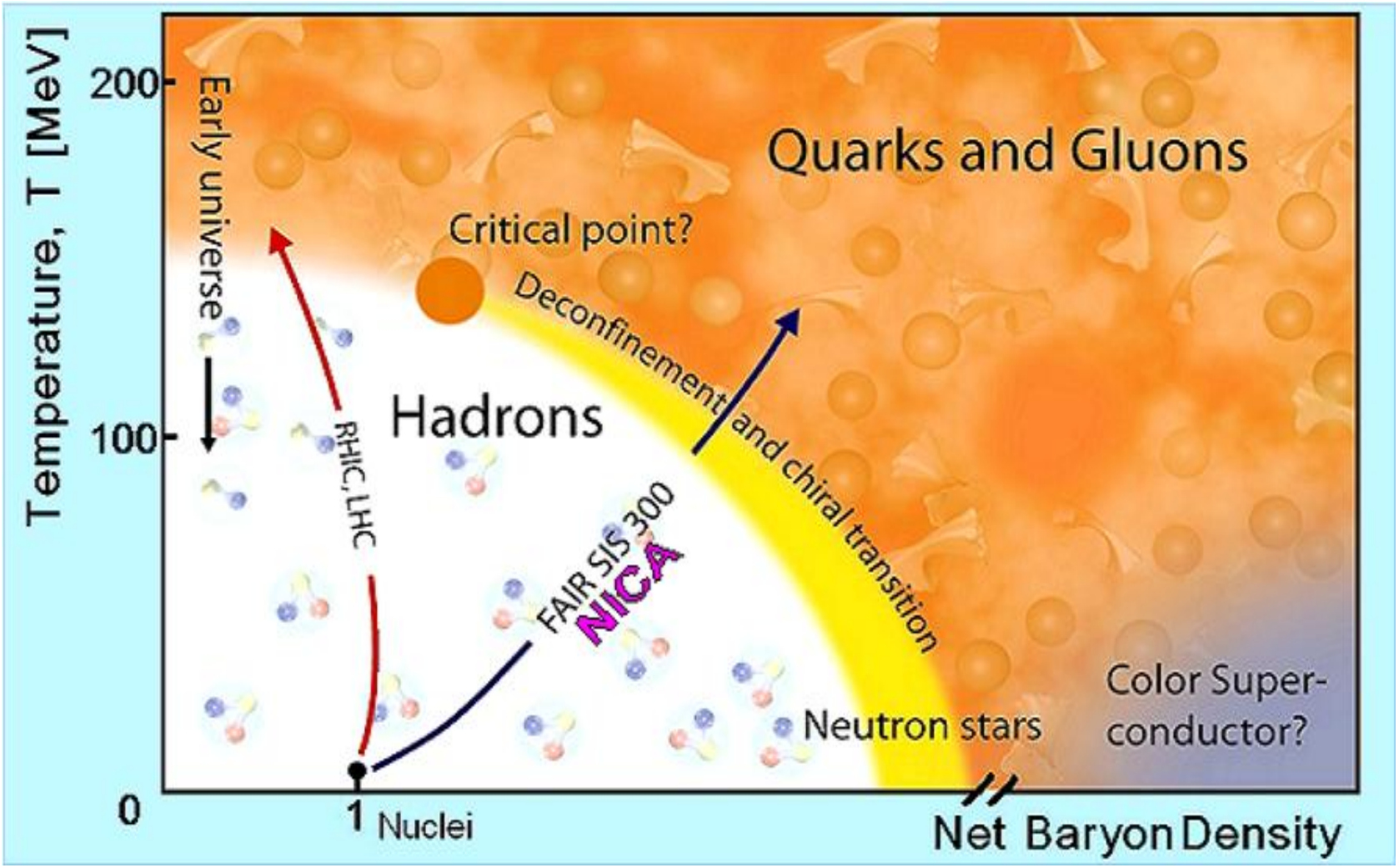
Physics motivation

- *In-medium properties of hadrons*
  & nuclear matter equation of state will be studied
  including a search for
  possible manifestation of de-confinement
  and/or chiral symmetry restoration,
  phase transition, mixed phase & critical end-point

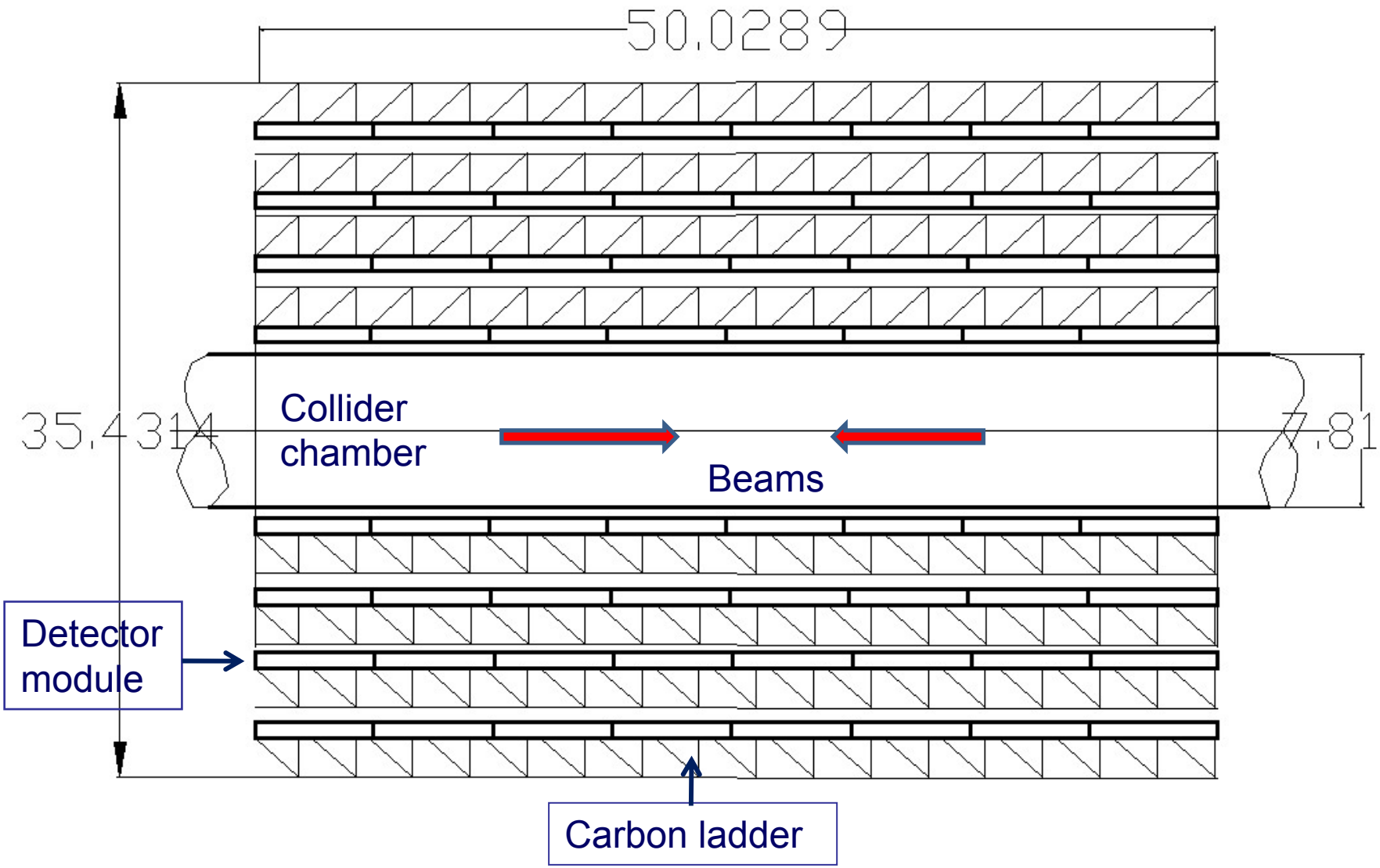
  *in collisions of **heavy ion** (over atomic mass range A = **1-238**)*
  *by scanning of the energy region $\sqrt{s_{NN}}$ = **3-9 GeV***

- *These investigations are relevant for understanding of*
  the physics of heavy ion collisions,
  the evolution of the Early Universe
  & formation of the neutron stars

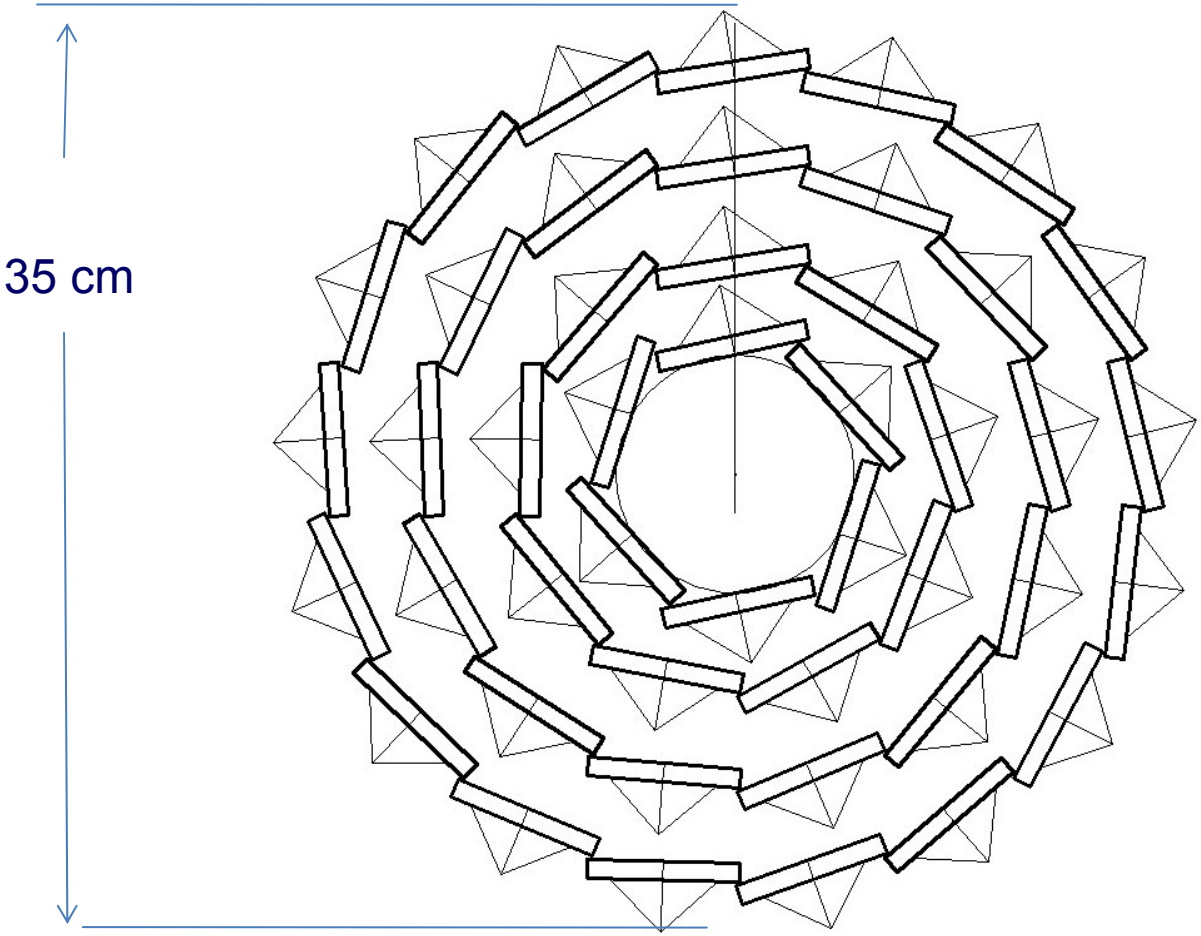
Physics motivation



Longitudinal view of MPD SVT



Transverse view of MPD SVT



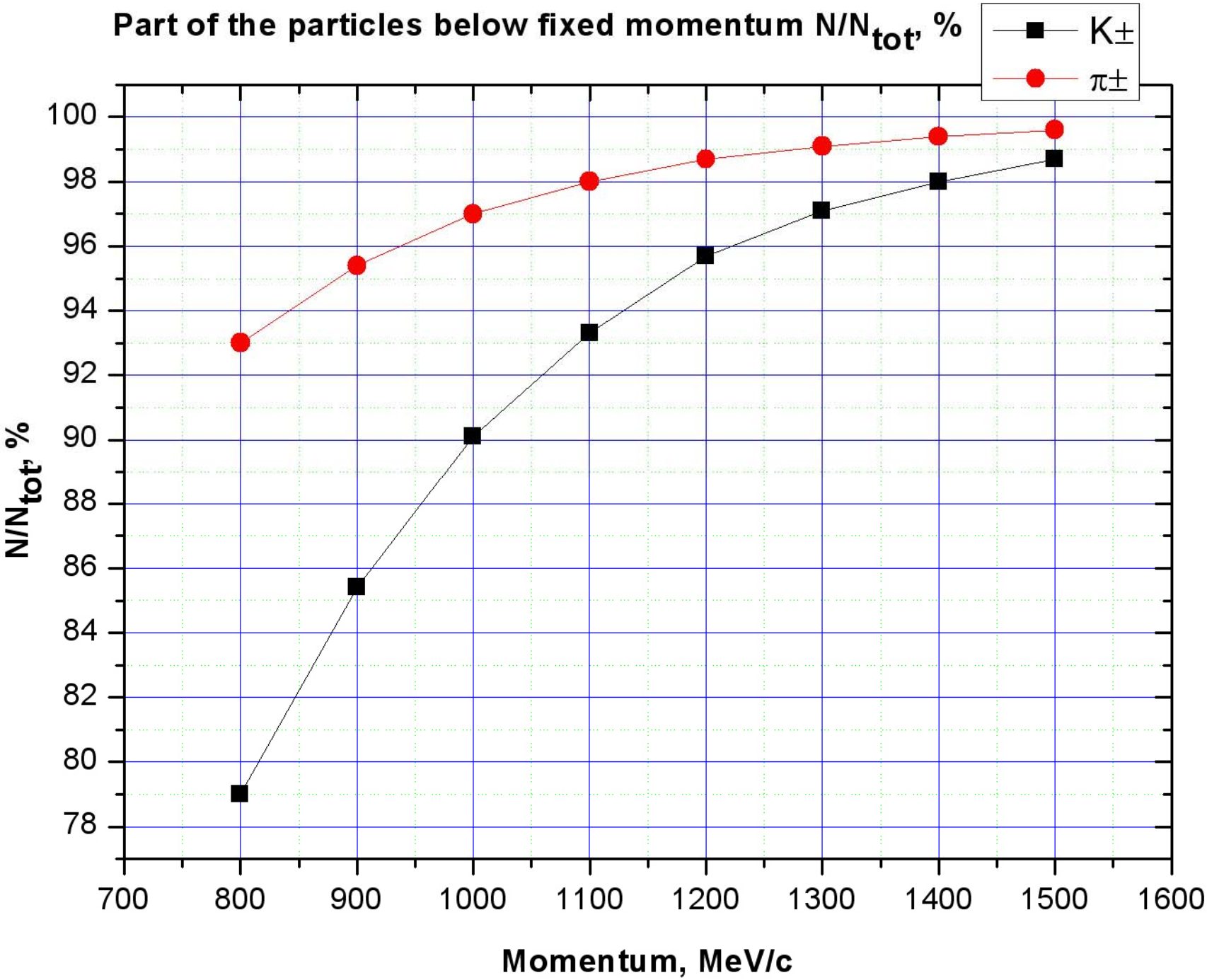
Number of modules 357.

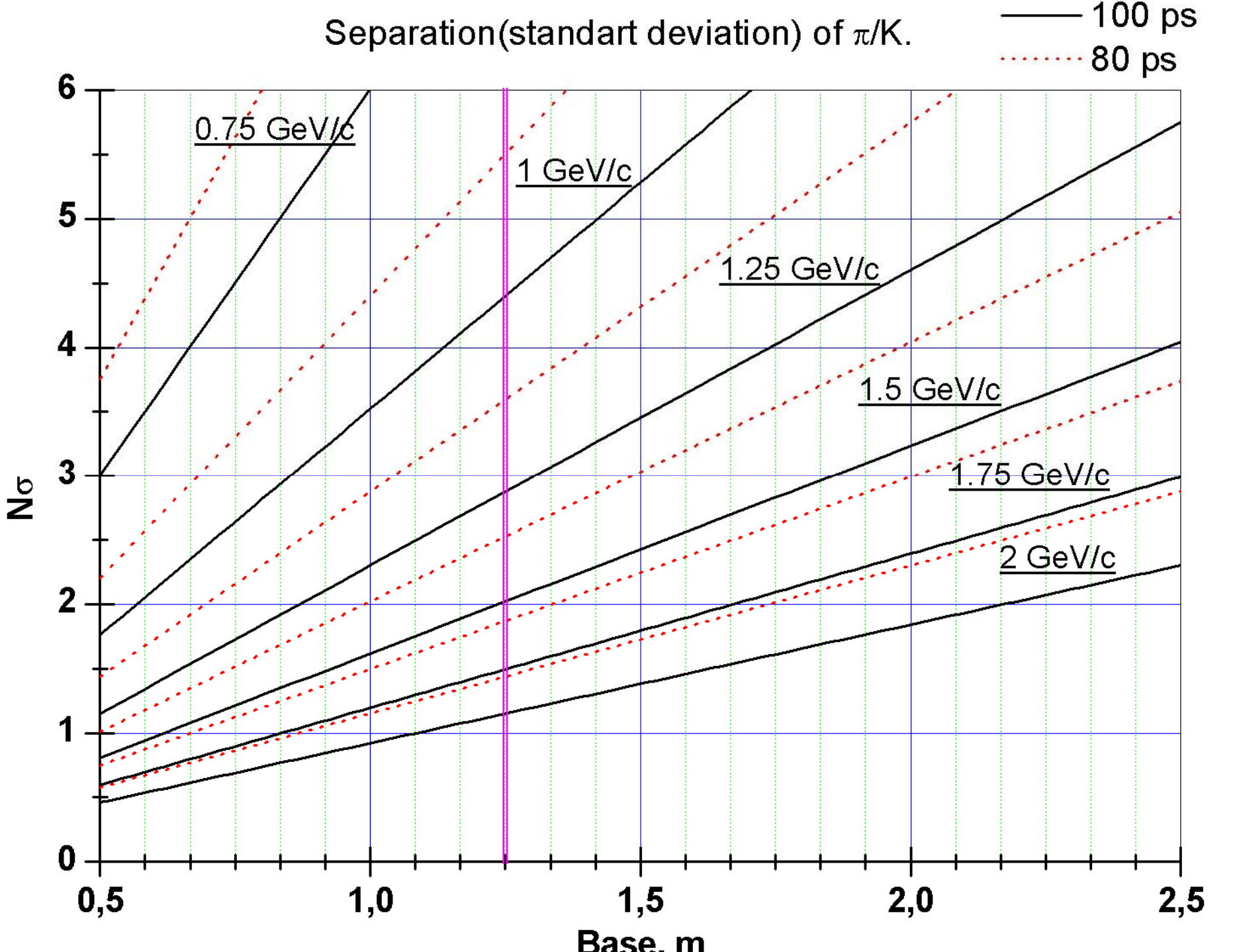
Number of detectors 714.

Number of electronic channels 215 500

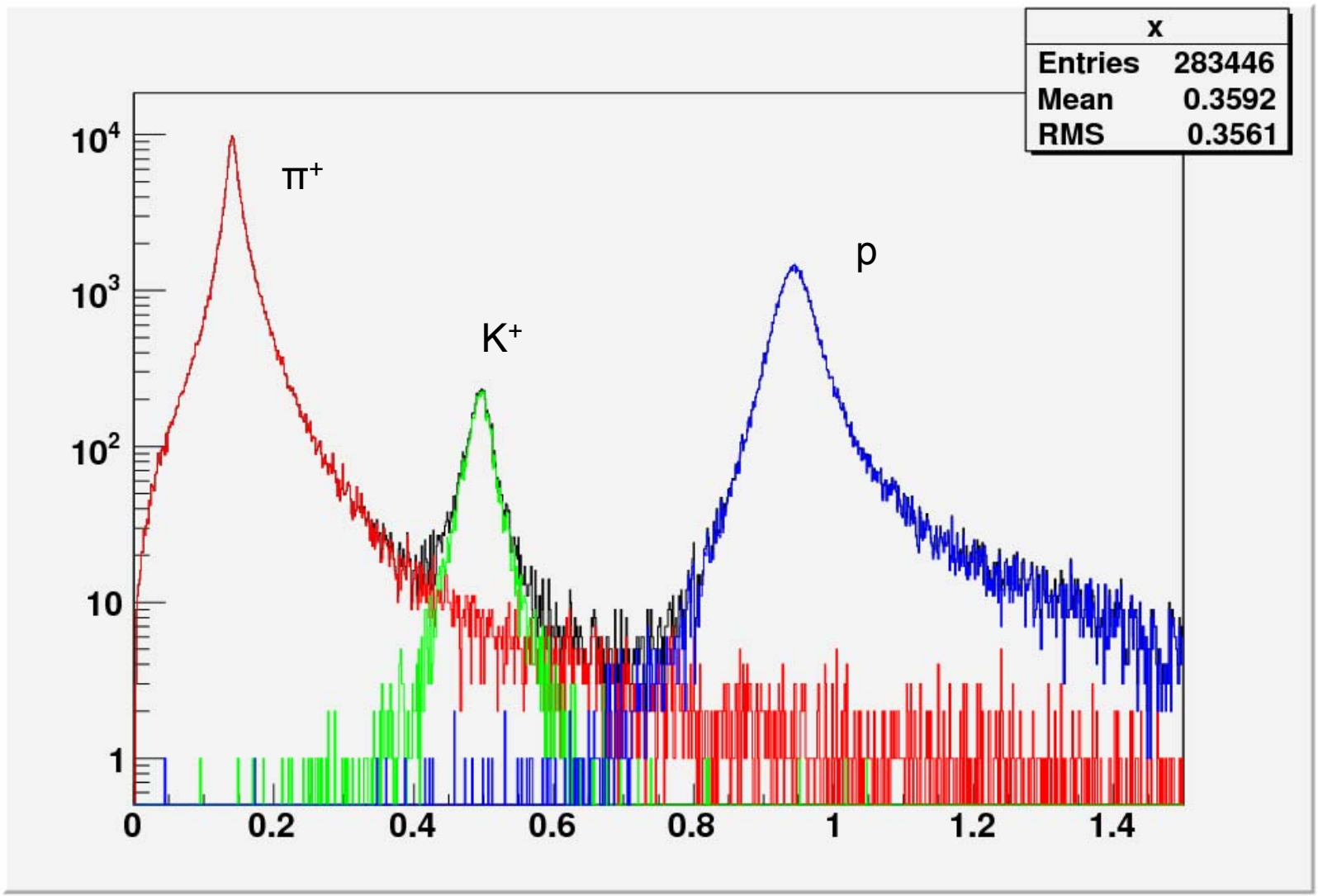
Proposed parameters

- Radius from the beam line - 1,3 m
- Time resolution -100 ps
- Max momentum of π/K system separated
  better than 2,5 σ at 1,3GeV/c
- Efficiency (acceptance) for π/K – better than 97%


Part of the particles below fixed momentum N/N$_{tot}$, %
K±
π±
N/N$_{tot}$, %
100
98
96
94
92
90
88
86
84
82
80
78
700
800
900
1000
1100
1200
1300
1400
1500
1600
Momentum, MeV/c


Separation(standart deviation) of π/K.
100 ps
80 ps
0.75 GeV/c
1 GeV/c
1.25 GeV/c
1.5 GeV/c
1.75 GeV/c
2 GeV/c
Nσ
Base, m
0
1
2
3
4
5
6
0,5
1,0
1,5
2,0
2,5

Separation primary particles for Central events

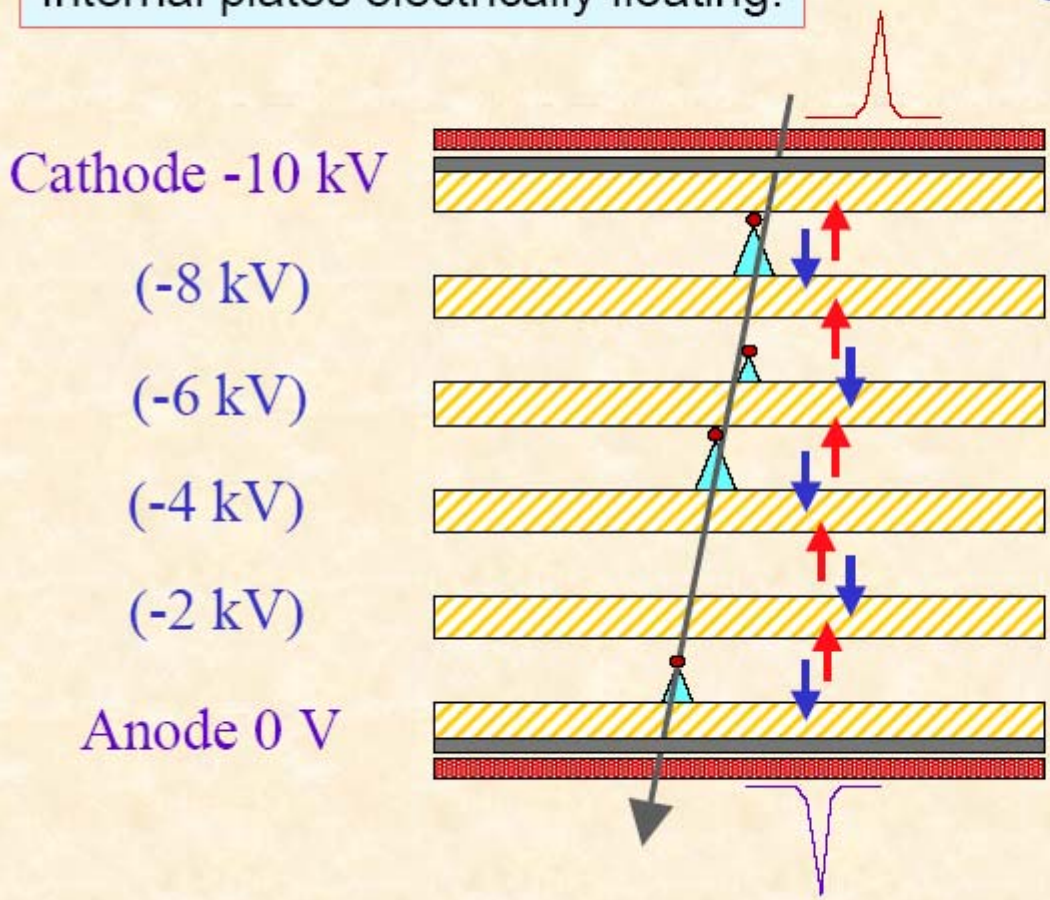


MULTIGAP RESISTIVE PLATE CHAMBER

E.Nappi
INFN-Bari

Internal plates electrically floating!

Stack of equally-spaced resistive plates with
voltage applied to external surfaces
Pickup electrodes on external surfaces
(resistive plates transparent to fast signal)

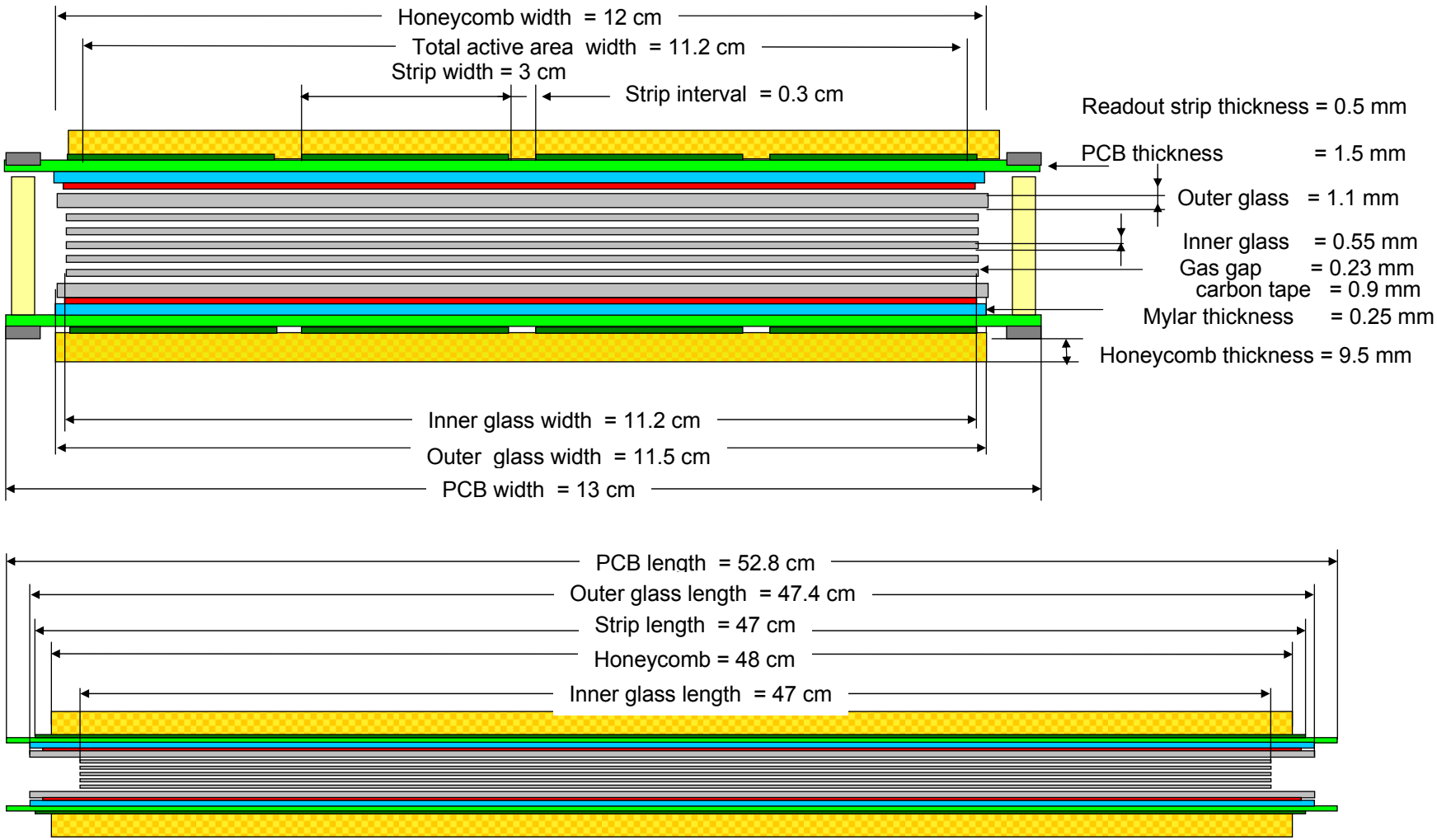


Flow of electrons and negative ions

Flow of positive ions

In this example: 2 kV across each gap (same E field in each gap) since the gaps are the same size - on average - each plate has same flow of positive ions and electrons (from opposite sides of plate) - thus zero net charge into plate.
STABLE STATE

TOF RPC design



Beam Beam Counter
at Hiroshima university

Run No.	Type of PMT	Type of radiator	Time resolution, ps
3	Hamamatsu R3432–01	Quartz	53
3	Hamamatsu R3432–01	Lucite	50
7	Hamamatsu R3432–01	Lucite	54
8	Hamamatsu R3432–01	Lucite	56
9	Hamamatsu R5506	Quartz	59
10	Hamamatsu R5506	Lucite	75
11	FEU–187	Quartz	55
12	FEU–187	Quartz	58
13	FEU–187	Quartz	52
14	FEU–187	Quartz	42

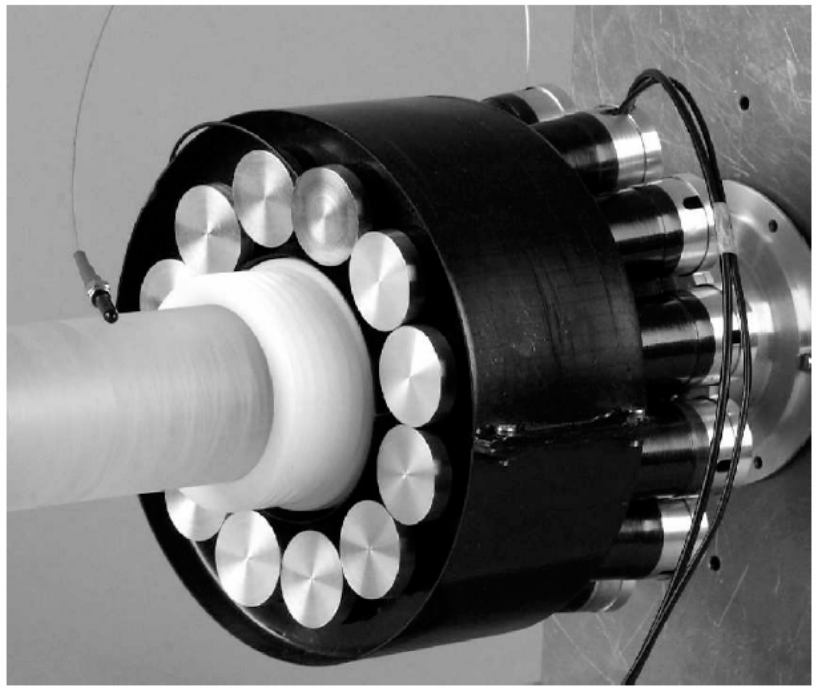
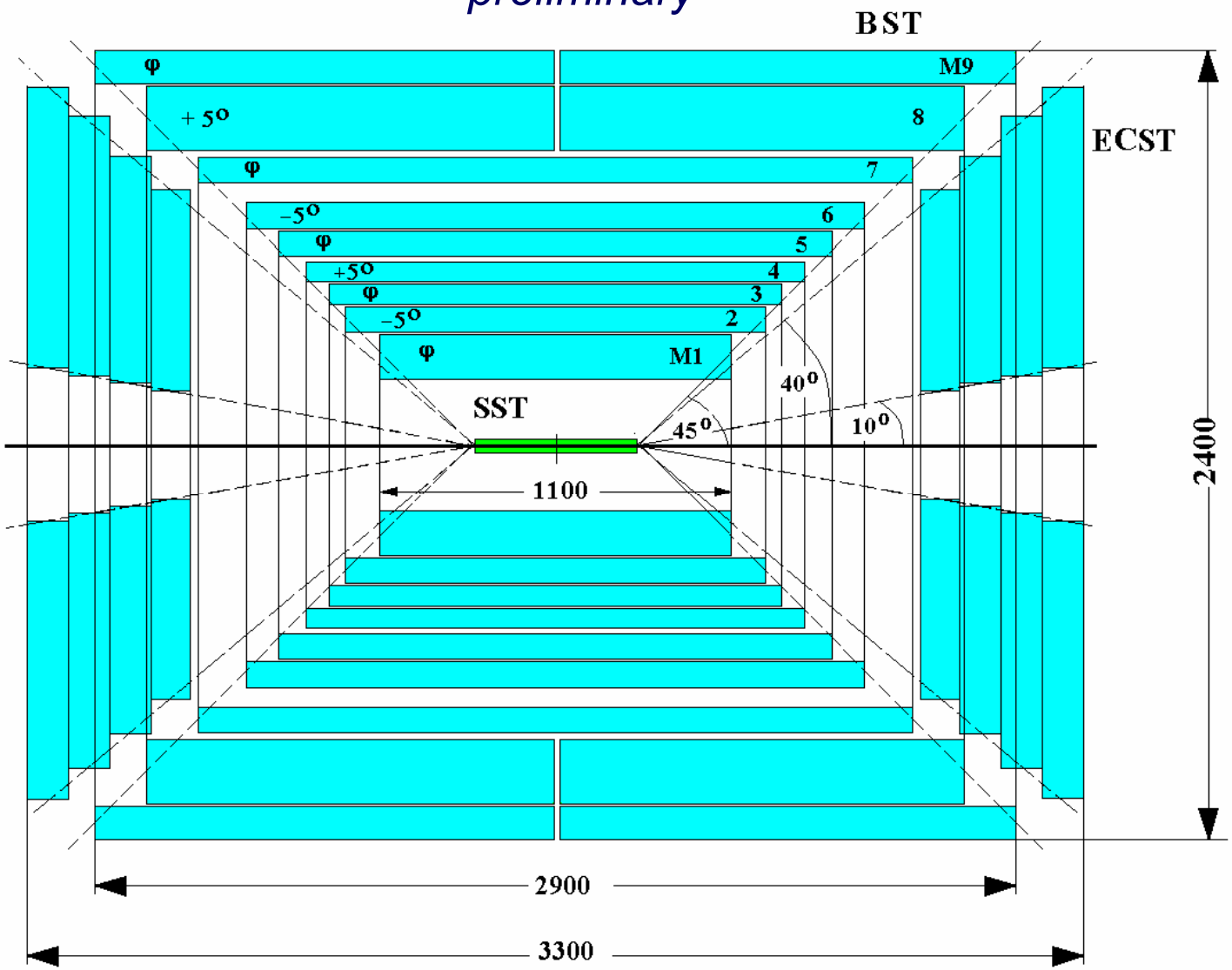


Figure 2.1: Photography of the prototype of T0-C.

Straw Tracker

preliminary



Barrel Straw Tracker

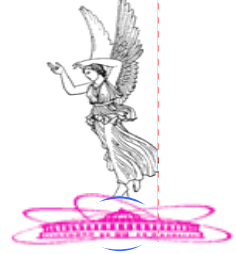


Table 1. BARREL STRAW-TRACKER. Diameter of straws – 4 mm.

Module	R_m, cm	ΔR, cm	Rate $_{max}$, n/cm^2	L straw, cm	Number per straw		O, %	L_{ins}, %	Number	
					spacers	segments			straws	channels
1M (φ)	30	20÷33	0,047	110	8	18	6,6	12,6	L#1 – 454 L#2 – 460	16452
2M	40	34÷42	0,027	130	8	18	6,6	11	L#1 – 608 L#2 – 614	21996
3M(φ)	45	43÷49	0,021	140	8	18	6,7	10,2	L#1 – 684 L#2 – 690	24732
4M	53	50÷56	0,016	156	8	18	6,6	9,2	L#1 – 808 L#2 – 814	29196
5M(φ)	60	58÷65	0,012	170	8	18	6,8	8,4	L#1 – 914 L#2 – 920	33012
6M	70	66÷74	0,009	190	8	18	6,7	7,5	L#1 – 1068 L#2 – 1074	38556
7M(φ)	85	78÷88	0,006	220	8	18	6,9	6,5	L#1 – 1294 L#2 – 1300	46692
8M-1 8M-2	100	90÷108	0,004	2×150	2×4	2×10	7,1	5,1	L#1 – 1526 L#2 – 1532	61160
9M-1(φ) 9M-2(φ)	114	110÷120	0,003	2×160	2×4	2×10	7	4,7	L#1 – 1800 L#2 – 1800	72000
Total length of straws: ~ 41 km								Total:	~ 36 000	~ 343 796

EC Straw Tracker

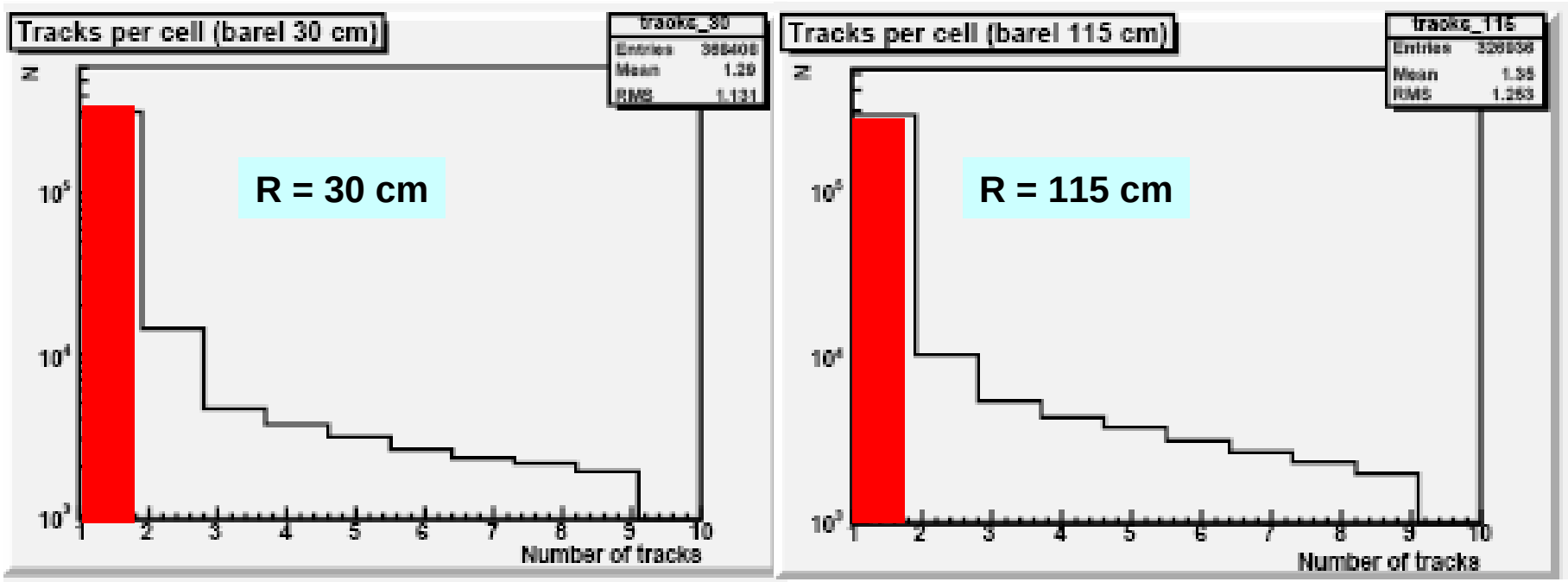
Table 2. Modules of End-Cap Straw Tracker (φ). Diameter of straws – 4 mm.

Type	N of layers	L straw, mm	N straws per layer	N straws per 2 modules	Number of channels
2 x M1	6	884	302	3624	14496
2 x M2	6	801	274	3288	13152
2 x M3	6	719	246	2952	11808
2 x M4	6	636	217	2604	10416
			Total:	**12 470**	**49 900**

Total length of the straws ≈ 9,7 km

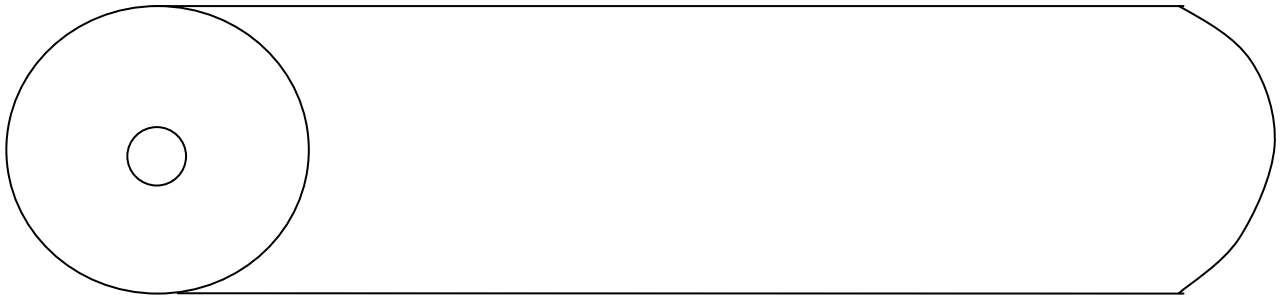
Occupancy in the straw segments

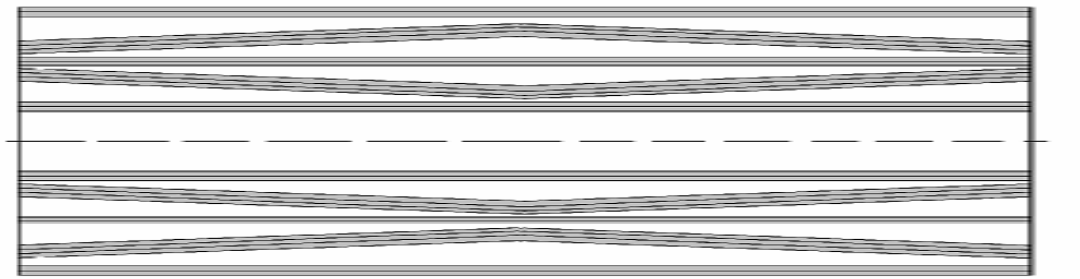
at various radiuses



Tracker (Barrel Straw Tracker)

preliminary





5 Modules: 1-st, 3-th, 5-th – φ (2; 2; 4 layers); 2-d, 4-th - ± 7° (3; 3 layers)

L -2,4 m; R - from 20 cm to 120 cm

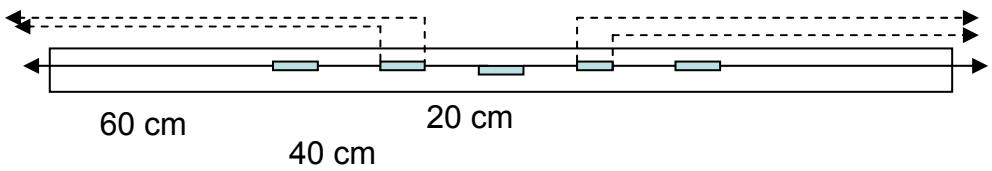
4 mm in diameter straws – 12 610;

Tracker (Barrel Straw Tracker)

continuation

4 mm in diameter segmented straws, L -2,4 m: – 12 610 pc

Segmentation of 1-st and 2-d modules:



Total: 61860 channels

Segmentation of 3-th, 4-th and 5-th modules: