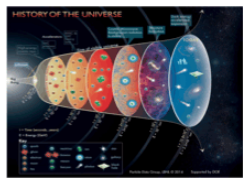
数理物質融合科学センター　光量子計測器ワークショップ

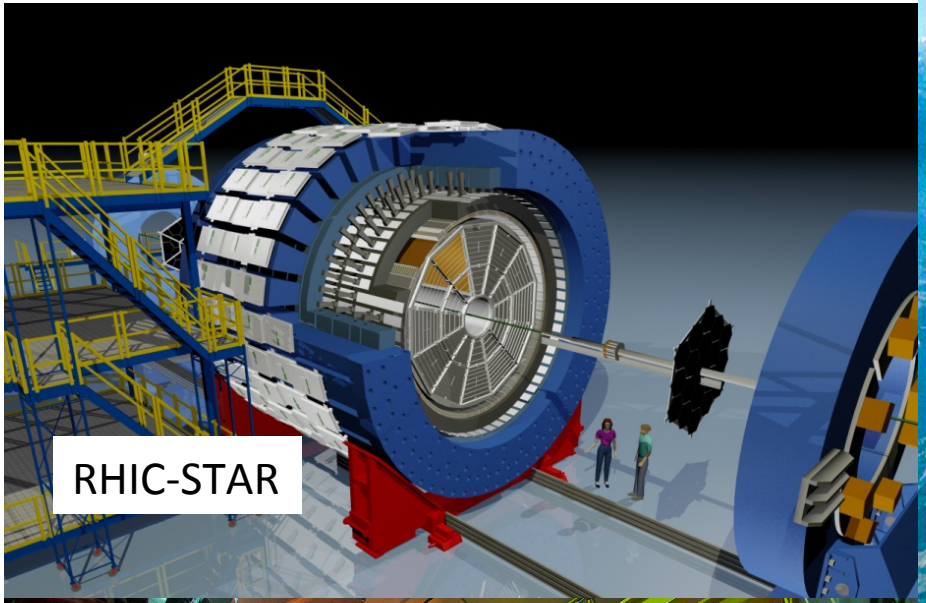
シリコン電磁カロリメータ等

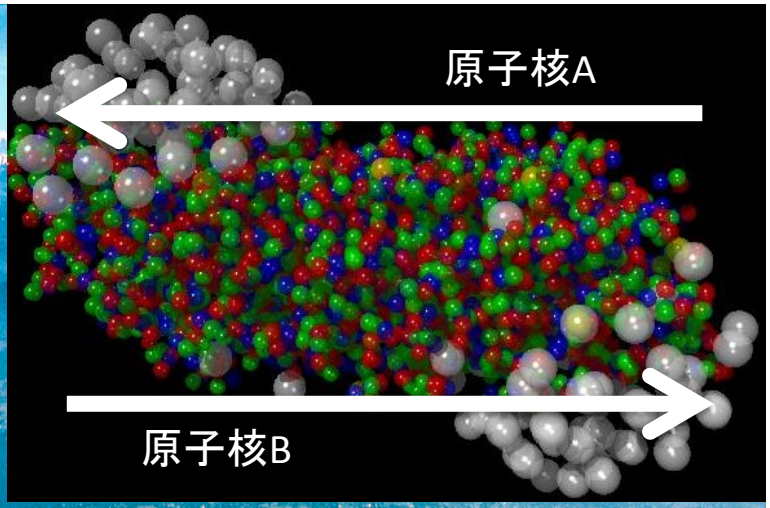
筑波大学　数理物質融合科学センター
宇宙史国際研究拠点　クォーク・核物質部門
数理物質系　物理学域　　江角 晋一

- Introduction on High-Energy Heavy-Ion Collision and QGP
- Si/W calorimeter for ALICE FoCal upgrade
- Event Plane Detector, iTPC and Fixed target mode for STAR-BES2
- MRPC(multi-gap resistive plate chamber) for High-resolution TOF

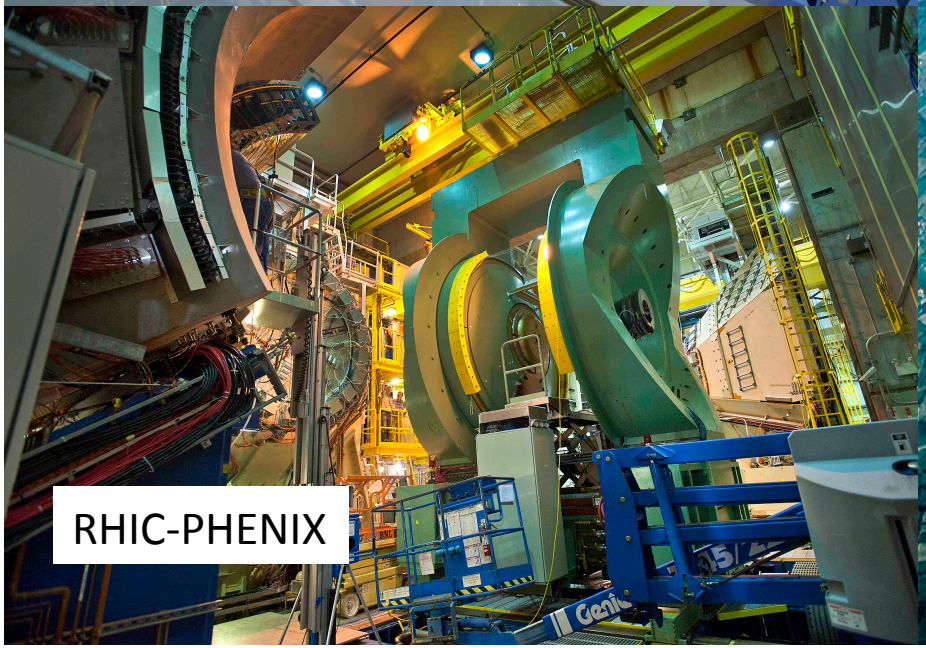


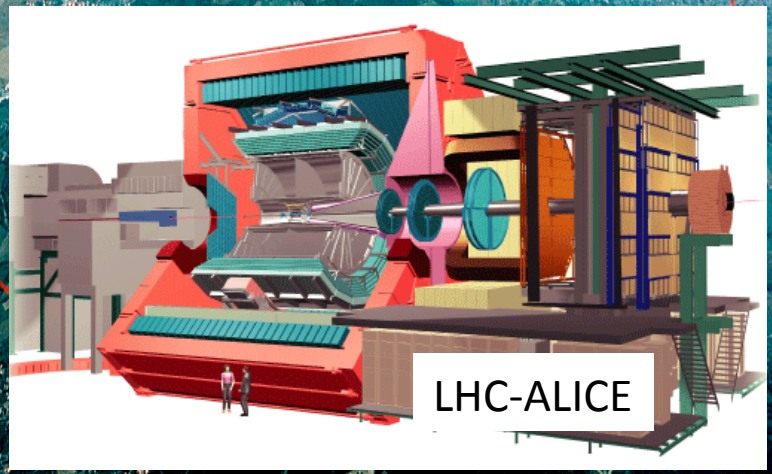
高エネルギー原子核実験 (RHIC,LHC)



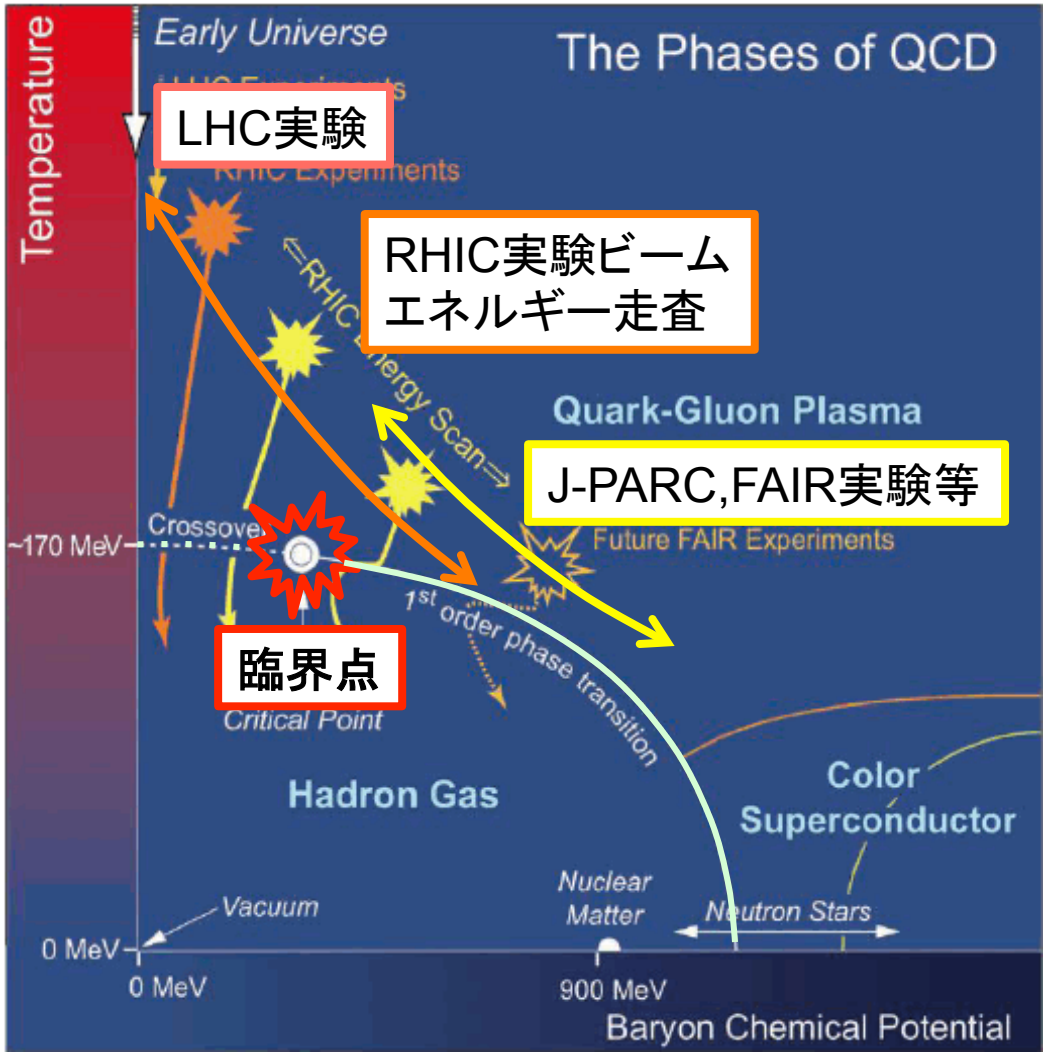


LHC at CERN

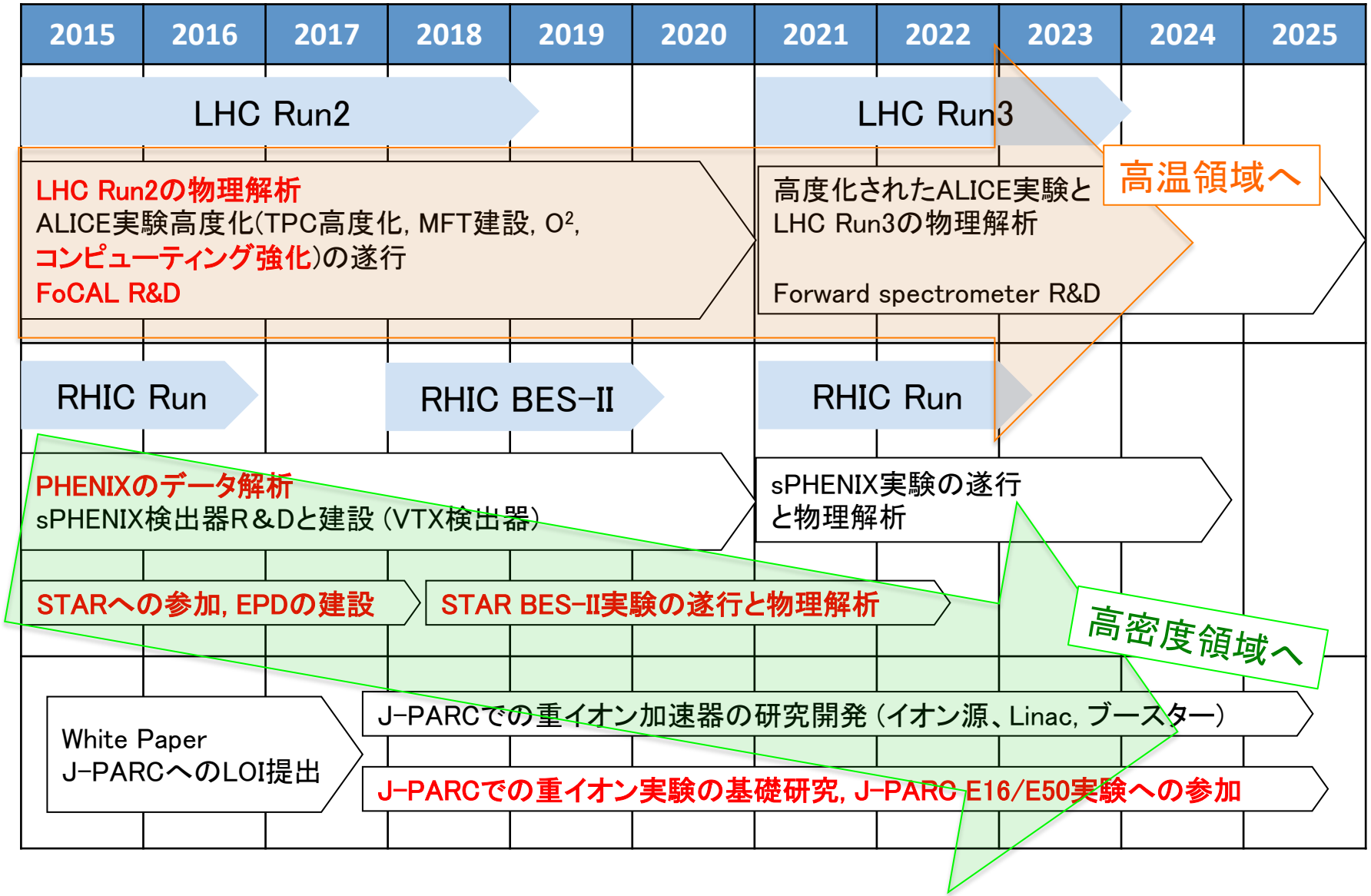




クォーク・グルーオン・プラズマ（QGP）相転移
QCD臨界点探索

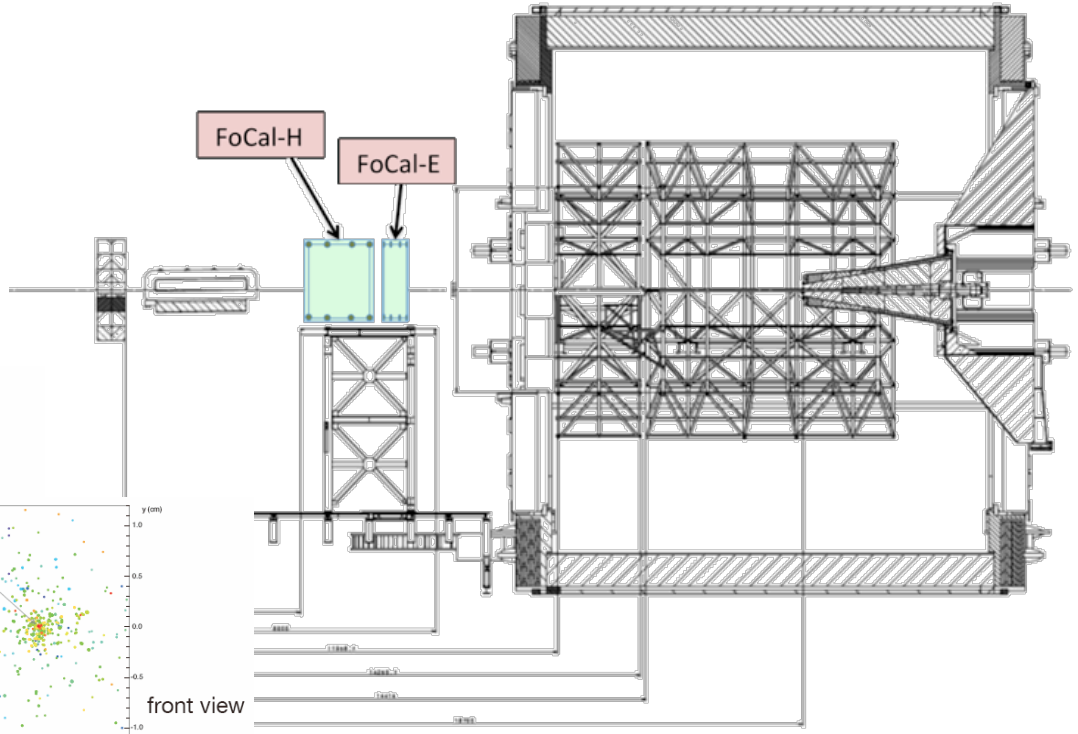


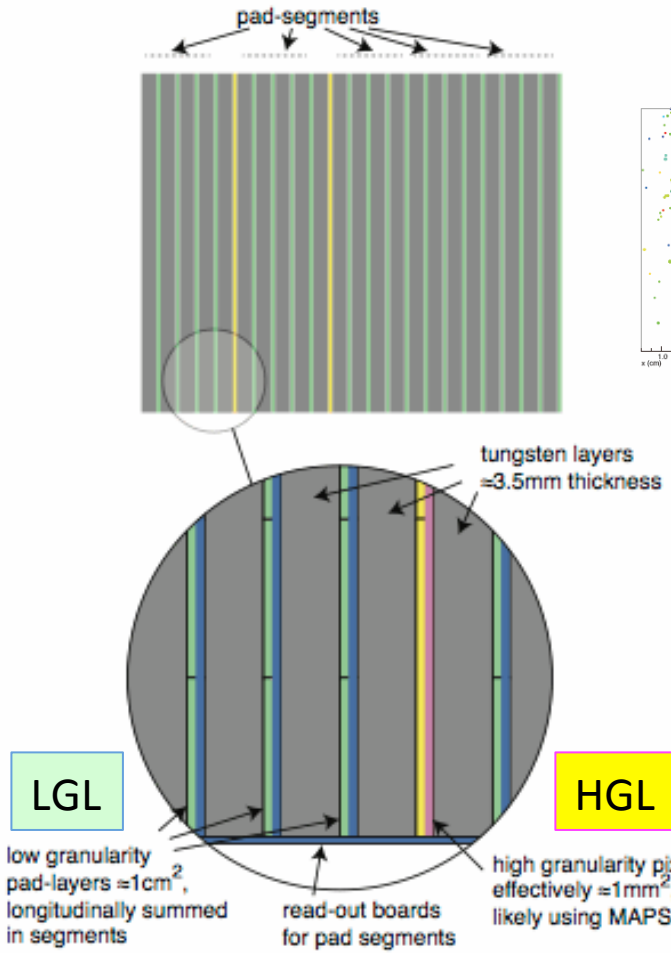
研究計画

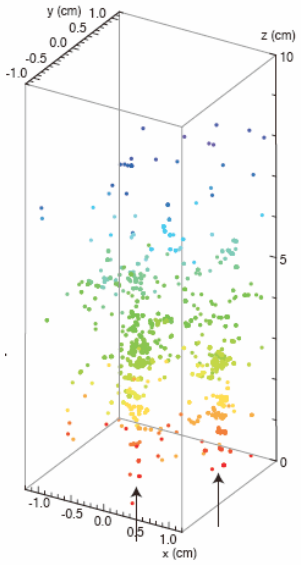

2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
LHC Run2
LHC Run3
LHC Run2の物理解析
ALICE実験高度化(TPC高度化, MFT建設, O2,
コンピューティング強化)の遂行
FoCAL R&D
高度化されたALICE実験と
LHC Run3の物理解析
Forward spectrometer R&D
高温領域へ
RHIC Run
RHIC BES-II
RHIC Run
PHENIXのデータ解析
sPHENIX検出器R&Dと建設 (VTX検出器)
sPHENIX実験の遂行
と物理解析
STARへの参加, EPDの建設
STAR BES-II実験の遂行と物理解析
高密度領域へ
White Paper
J-PARCへのLOI提出
J-PARCでの重イオン加速器の研究開発 (イオン源、Linac, ブースター)
J-PARCでの重イオン実験の基礎研究, J-PARC E16/E50実験への参加

ALICE FoCal upgrade

for forward photon and pi0
W/Si sampling EM-calorimeter
  Moliere radius ~9mm
  Radiation length ~3.5mm/layer



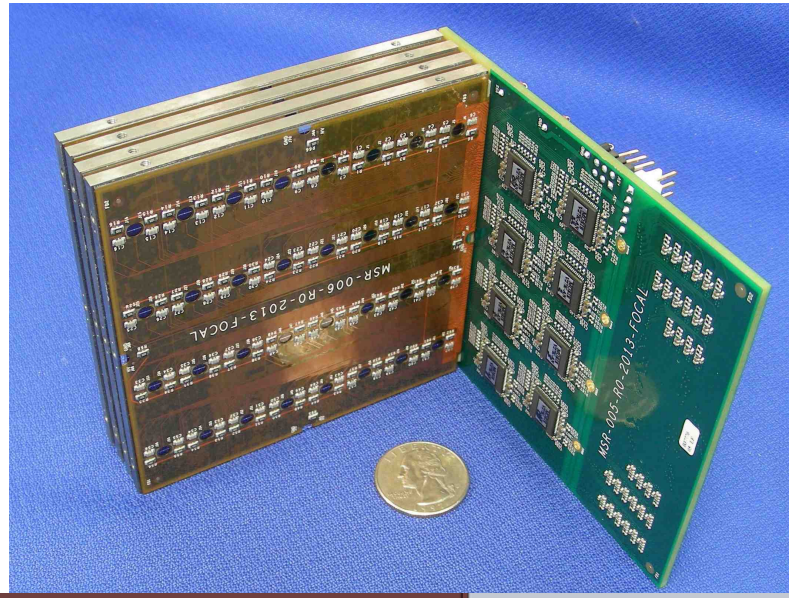


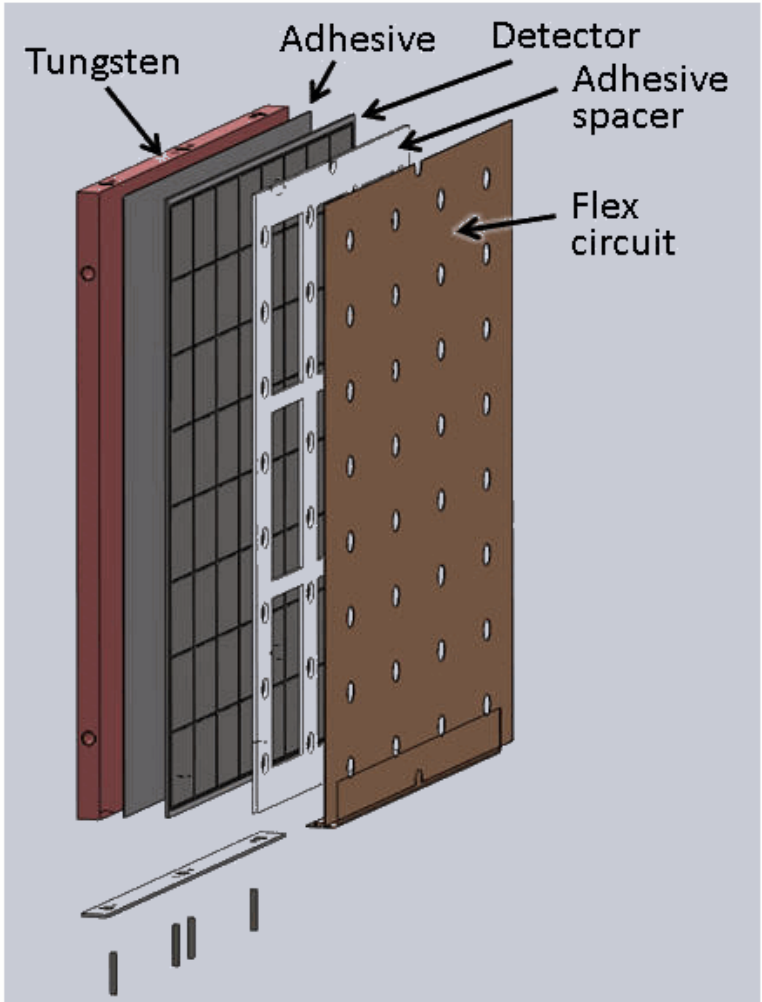


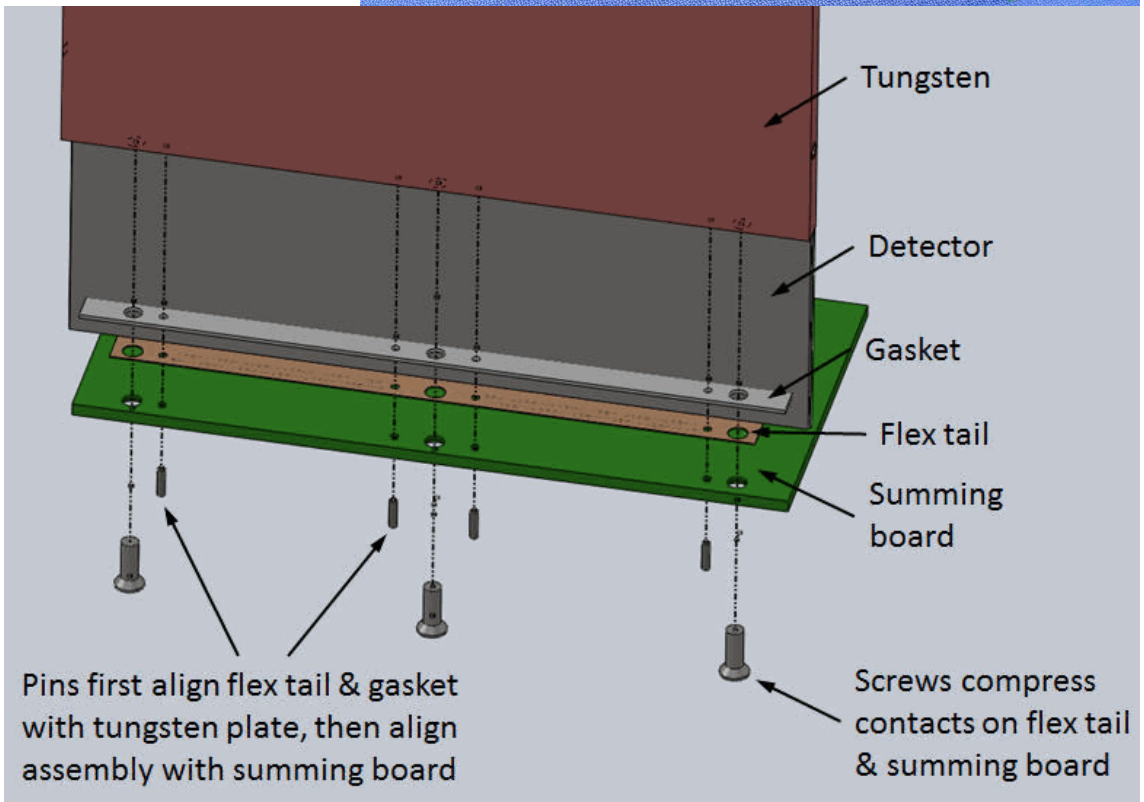
LGL : low granularity layer
  1x1 cm^2 Si-pad
  Analog read-out per 4 layers
  5 LGL modules

HGL : high granularity layer
  25x25 μm^2 CMOS-pixel (MAPS)
  digital sum (40x40 pixels)
  1x1 mm^2 effective cell per 1 layer
  2 HGL modules

4-layer LGL module







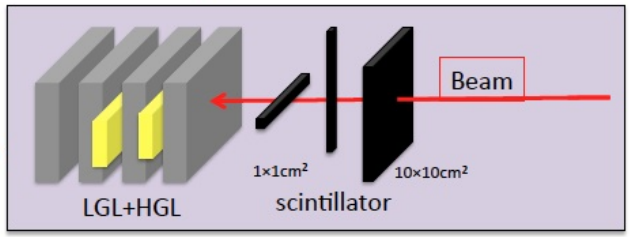
CERN PS/SPSでのテストビーム実験

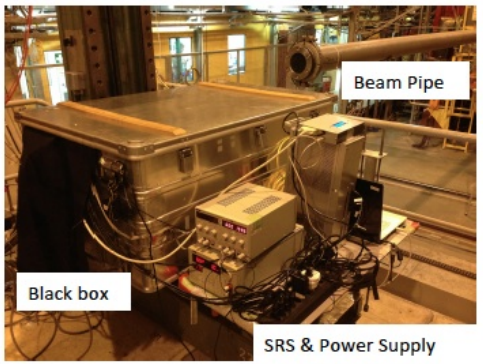
- Sep-Oct/2014 at PS
- Nov/2014 at SPS
- Oct/2015 at PS,SPS

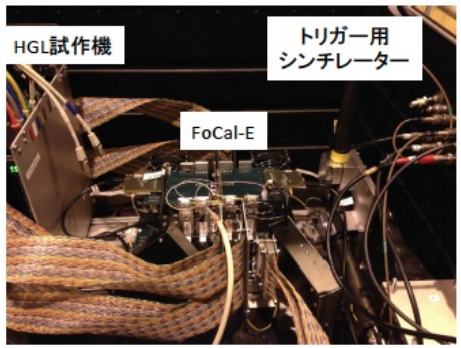
筑波大、中條先生
筑波技術大、稲葉先生
佐藤（H26年度修士論文）
伊藤（H26年度卒業論文）
平野（H27年度修士論文）

SPS test beam experiment

T4-H8 beam line
期間：2014年11月
エネルギー：30～100GeV
rate ~300Hz



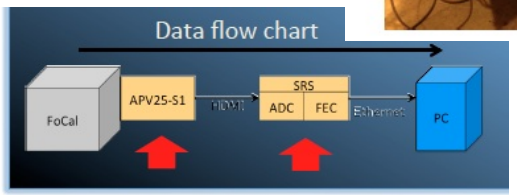


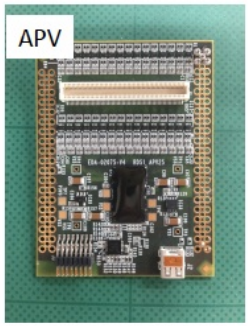


エレクトロニクス

- APV25-S1 chip

・128ch、40MHz(25nsec)のサンプリング
・読み出し極性を変える事で
Low Gain(1/16) or High Gain(1/1)
の切り替えが可能

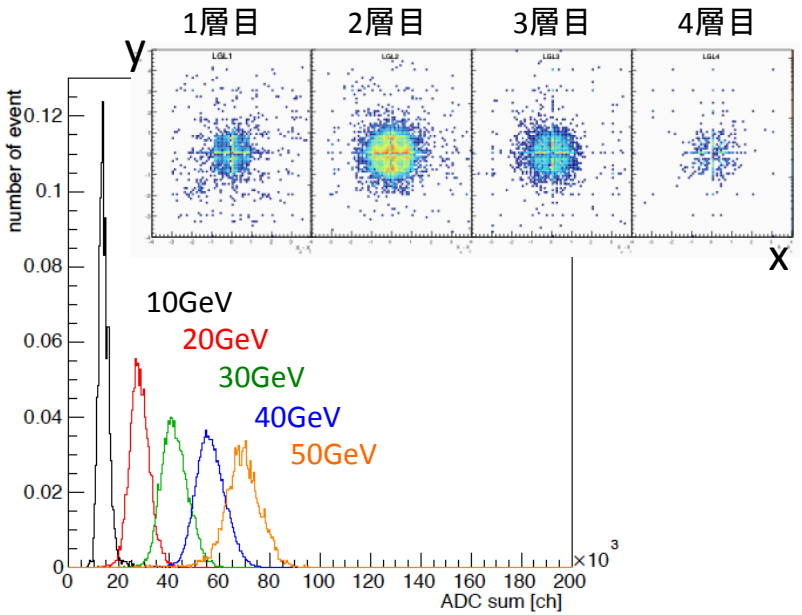




-SRS(Scalable Readout System)

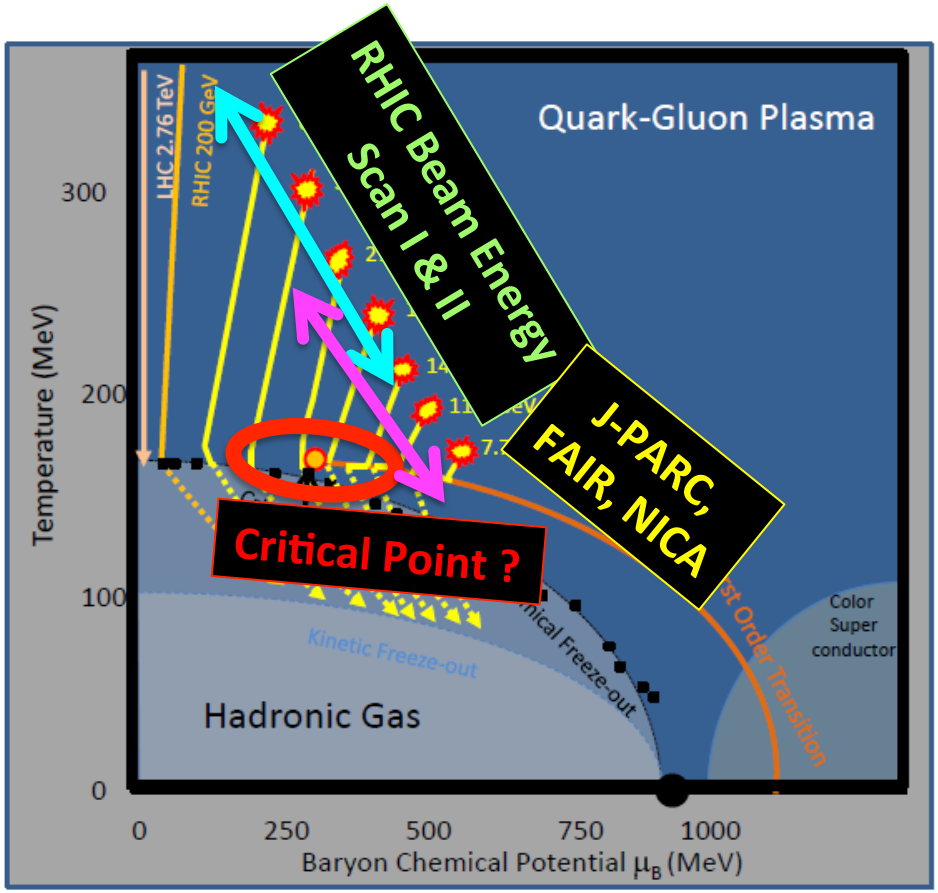
-> ADC board
12 bit ADC
8port(計16枚)のAPVを同時読み出し

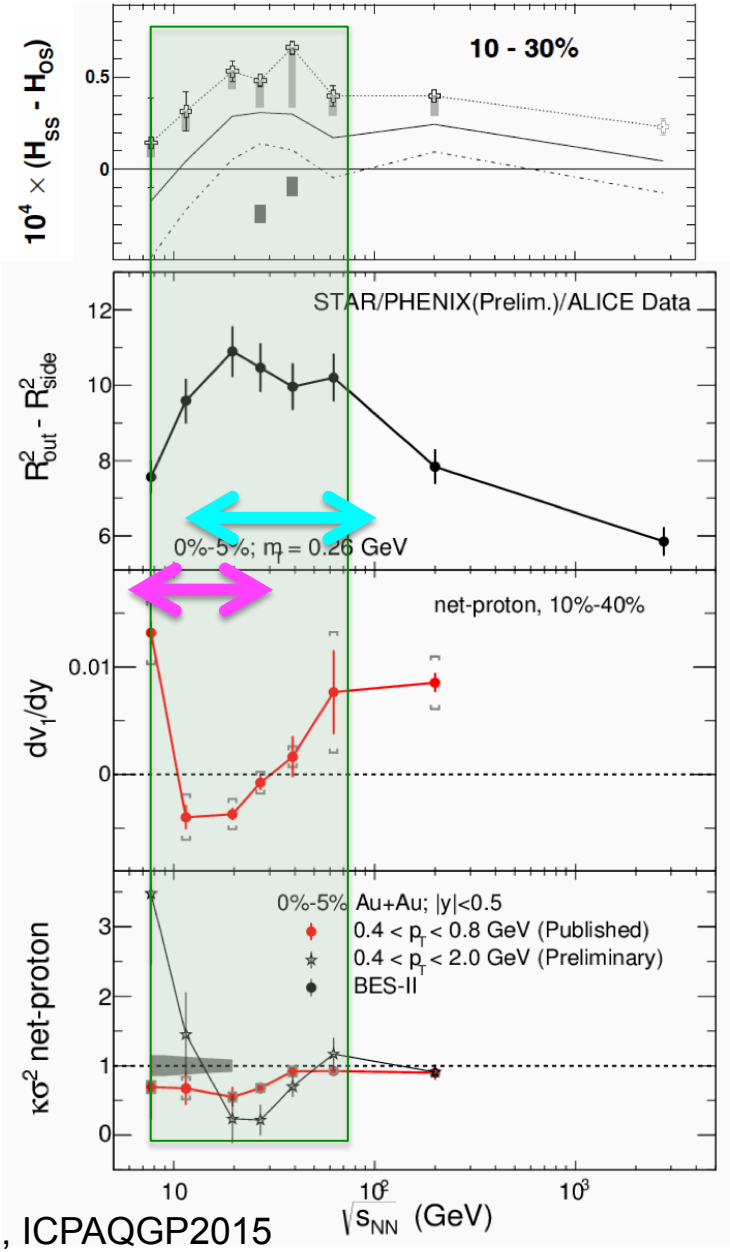
-> FEC board
ADCから送られて来た情報を
処理するフロントエンド



RHIC beam energy scan (BES) program from phase I to phase II

~ 2016 2019 ~

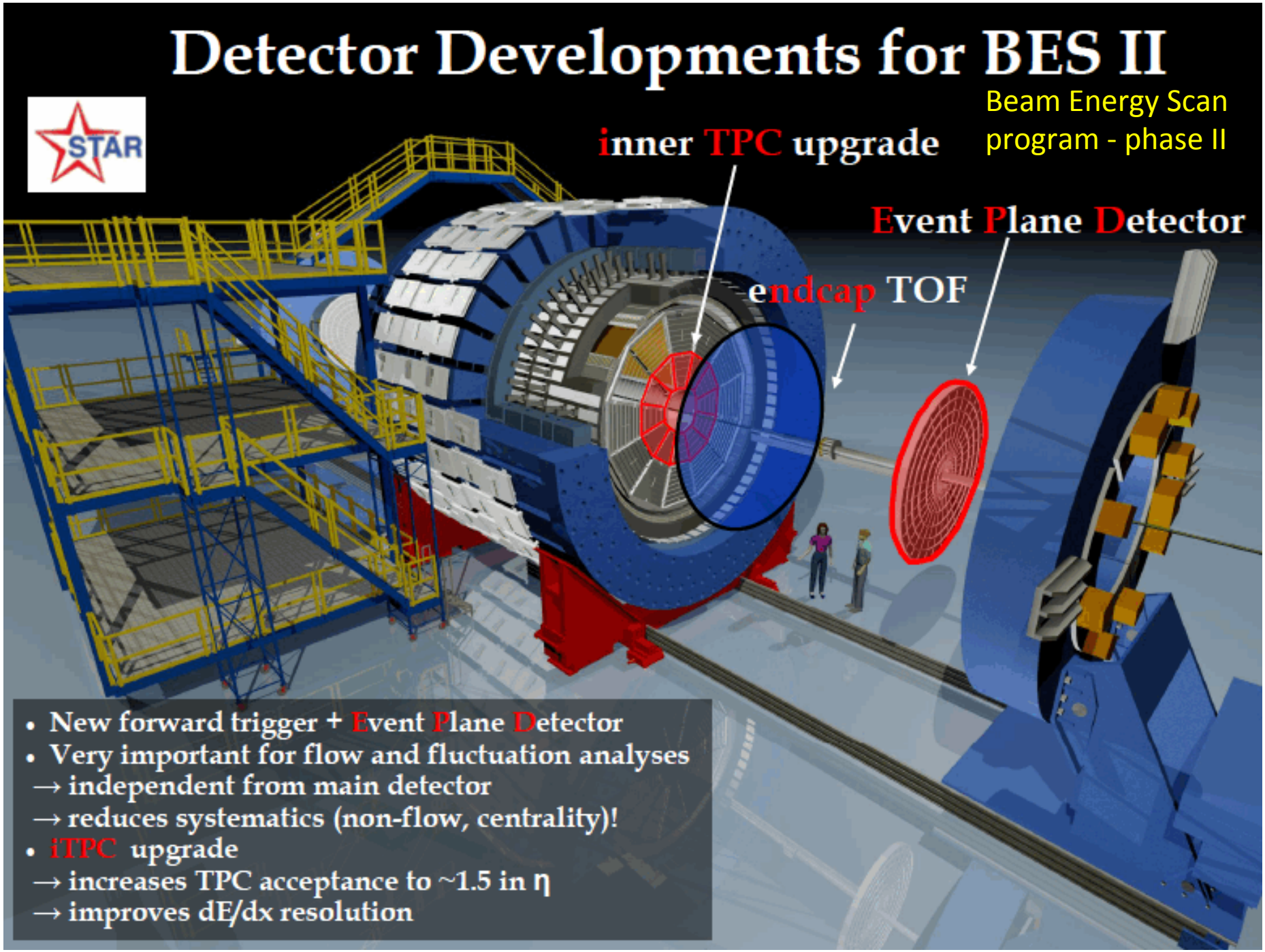




Z. Xu, ICPAQGP2015

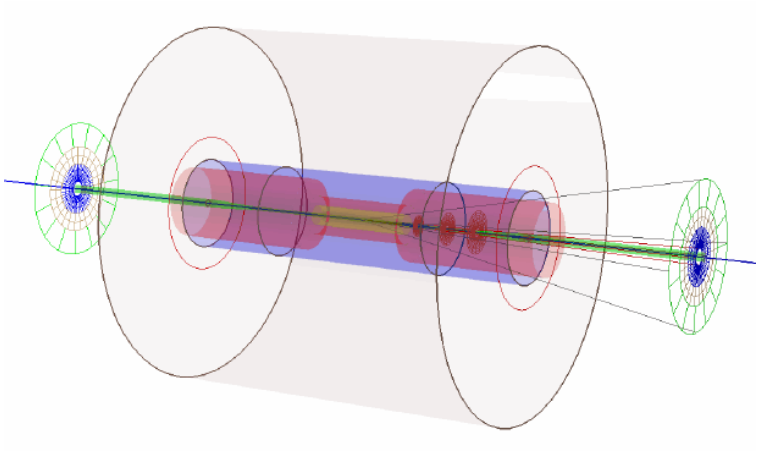
Detector Developments for BES II

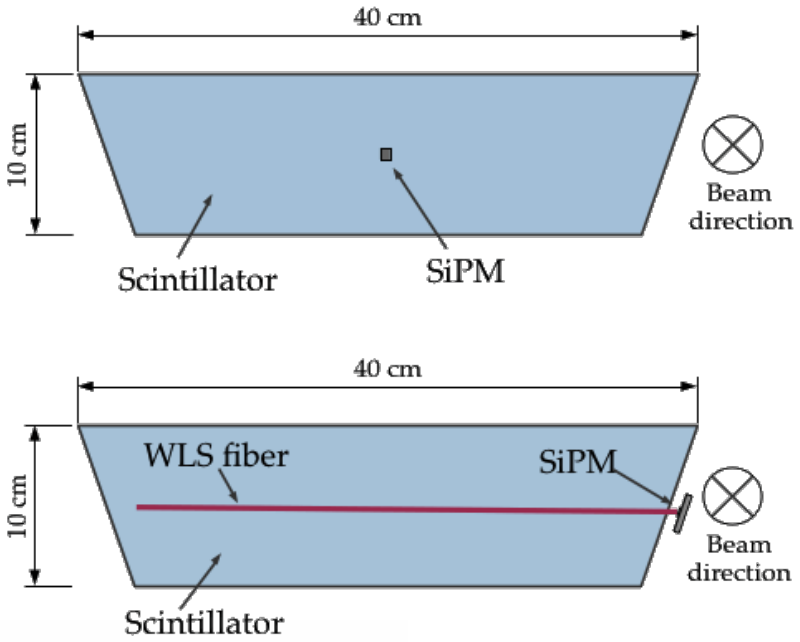
Beam Energy Scan program - phase II

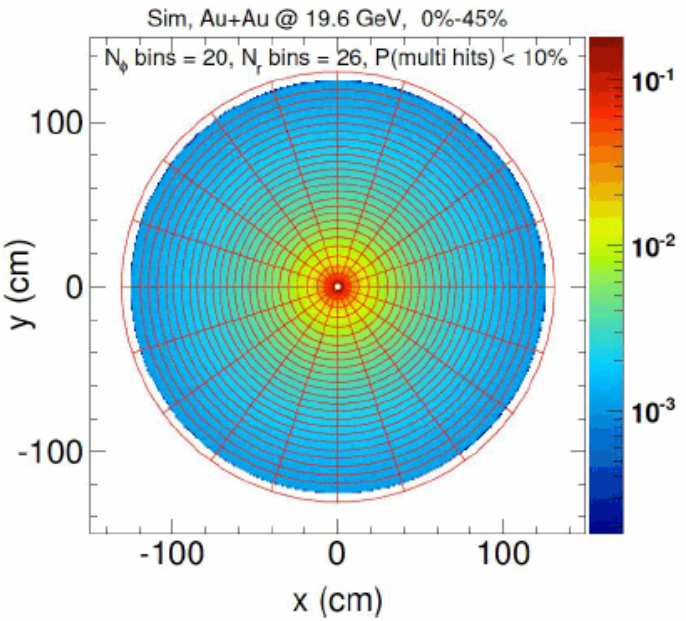


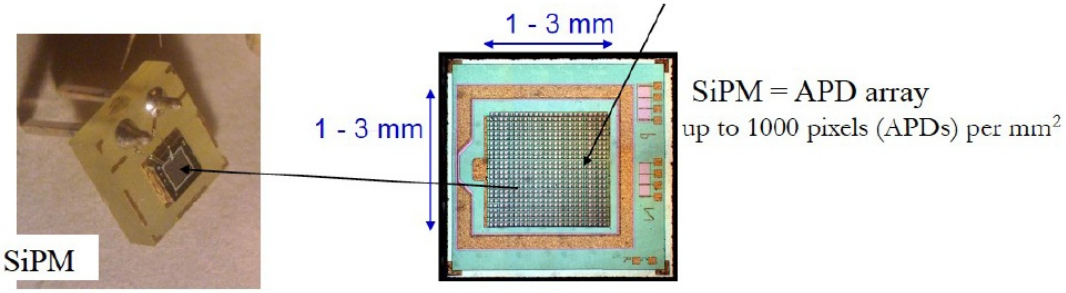
- New forward trigger + Event Plane Detector
- Very important for flow and fluctuation analyses
  → independent from main detector
  → reduces systematics (non-flow, centrality)!
- iTPC upgrade
  → increases TPC acceptance to ~1.5 in η
  → improves dE/dx resolution

Event Plane Detector for BES2 at STAR

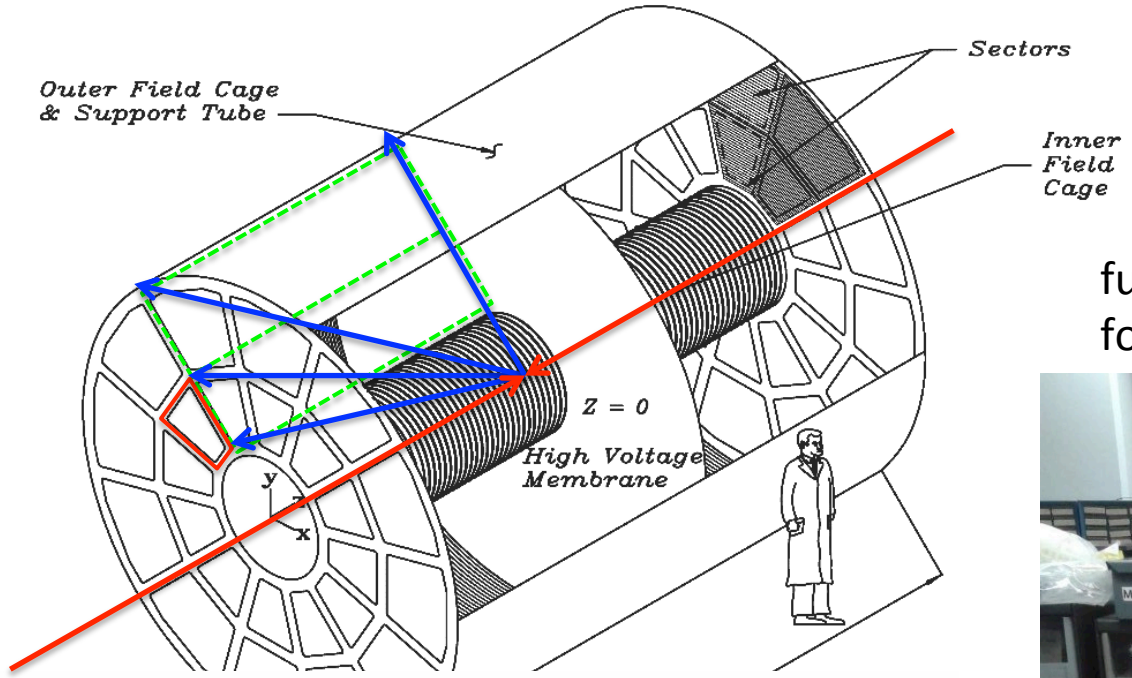






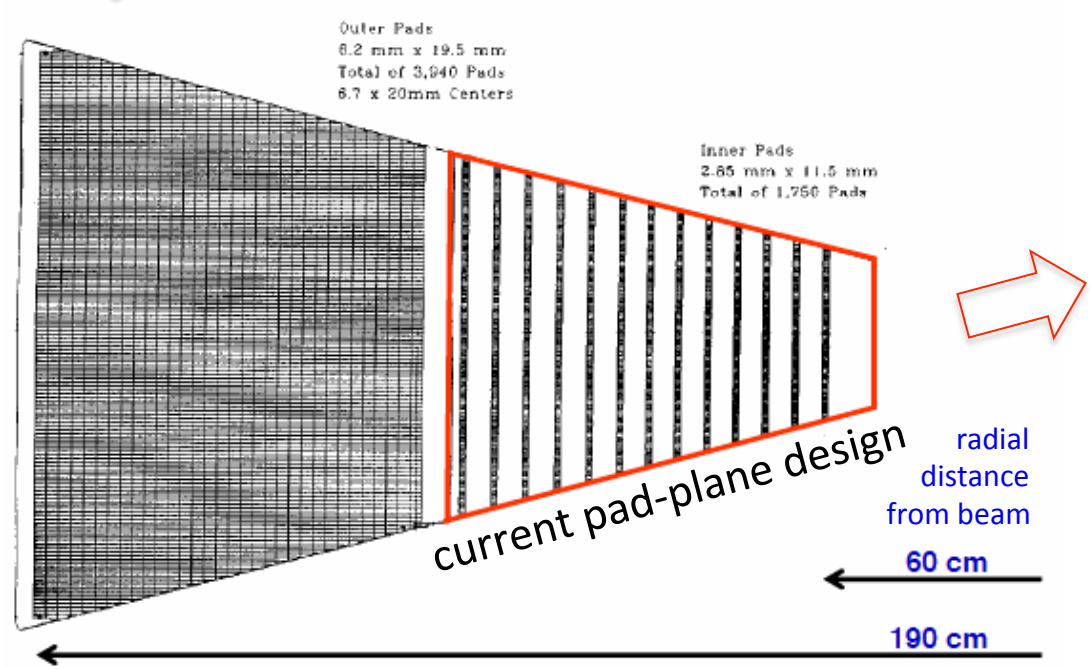


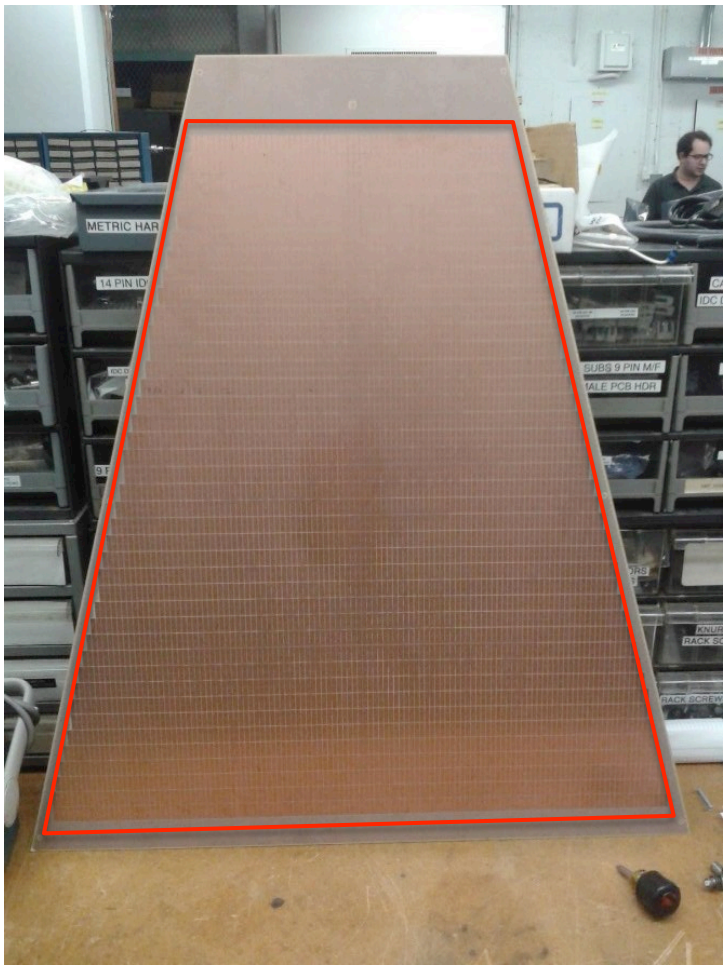
- **Large area coverage**
  - plastic scintillator (fast, efficient, cheap)
- **Silicon PhotoMultiplier (SiPM)**
  - for readout of tiles
  - cheap, equivalent to standard photomultiplier



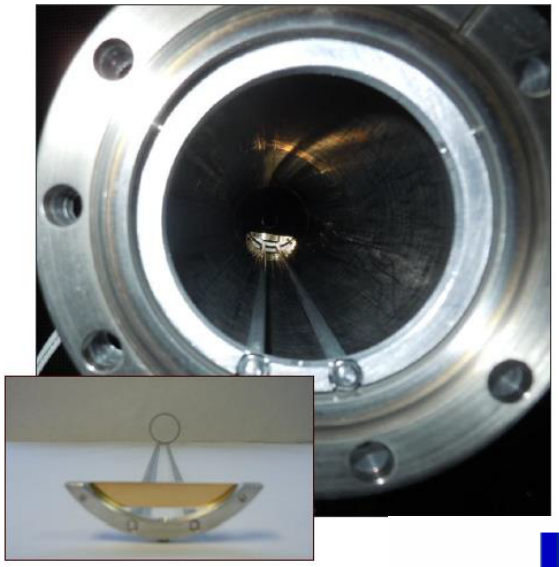
iTPC upgrade
for BES2 at STAR

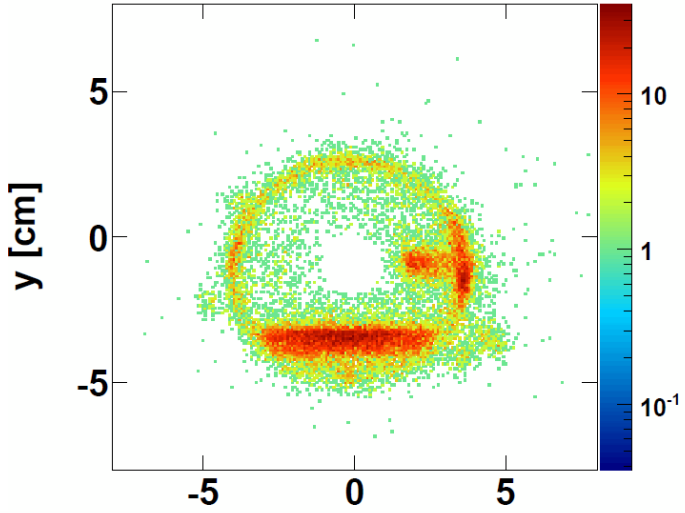
full read-out of inner TPC part
for wider eta-acceptance

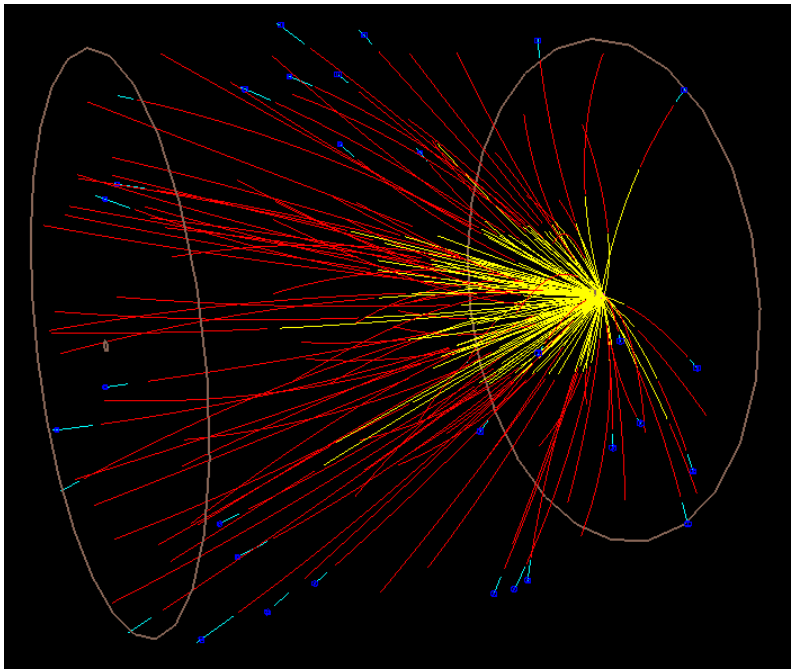


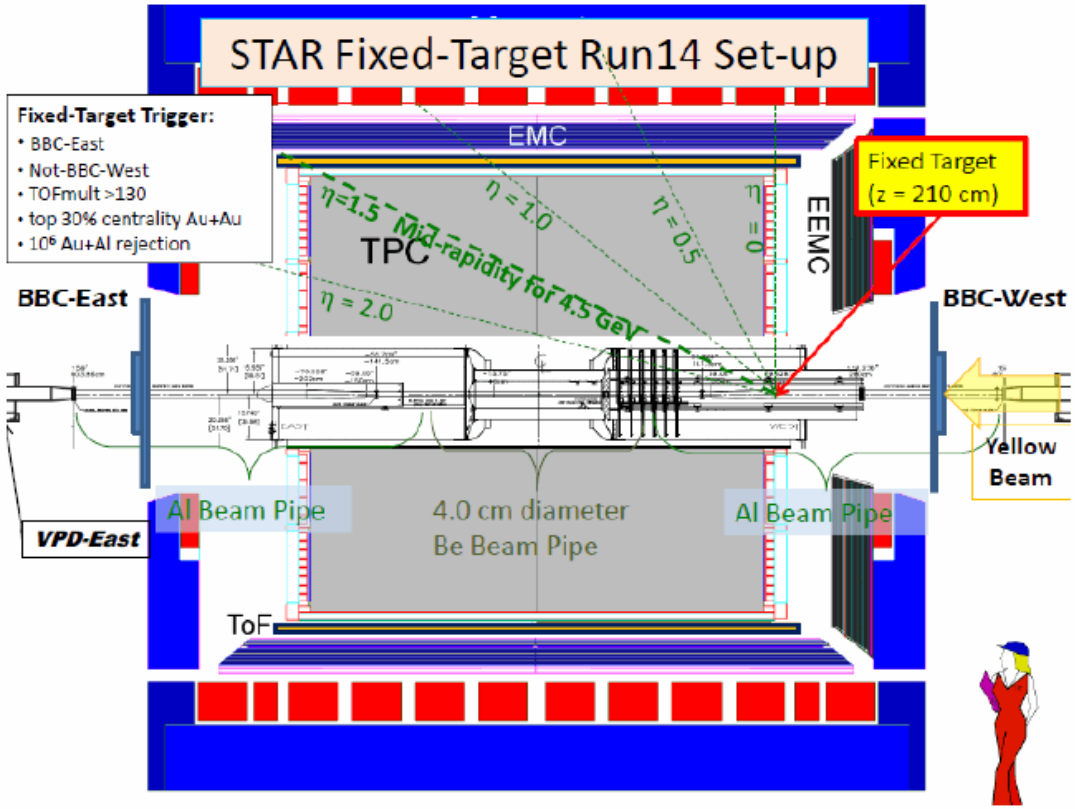


Fixed target mode run at STAR

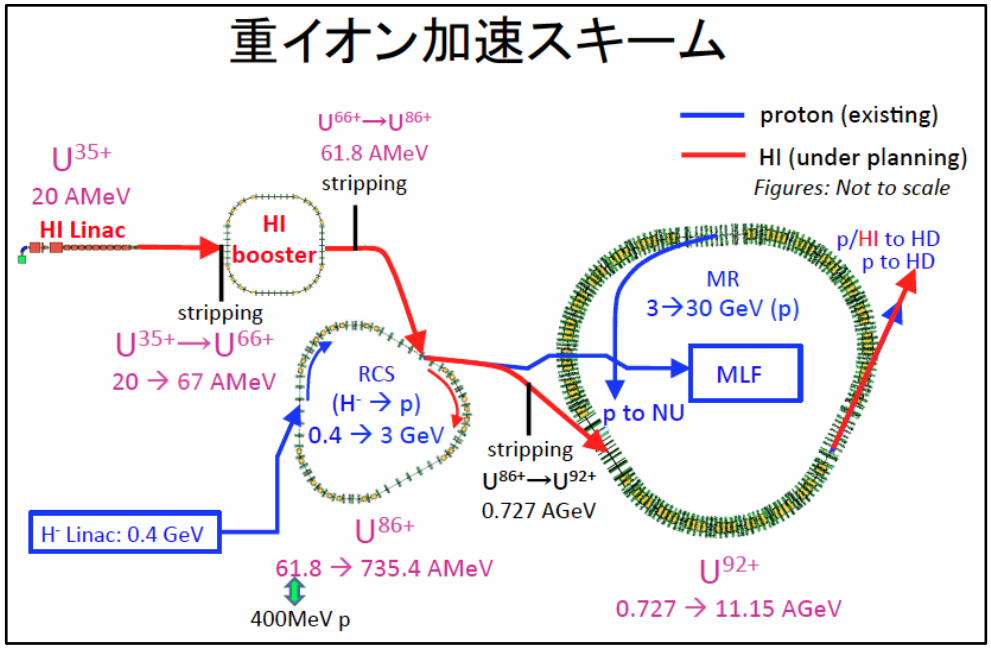






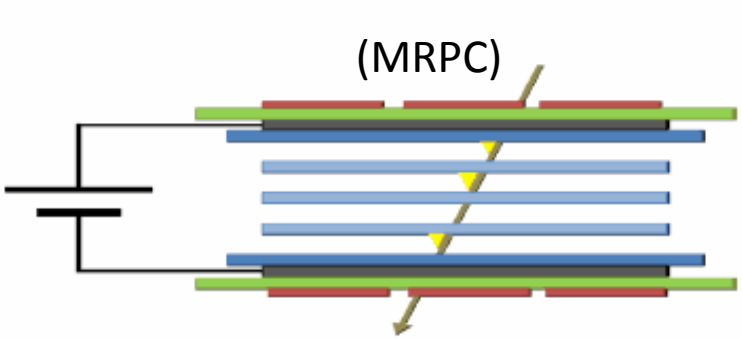


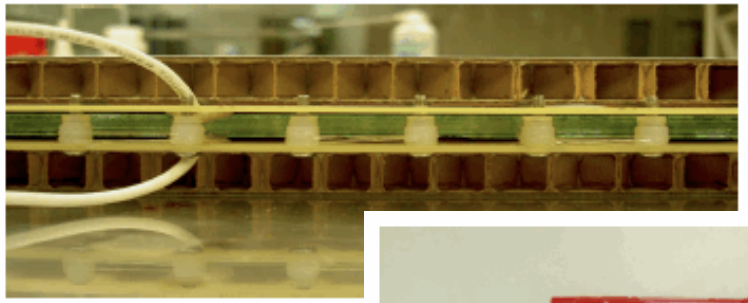
現在のJ-parc施設

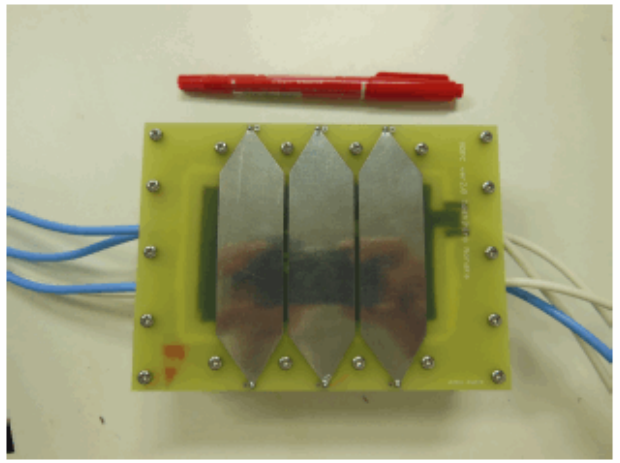


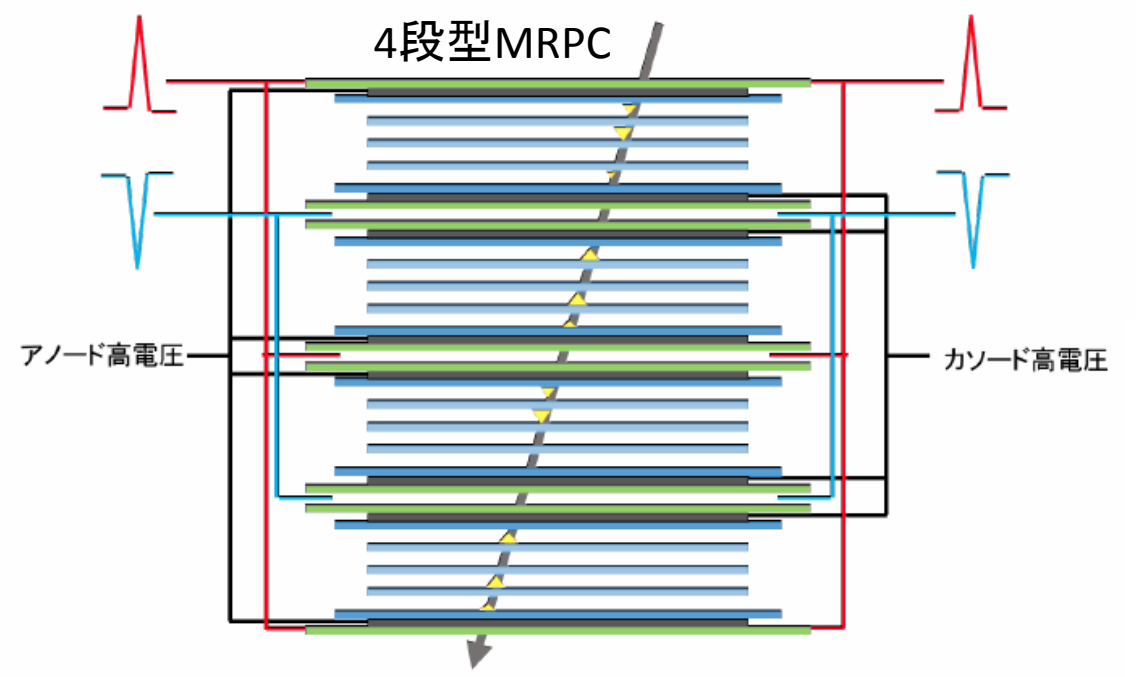
QCD相図
（hadron相→QGP層）
高温領域から高密度領域へ

Multi-gap Resistive Plate Chamber の開発　　--- J-parc 重イオン実験へ向けて ---

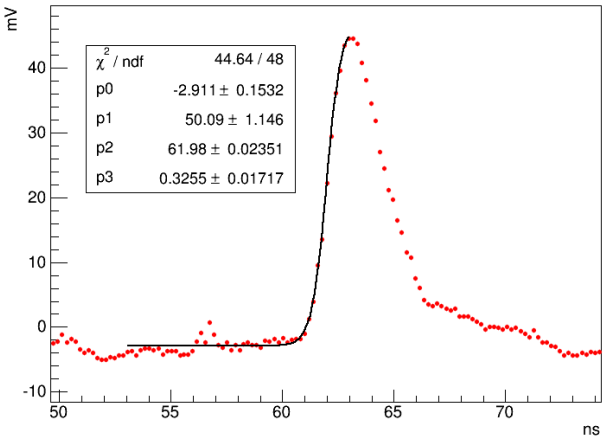








MRPC signal taken by DRS4



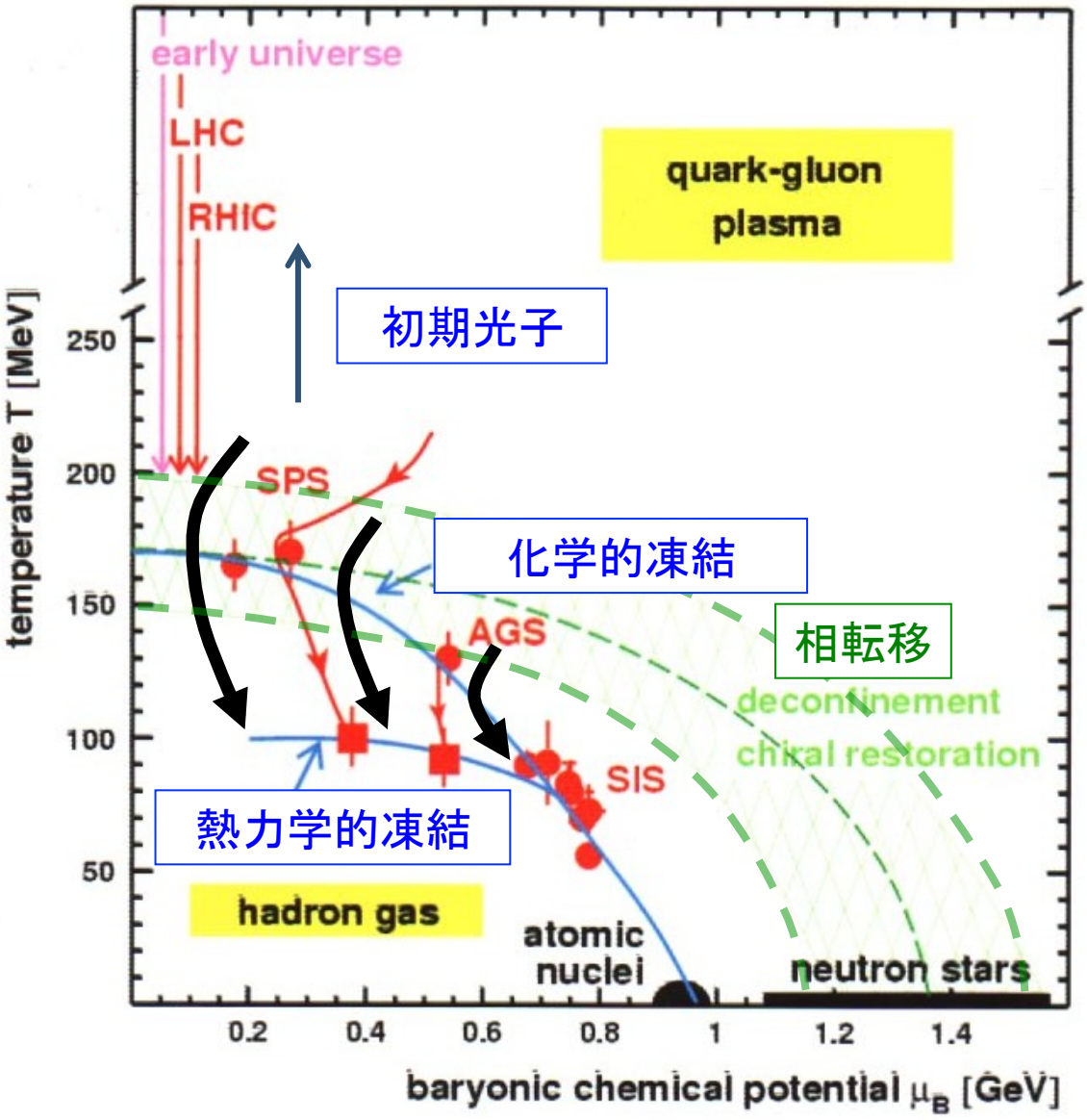
野中（H26年度修士論文）
佐藤（H27年度卒業論文）

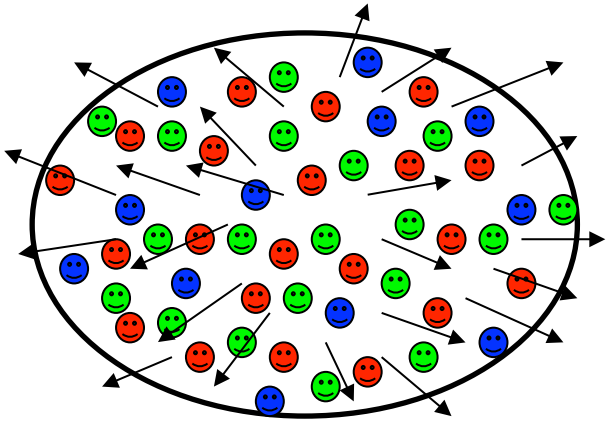
これまでに分解能20ps程度の報告あり。
現状では、40ps程度を達成。目標10ps!

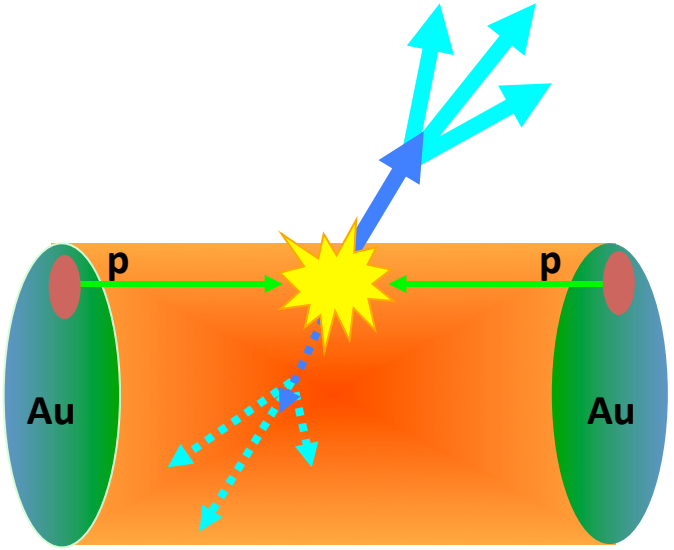
Summary

- Si/W calorimeter for ALICE FoCal upgrade
- Event Plane Detector, iTPC and Fixed target mode for STAR-BES2
- MRPC(multi-gap resistive plate chamber) for High-resolution TOF

Backup slides


early universe
LHC
RHIC
quark-gluon plasma
初期光子
SPS
化学的凍結
AGS
相転移
deconfinement
chiral restoration
SIS
熱力学的凍結
hadron gas
atomic nuclei
neutron stars
temperature T [MeV]
250
200
150
100
50
0.2
0.4
0.6
0.8
1
1.2
1.4
baryonic chemical potential μ_B [GeV]

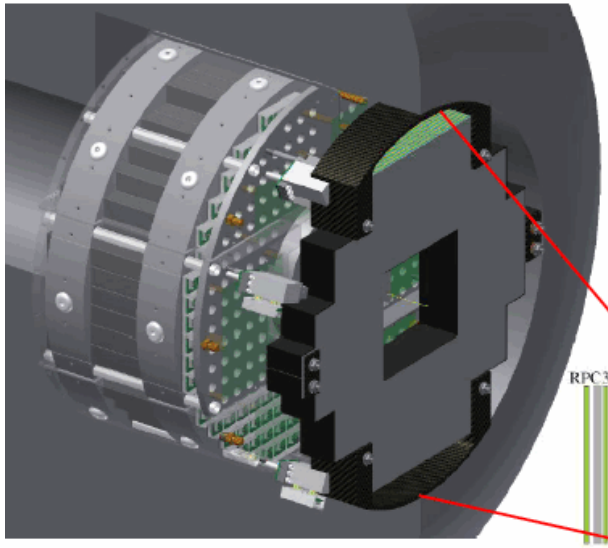



p
p
Au
Au

	SiPM (S12572-025P)	MAPM (H7546A/B)
Effective Photosensitive Area	3 mm x 3 mm	18.1 mm x 18.1 mm
Spectral response range	320 – 900 nm	300 – 650 nm
Gain	5×10^5	3×10^5
Supply voltage	68 V	800 V
Sensitive to magnetic field?	No	Yes
Photon Detection Efficiency (PDE)	35%	~25%
Time resolution	250 ps	~1 ns
Dark count rate	1MHz	few Hz

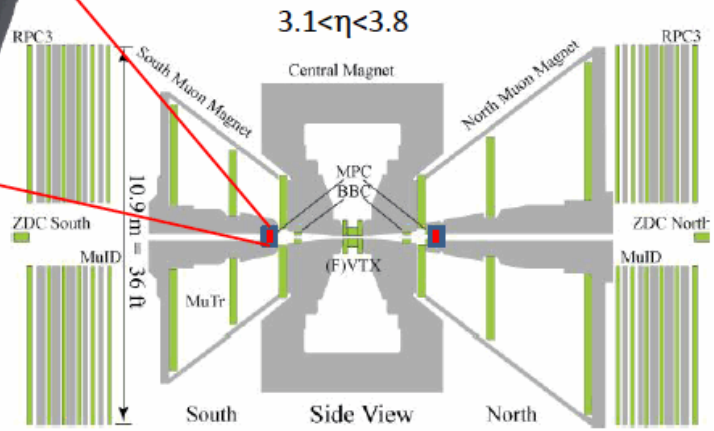
The MPC-EX Detector

EPC-EX (pre-shower)
in front of MPC (EMcal)
at RHIC-PHENIX

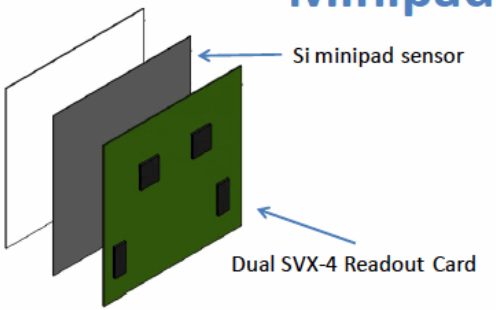


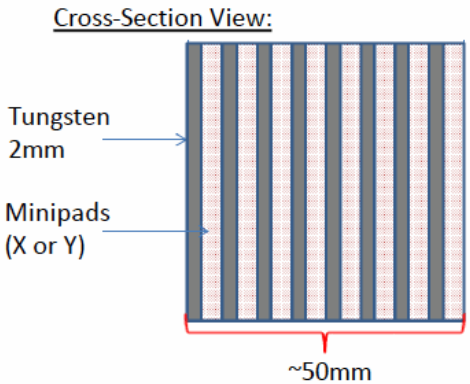
A combined charged particle tracker and EM preshower detector – dual gain readout allows sensitivity to MIPs and full energy EM showers.

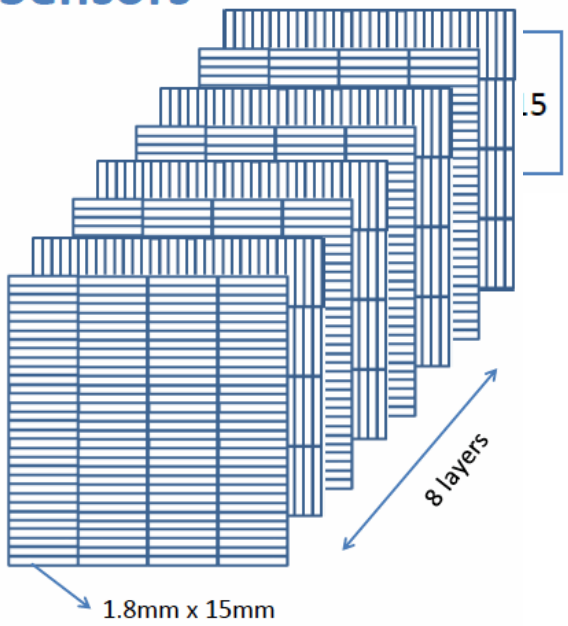
- π^0 rejection (prompt photons)
- π^0 reconstruction out to >80GeV
- Charged track identification

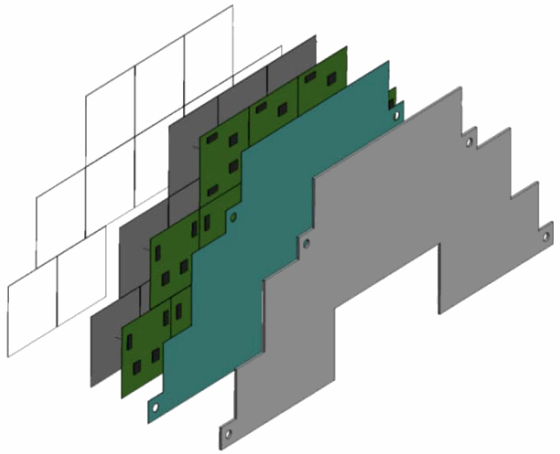


Minipad Sensors

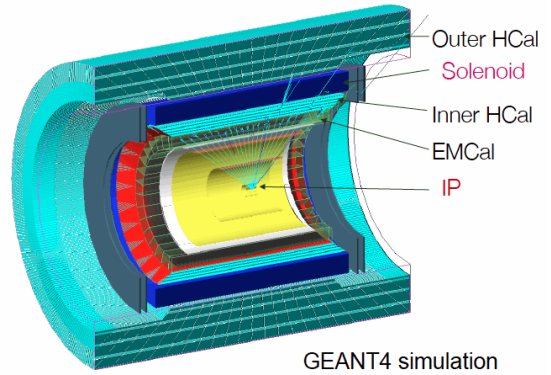








A new RHIC Jet and Upsilon detector (sPHENIX)



GEANT4 simulation

- EMCAL Tungsten-scintillating fiber
  - $\Delta\eta \times \Delta\phi \approx 0.025 \times 0.025$
  - 96 x 256 readout channels
  - EMCal $\sigma_E/E < 15\%/\sqrt{E}$ (single particle)
- HCAL steel and scintillating tiles with wavelength shifting fiber
  - 2 longitudinal segments.
  - An Inner HCAL inside the solenoid.
  - An Outer HCAL outside the solenoid.
  - $\Delta\eta \times \Delta\phi \approx 0.1 \times 0.1$
  - 2 x 24 x 64 readout channels
  - HCAL $\sigma_E/E < 100\%/\sqrt{E}$ (single particle)
- Readout with solid state photodetectors (silicon photomultipliers)

SiPM readout