The sPHENIX Barrel Upgrade: Jet Physics and Beyond

John Haggerty

Brookhaven National Laboratory

on behalf of the PHENIX collaboration

Quark Matter 2012

The sPHENIX concept

Design a major upgrade to PHENIX to address fundamental questions about the nature of the strongly coupled QGP near T_c at RHIC

- Emphasizes jet physics observables with calorimetry initially
- Provides a solid platform for future upgrades and enhancements
- Takes advantage of the luminosity improvements due to stochastic cooling and the wide range of species and energies available at RHIC
- Designed around new technologies that enable a more compact detector, and reuses as much of the PHENIX infrastructure as possible, both helping to keep costs down

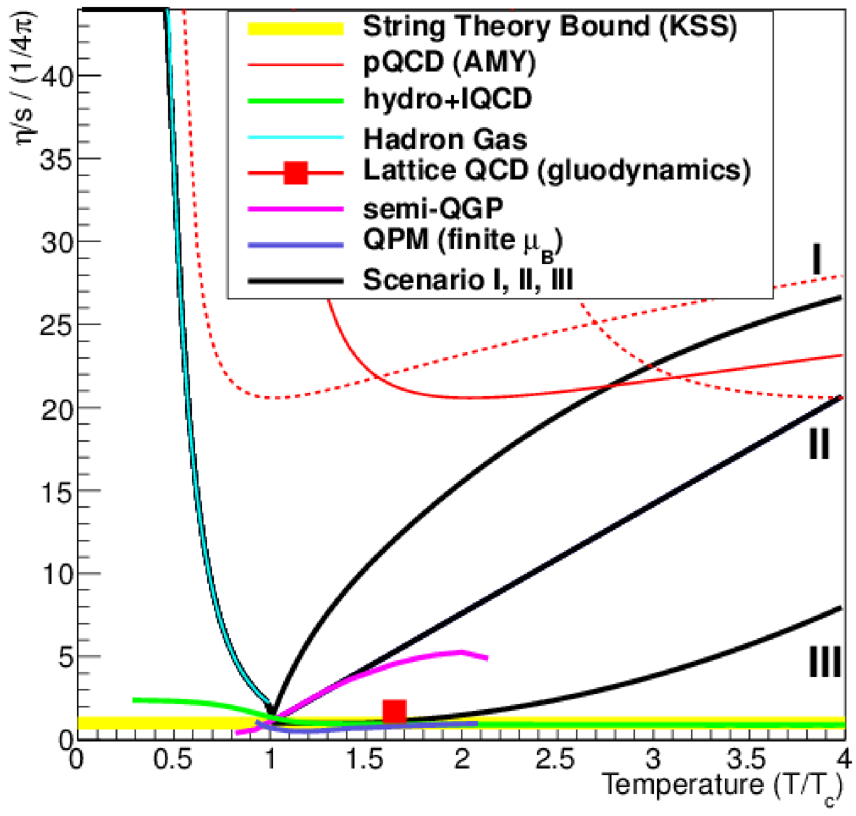
Outline

- Physics motivation
- The detector concept and design goals
- Description of the detector design
- Expected performance of the detector
- Where to get more information
- Summary

η/s

- How does η/s go from being nearly as small as possible near T_c to the weakly coupled limit?

- The figure shows several state-of-the-art calculations and three generic scenarios approaching T_c

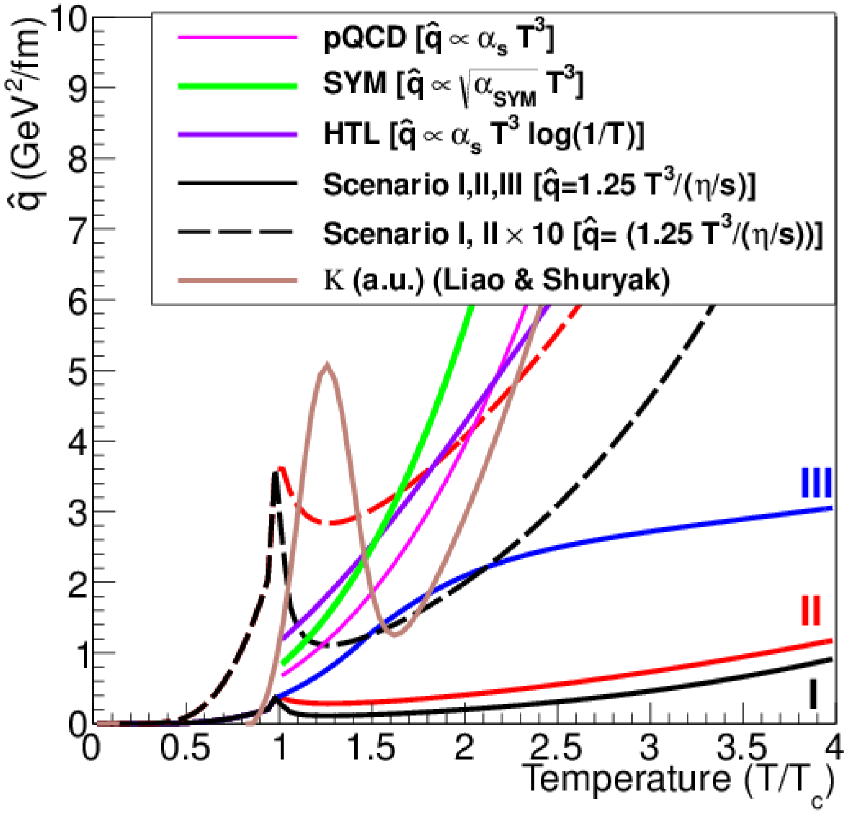


Jet observables

- A parton traversing the medium accumulates transverse momentum characterized by

$$\hat{q} = d(\Delta p_T^{\ 2}) / dx$$

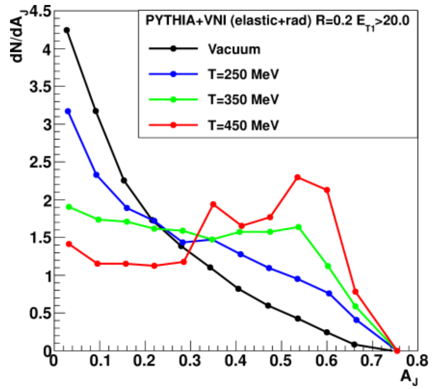
- Coupling parameters like q̂ are scale dependent and must approach weak coupling at high energies and strong coupling at thermal energies



Experiment to confront theory

- We have benefitted from the formation of a theoretical collaboration to study these issues
- The key questions for the feasibility of the experiment are:
  - Are the jet rates large enough at RHIC?
  - Are the jets distinguishable from background fakes?

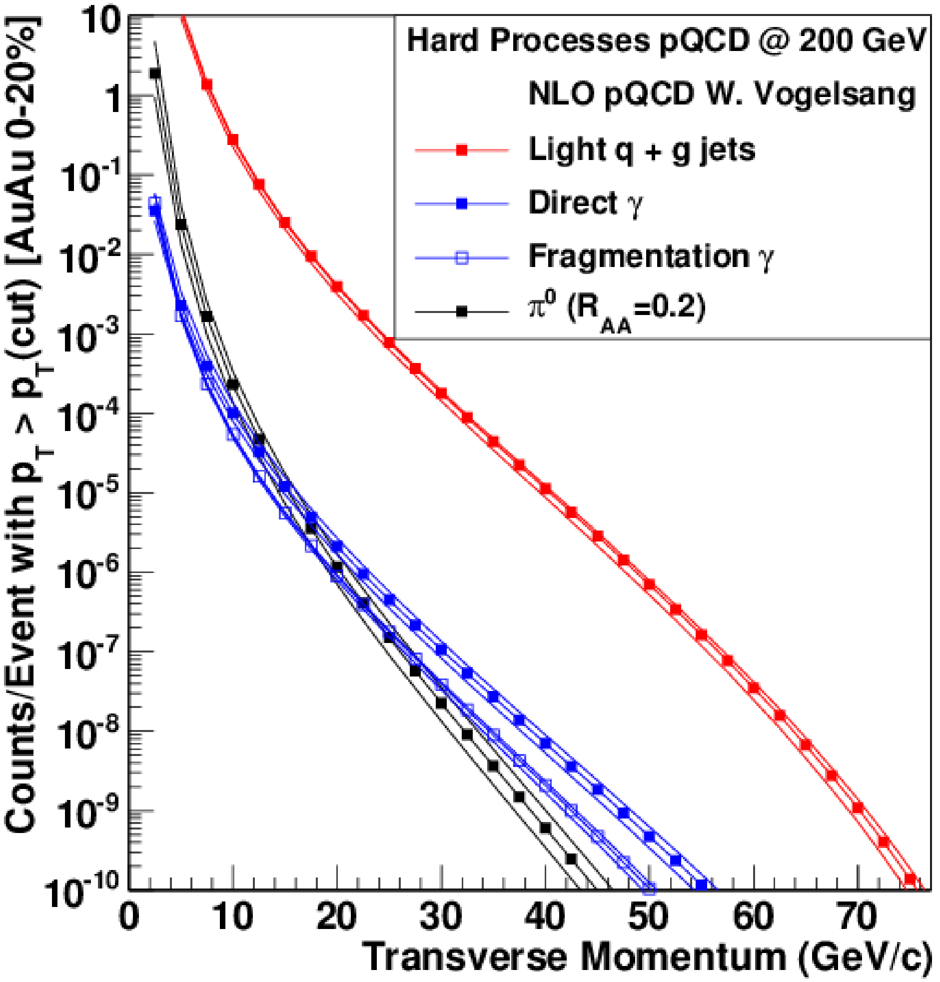
http://jet.lbl.gov/



See Coleman-Smith presentation, Thursday

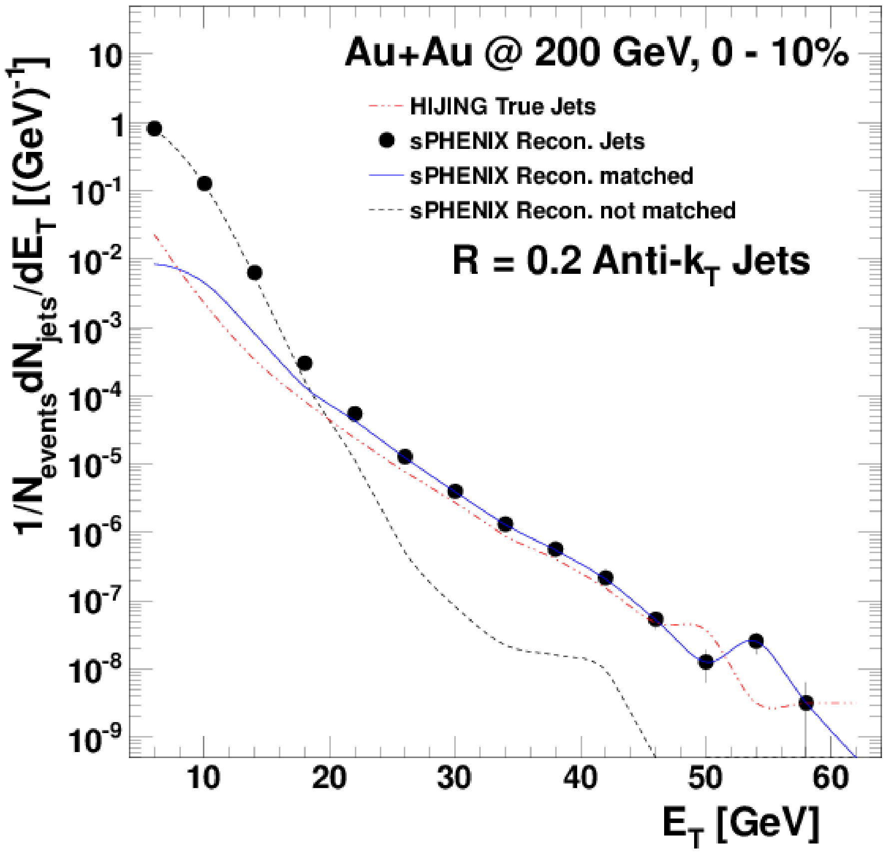
Jet rates at RHIC

- At present RHIC luminosity, in a 20 week Au+Au run we would have 10^6 jets above 30 GeV in 0-20% centrality



Fake jets

- Using 750M minimum bias HIJING events
- True jets outnumber fake jets for p_T > 20 GeV/c
- Details published as Hanks et al., arXiv:1203.1353, published in PRC August 10



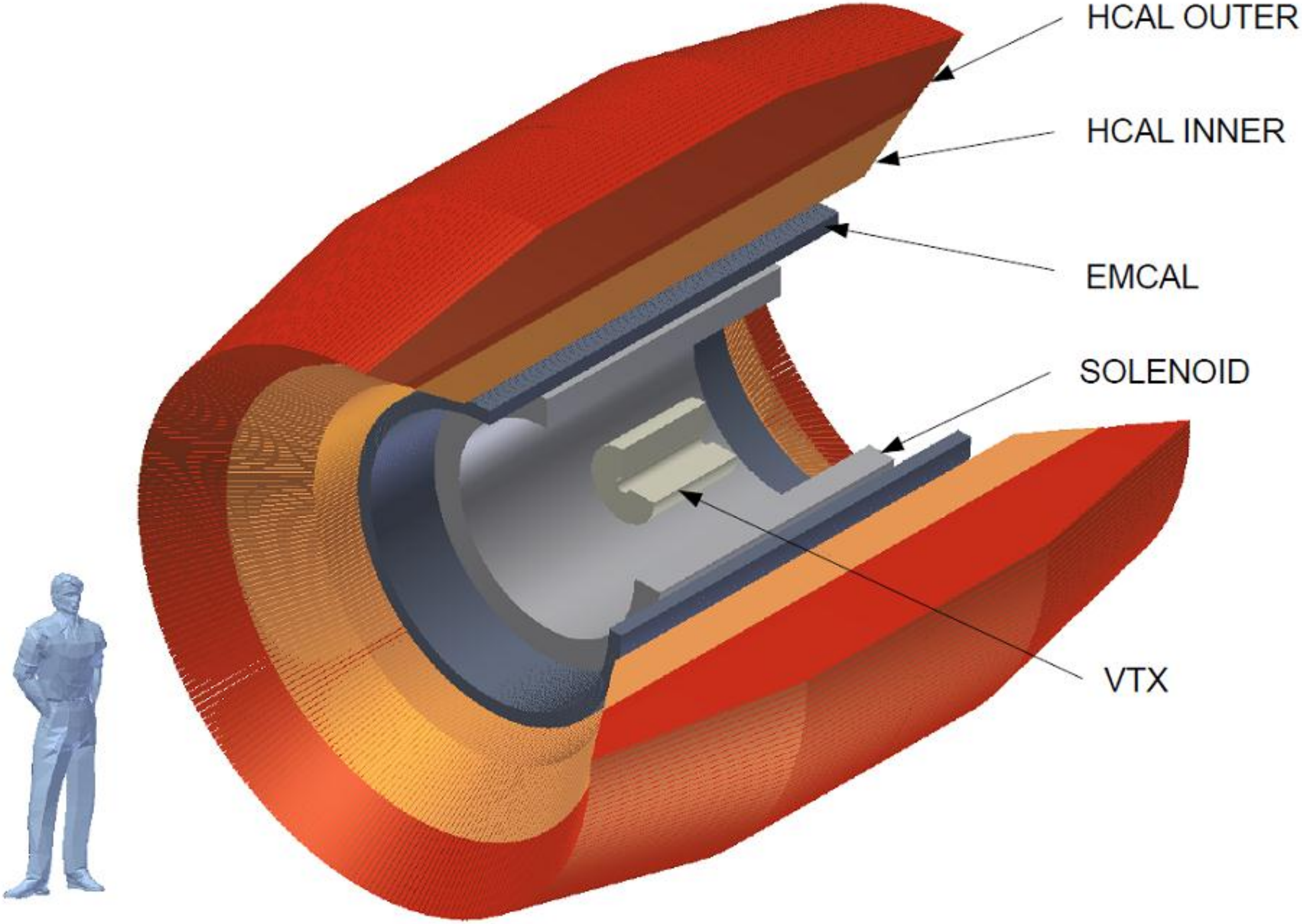
Design goals for a jet detector at RHIC

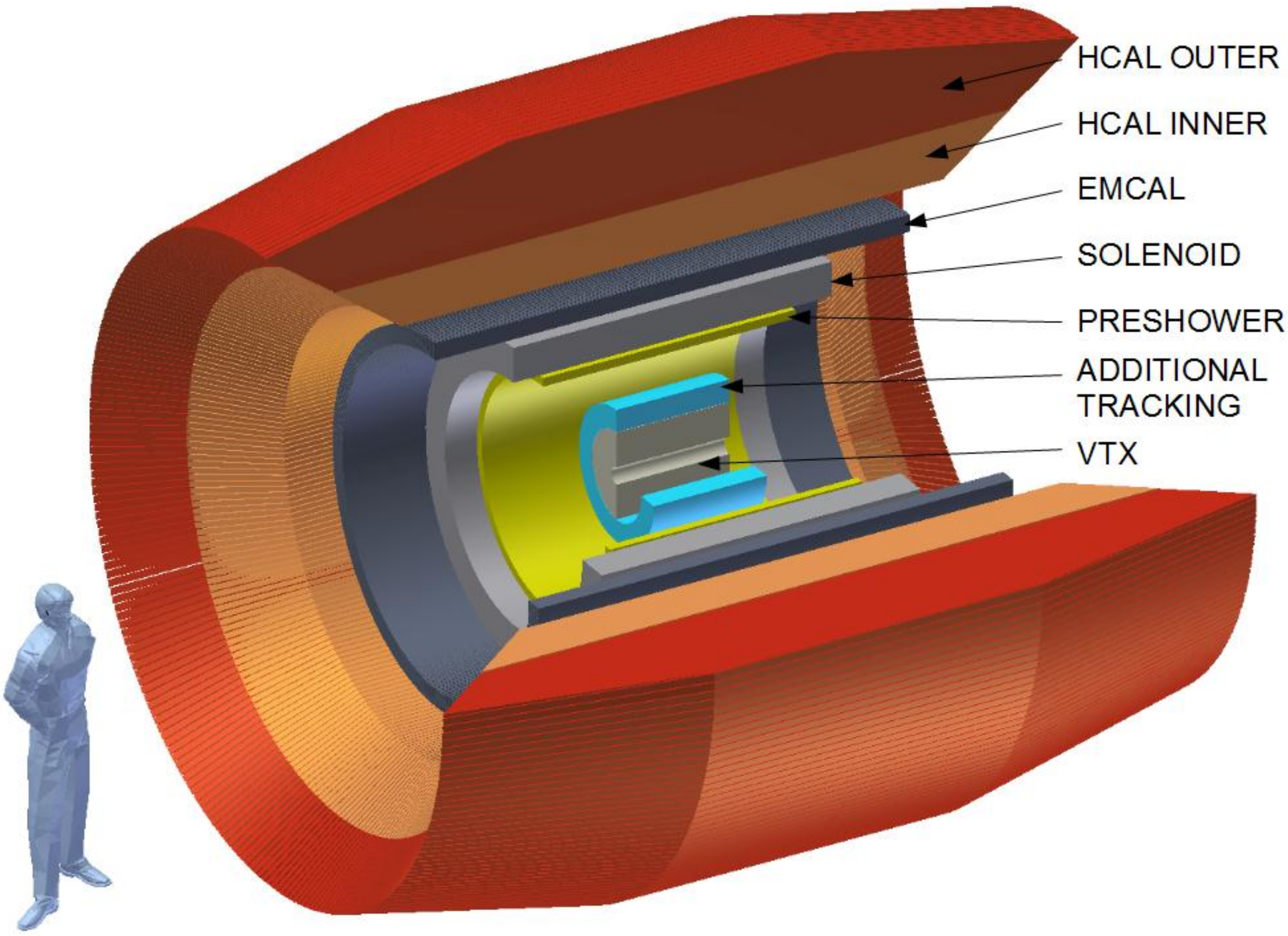
- Full azimuthal coverage in a fiducial region $|\eta|<1$
- 2 T solenoid to ultimately allow high resolution tracking in a small volume
- Electromagnetic and hadronic calorimetry
  - Electromagnetic
    - $\Delta\eta \times \Delta\varphi \approx 0.02 \times 0.02$
    - $\sigma_E/E \approx 15\%/\sqrt{E}$
  - Hadronic
    - $\Delta\eta \times \Delta\varphi \approx 0.1 \times 0.1$
    - $\sigma_E/E \approx 100\%/\sqrt{E}$
- Data acquisition capable of recording >10 kHz

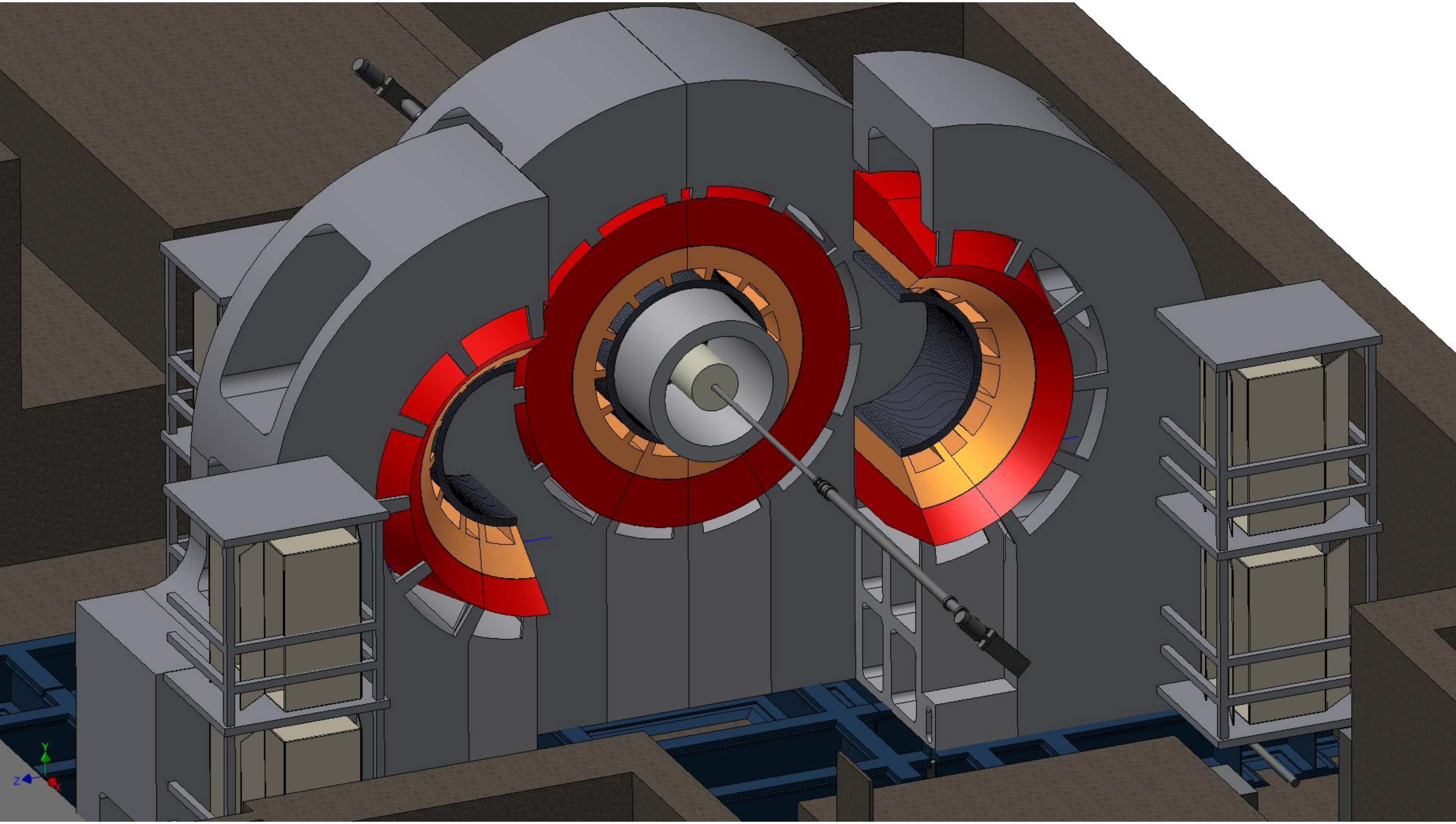
sPHENIX concepts

Take advantage of new technologies for a very compact design

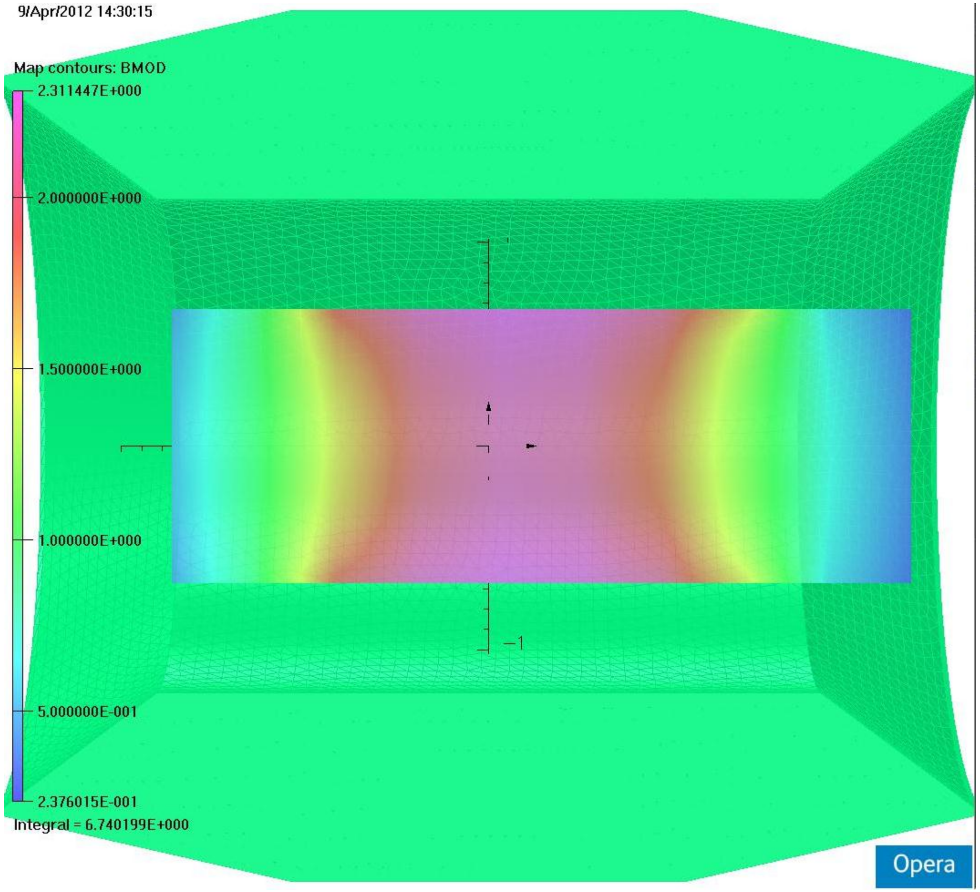
- Tungsten-scintillator EMCAL makes detector more compact than previously possible
- SiPM's or APD's are small, don't require high voltage, and work in a magnetic field
- Hadron calorimeter can serve as flux return
- HCAL uses fiber embedded in scintillator for light collection ala T2K
- Commercial electronics when possible, existing ASIC's when not
- New technologies not available ten years ago minimize costs and build on experience in PHENIX


HCAL OUTER
HCAL INNER
EMCAL
SOLENOID
VTX


HCAL OUTER
HCAL INNER
EMCAL
SOLENOID
PRESHOWER
ADDITIONAL
TRACKING
VTX



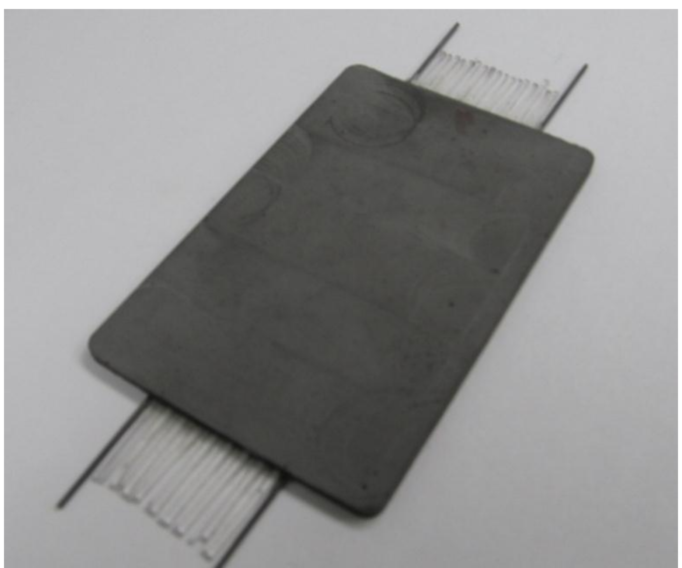
2 T Solenoid 70 cm inner radius

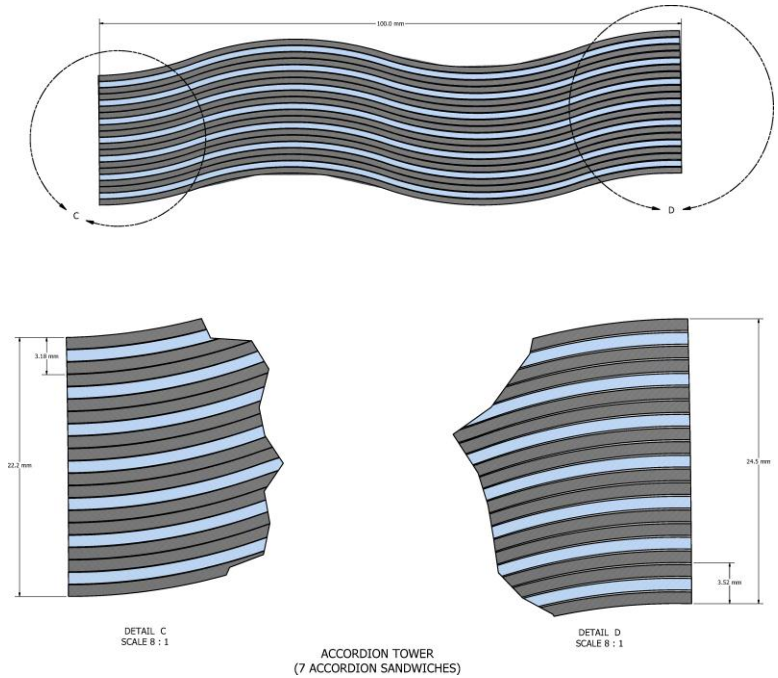


$\approx 1\ X_0$

sPHENIX

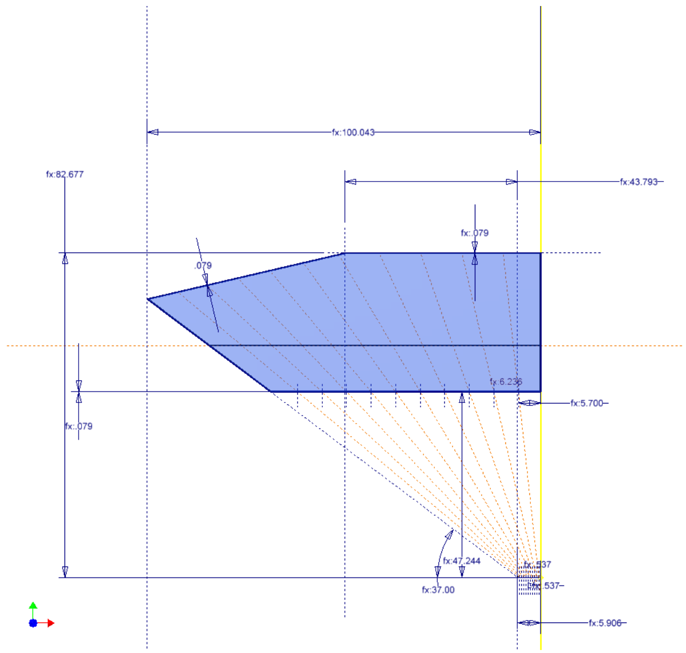
Electromagnetic calorimeter

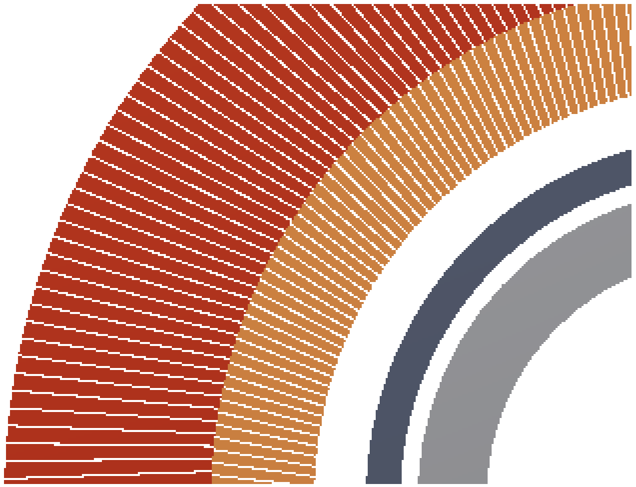


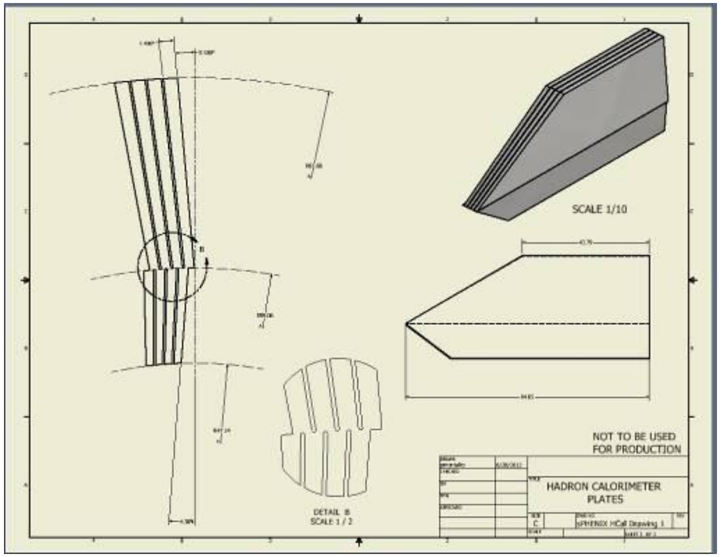


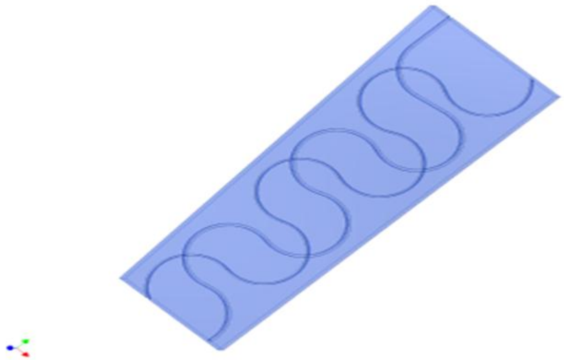
- Optical accordion
- Tungsten absorber
- Scintillating fiber

Hadronic calorimeter

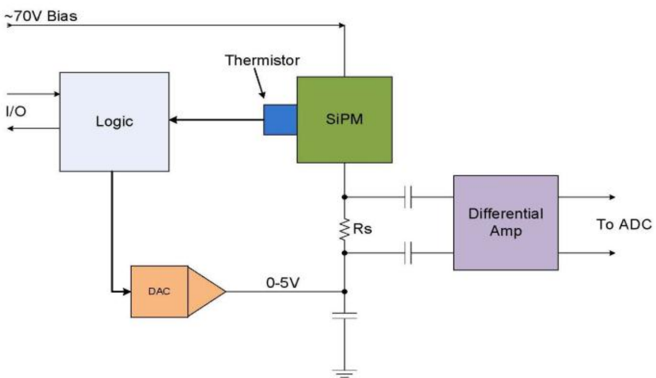


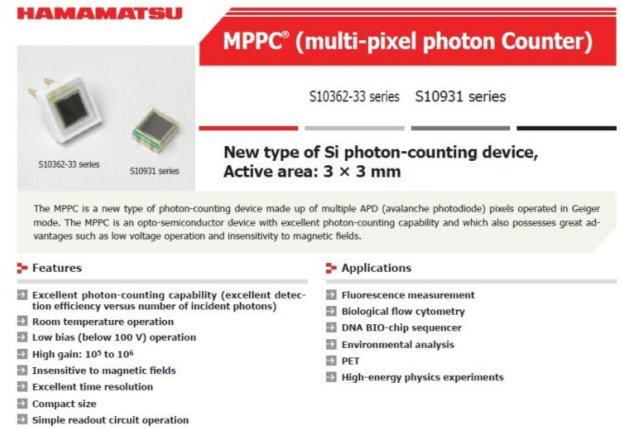






SiPM





HAMAMATSU

MPPC® (multi-pixel photon Counter)

S10362-33 series S10931 series

S10362-33 series

S10931 series

New type of Si photon-counting device,
Active area: 3 × 3 mm

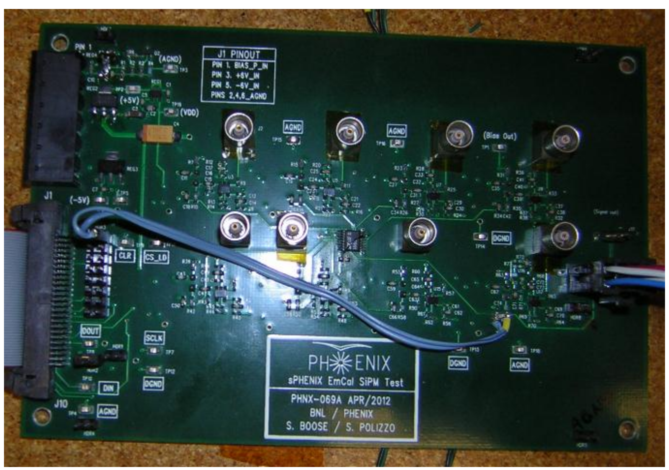
The MPPC is a new type of photon-counting device made up of multiple APD (avalanche photodiode) pixels operated in Geiger mode. The MPPC is an opto-semiconductor device with excellent photon-counting capability and which also possesses great advantages such as low voltage operation and insensitivity to magnetic fields.

Features

- Excellent photon-counting capability (excellent detection efficiency versus number of incident photons)
- Room temperature operation
- Low bias (below 100 V) operation
- High gain: 10^5 to 10^6
- Insensitive to magnetic fields
- Excellent time resolution
- Compact size
- Simple readout circuit operation

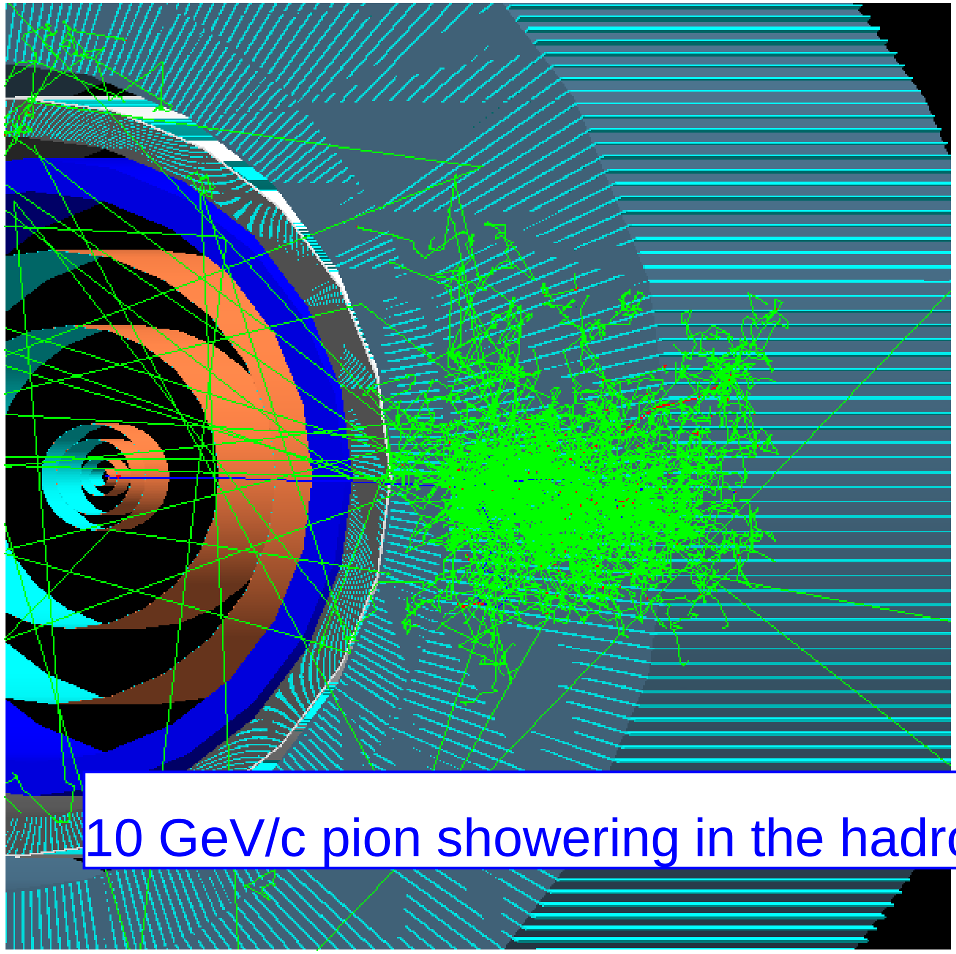
Applications

- Fluorescence measurement
- Biological flow cytometry
- DNA BIO-chip sequencer
- Environmental analysis
- PET
- High-energy physics experiments



- Design based on existing parts
- Gain stabilization on detector
- Economical in large quantities

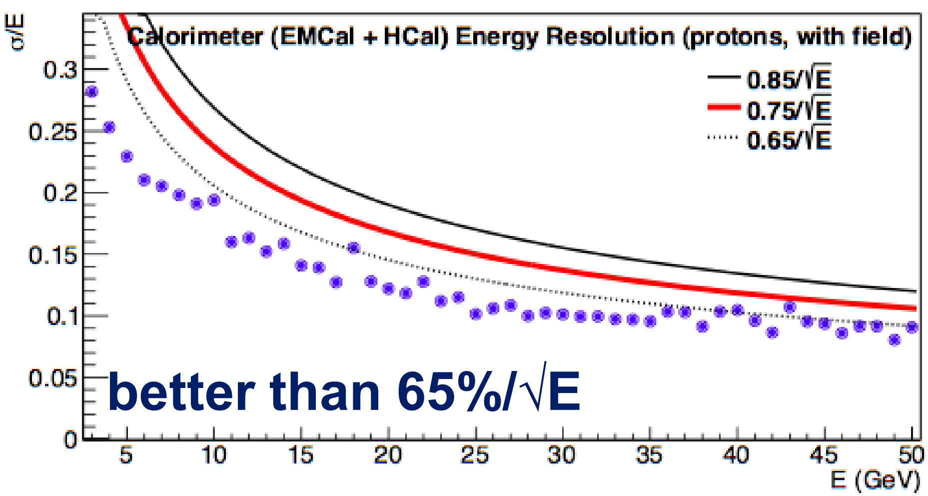
GEANT4 simulation



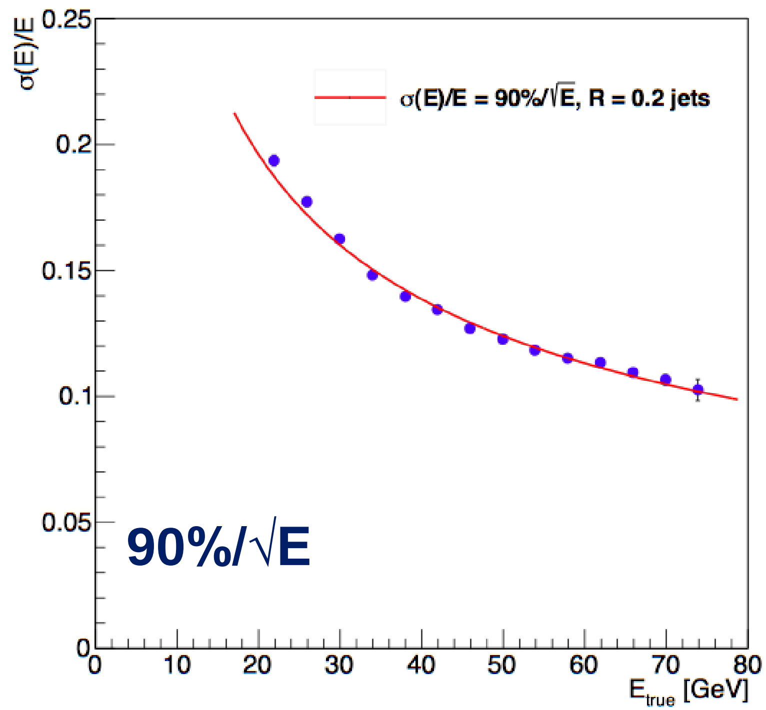
10 GeV/c pion showering in the hadronic calorimeter

Expected performance of calorimeters

Single particle resolution in EMCal+HCal

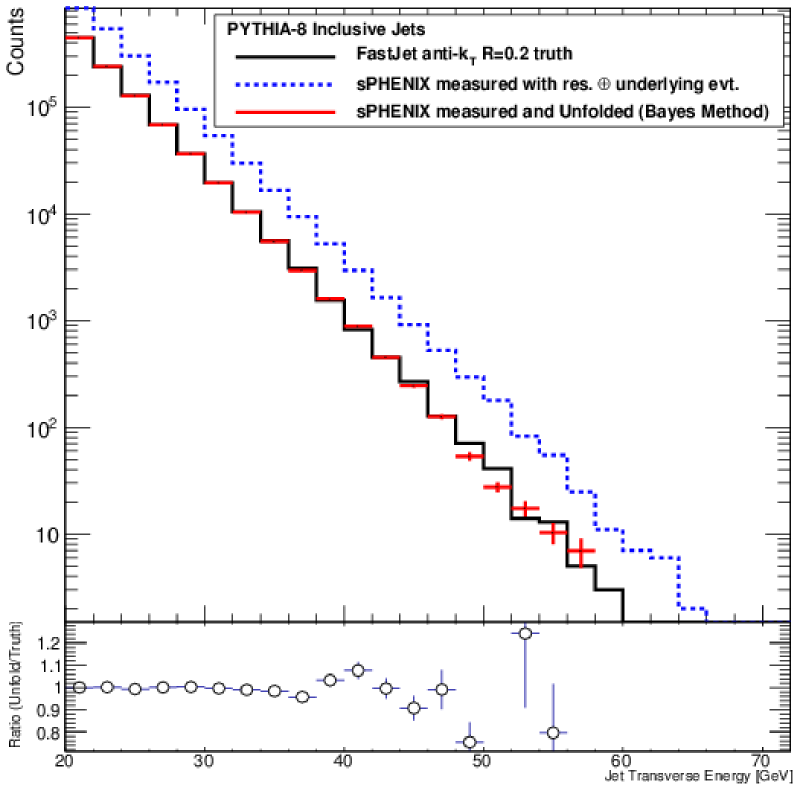


Jet energy resolution From GEANT4 in *p+p*

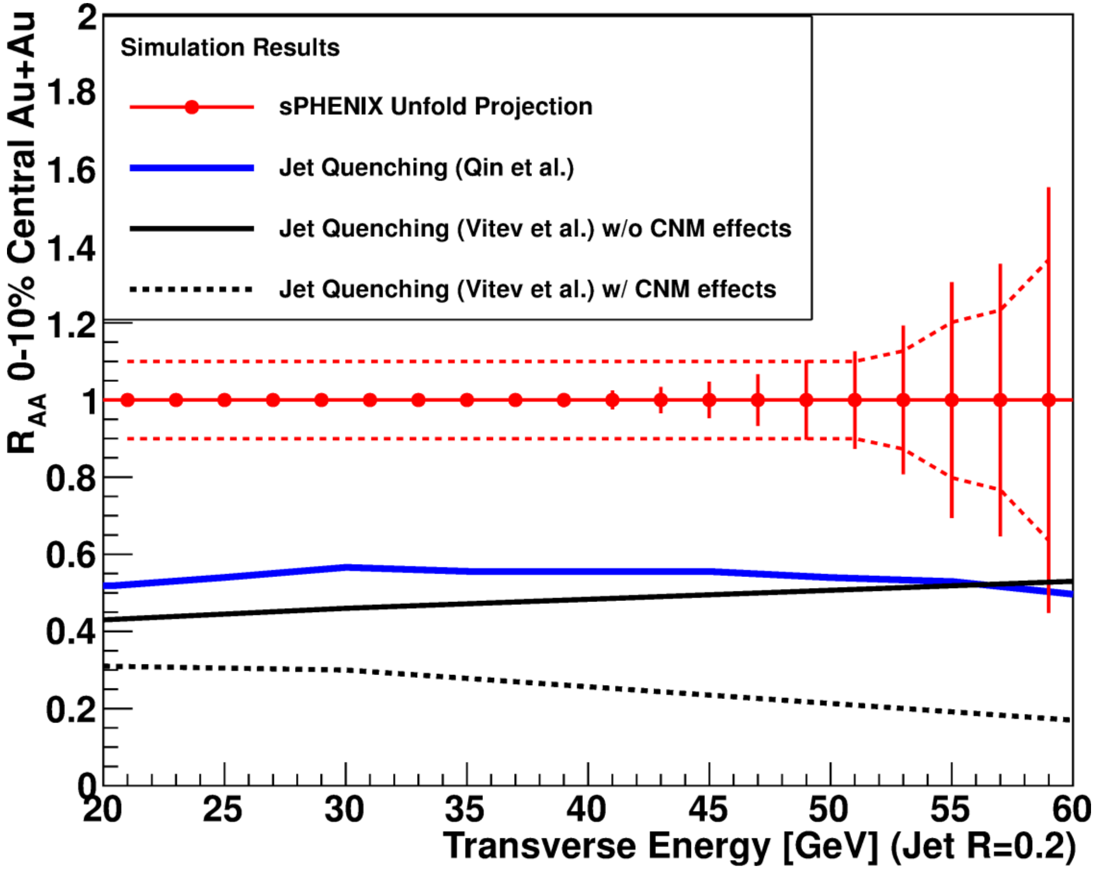


Jet physics sPHENIX

- Day 1 measurement of inclusive jet spectrum to measure jet quenching
- FASTJET anti-k_T algorithm applied to p+p and Au+Au collisions
  - Fast simulation using results of full detector simulation
  - Additional smearing of the underlying event added
  - Unfolding to recover input spectrum



R_{AA} resolution

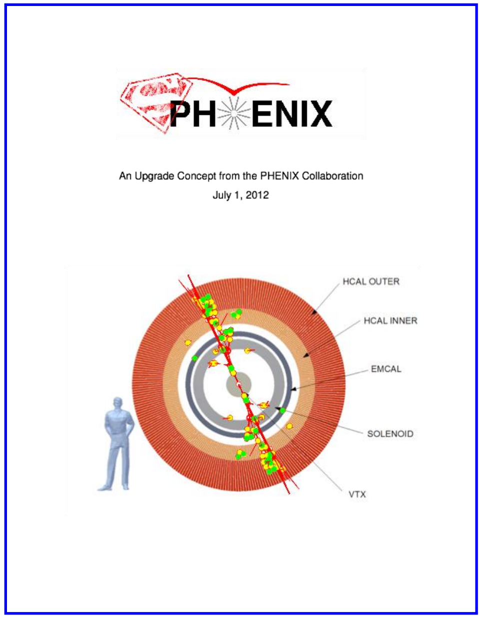


Beyond the baseline

sPHENIX can be extended

- Improved tracking in the magnetic field for high resolution momentum measurement
- A preshower detector which improves the reach of γ/π^0 separation and electron identification
- There is another effort exploring the possibility for forward physics with additional instrumentation
- We have considered from the beginning how it could evolve to a detector at an EIC

More detail



There is much more information in arXiv:1207.6378

sPHENIX posters

- 271 - sPHENIX Jet Upgrade Program: Unraveling Strong vs Weak Coupling, J. Nagle
- 258 - Jet Physics Simulations for the sPHENIX Upgrade, A. Hanks
- 323 - sPHENIX Jet Reconstruction Performance, A. Sickles
- 382 - Photon Reconstruction in the sPHENIX Electromagnetic Calorimeter, M. Purschke
- 171 - Quarkonium measurements with the proposed sPHENIX detector, M. Rosati
- 298 - The Tungsten-Scintillating Fiber Accordion Electromagnetic Calorimeter for the sPHENIX Detector, C.Woody
- 391 - Hadronic Calorimetry in the sPHENIX Upgrade Project at RHIC, E. Kistenev
- 288 - A Silicon Photomultiplier (SiPM) Based Readout for the sPHENIX Upgrade, E. Mannel

Next steps

- We submitted a proposal to Brookhaven management on July 1, 2012
- Most of the proposal is available as arXiv:1207.6378
- A laboratory review will take place in October
- We are pursuing an aggressive schedule to review, fund, and construct this detector

Summary

- Jet physics accessible at RHIC complements and extends measurements made at the LHC
- The sPHENIX proposal consists of a small number of well defined components which builds on the experience of building and operating the PHENIX detector to carry out a program of jet physics measurements at RHIC