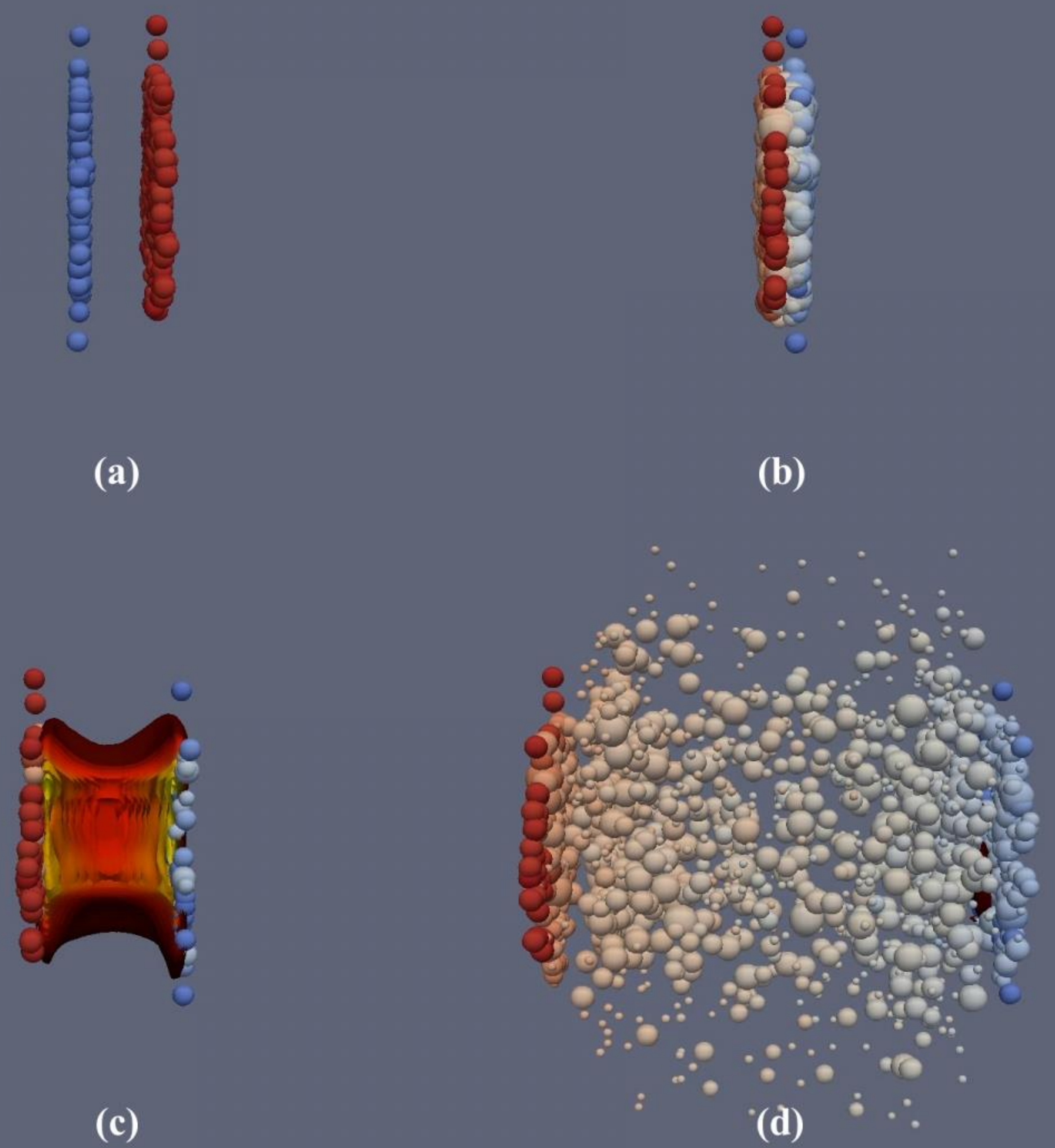
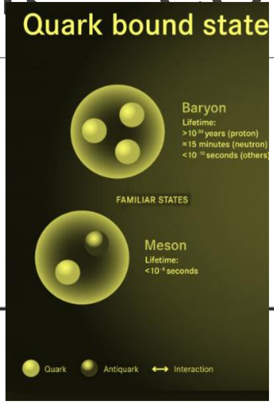


Why is colliding Heavy ions fun?

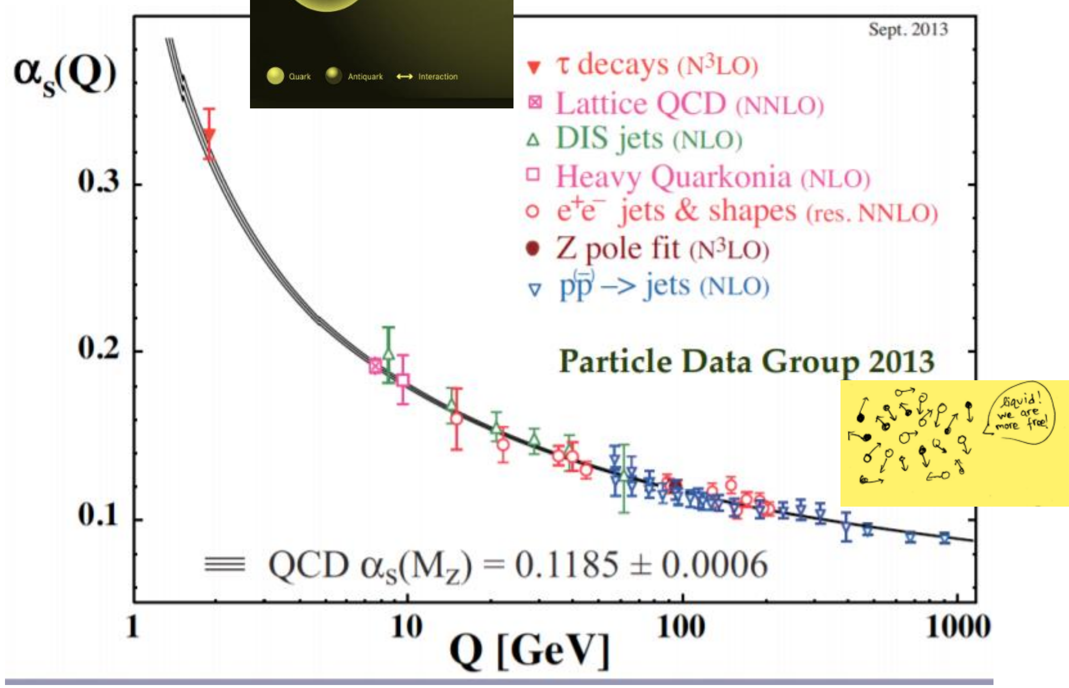
NIVEDITHA RAM

04/02/2019

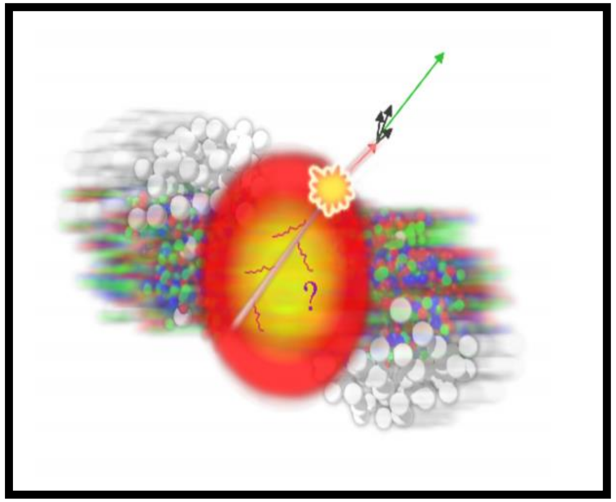
Running coupling “constants”



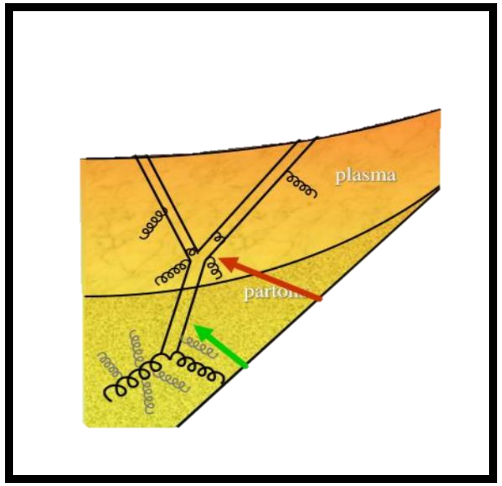
QCD



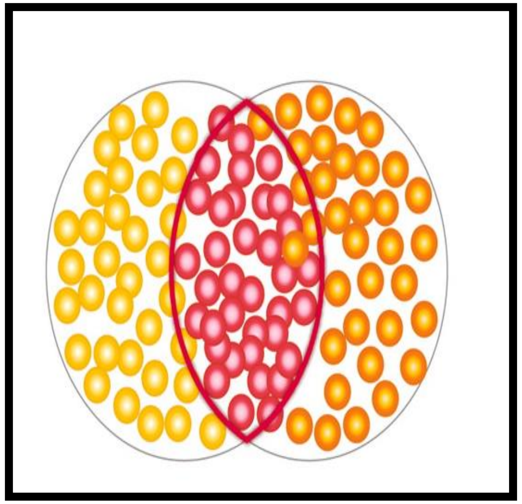
What are my observables to study QGP?



Jet Suppression



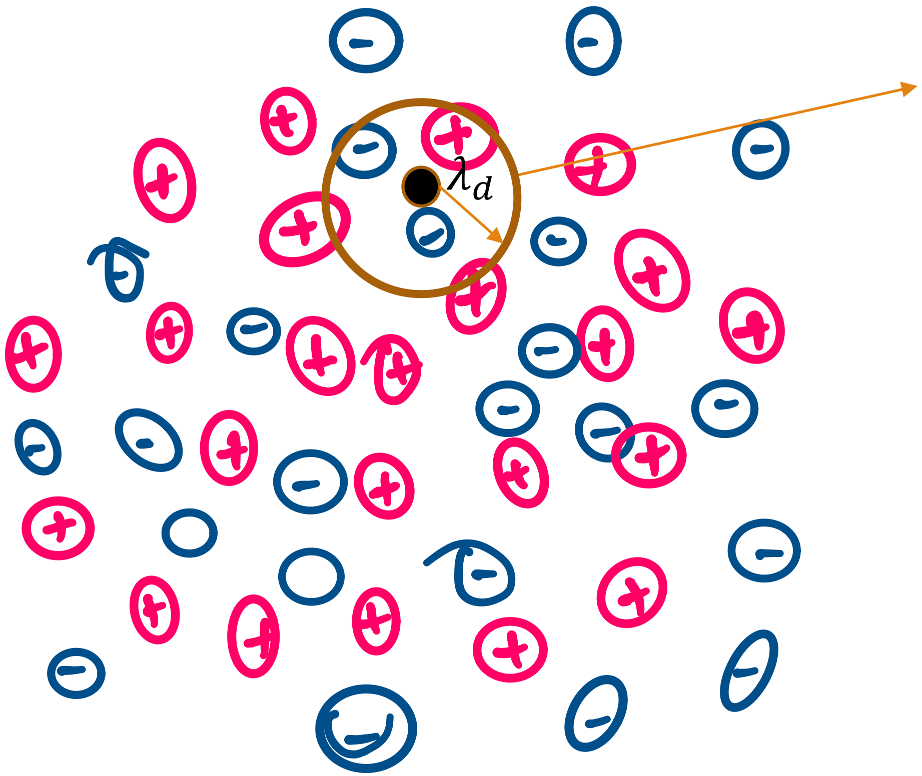
Quarkonium Suppression



Elliptic Flow

Quarkonium suppression

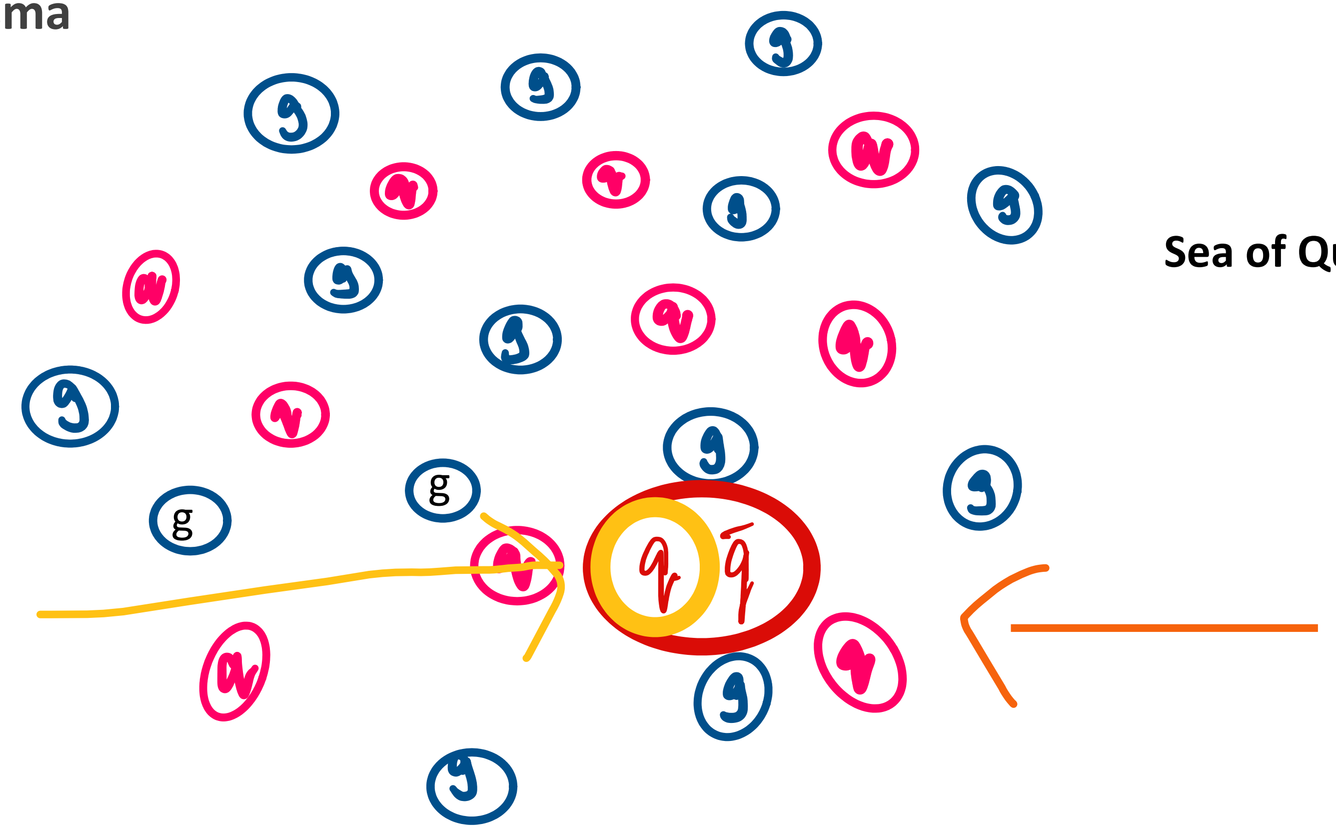
To understand this, let me remind you of what is a Plasma and Debye screening length.



Debye Screening length.
The length beyond which the impurity does not feel the EM effect of other particles

Quarkonium suppression

Quark Gluon Plasma



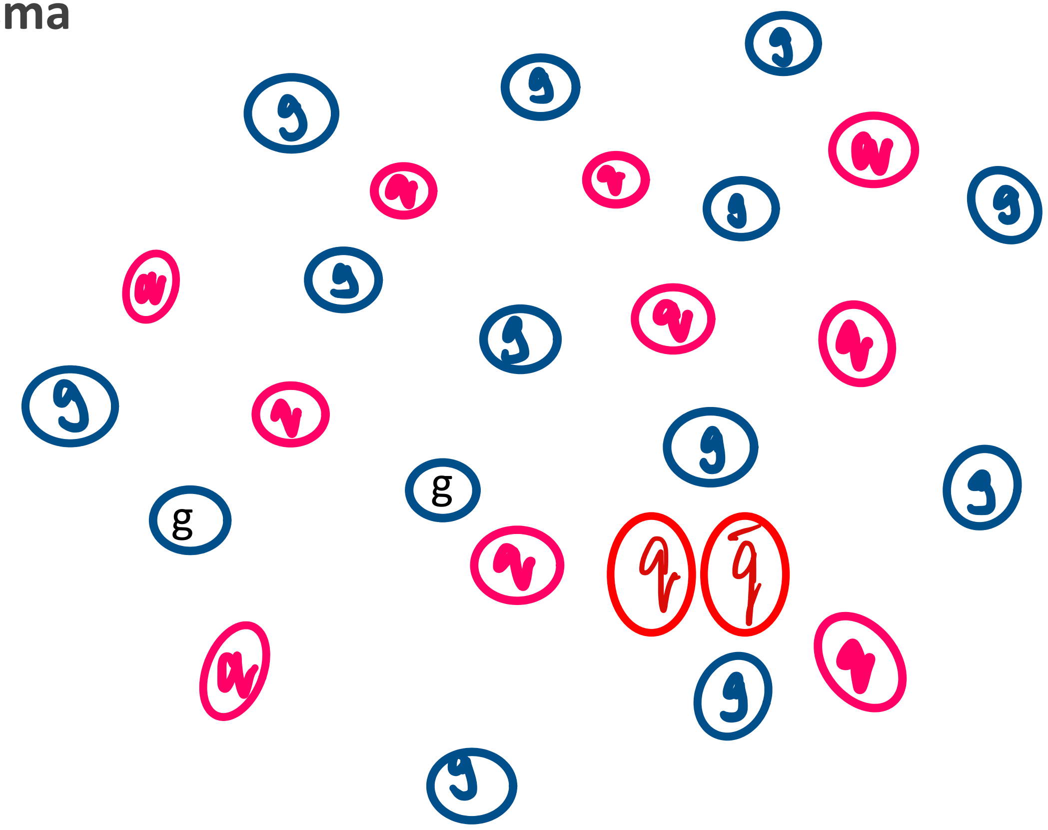
Sea of Quarks and gluons

(say) Debye screening length

Introducing an “impurity”: a bound state of quark-antiquark(meson)

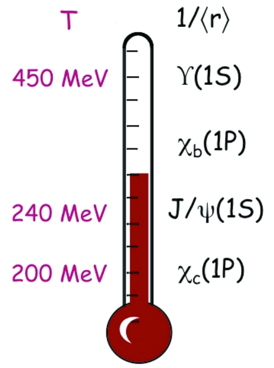
Quarkonium suppression

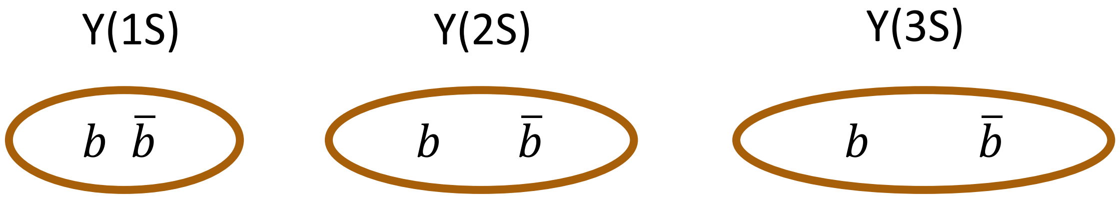
Quark Gluon Plasma



Melted into the QGP.
Not a bound state
anymore

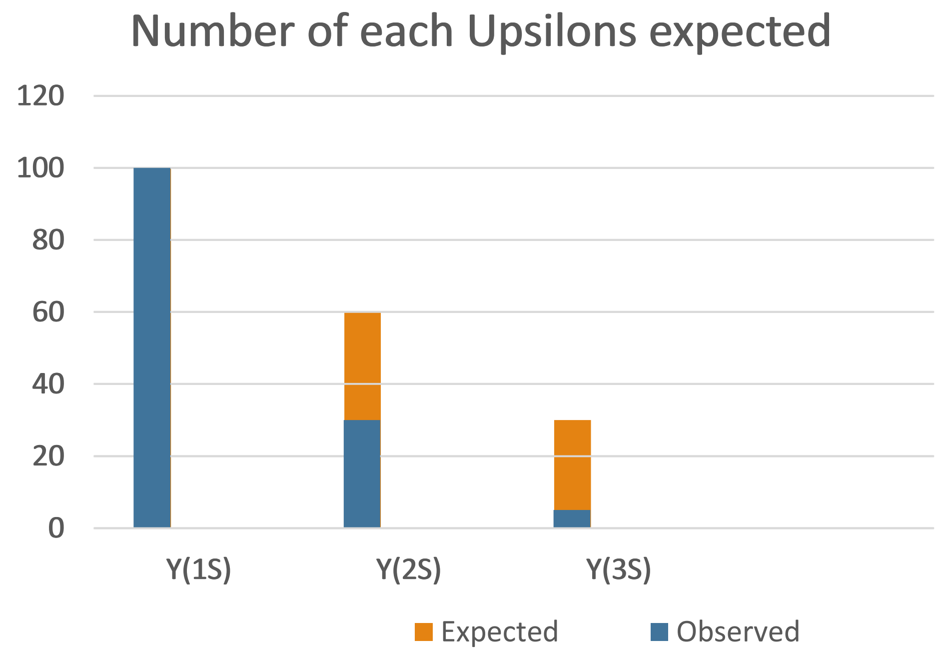
Quarkonium suppression as a QGP “thermometer”



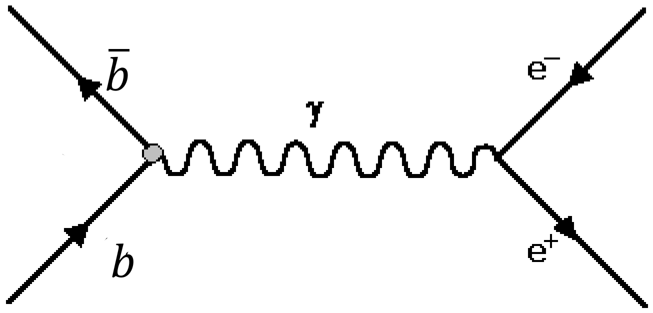


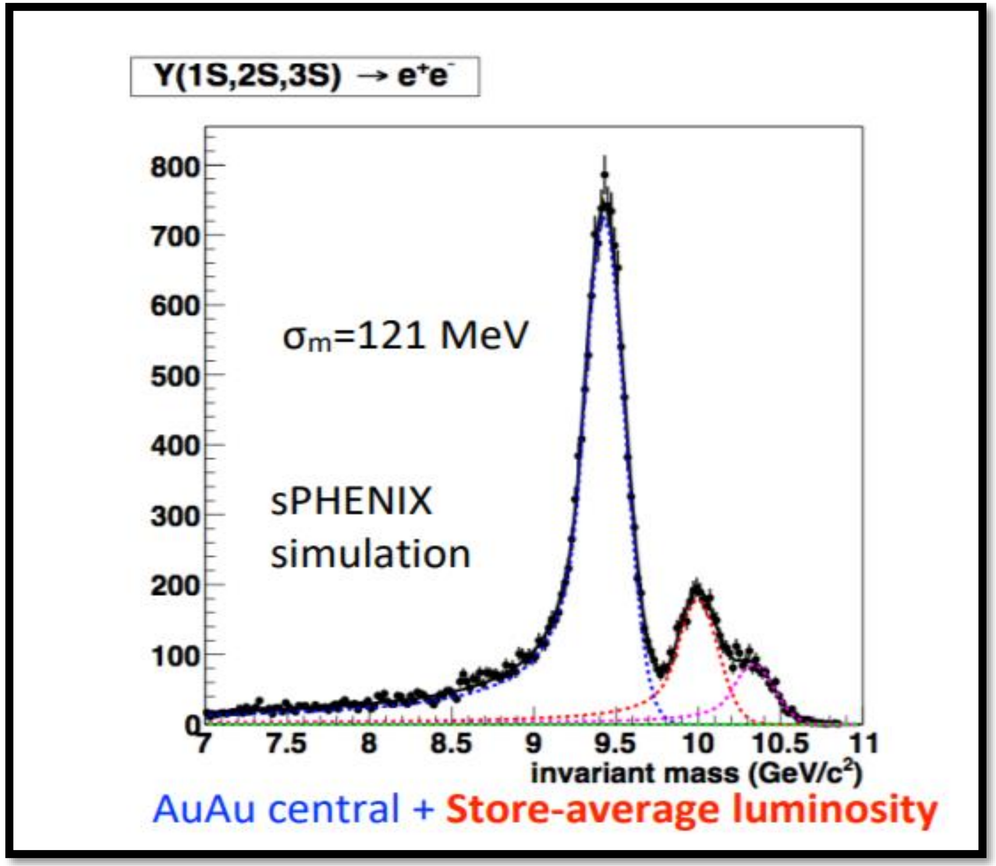
(say)

$$L_{1S} < \lambda_{QGP} < L_{2S} < L_{3S}$$



How do we measure these upsilon states?



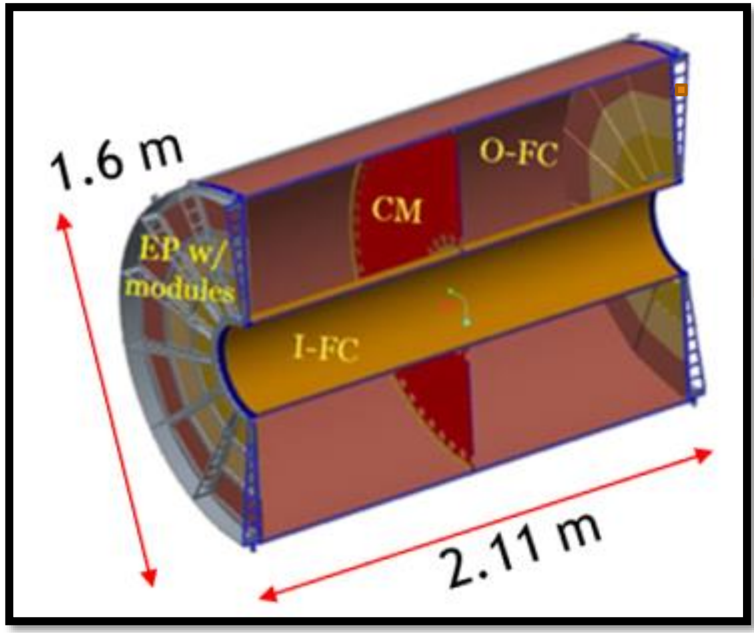


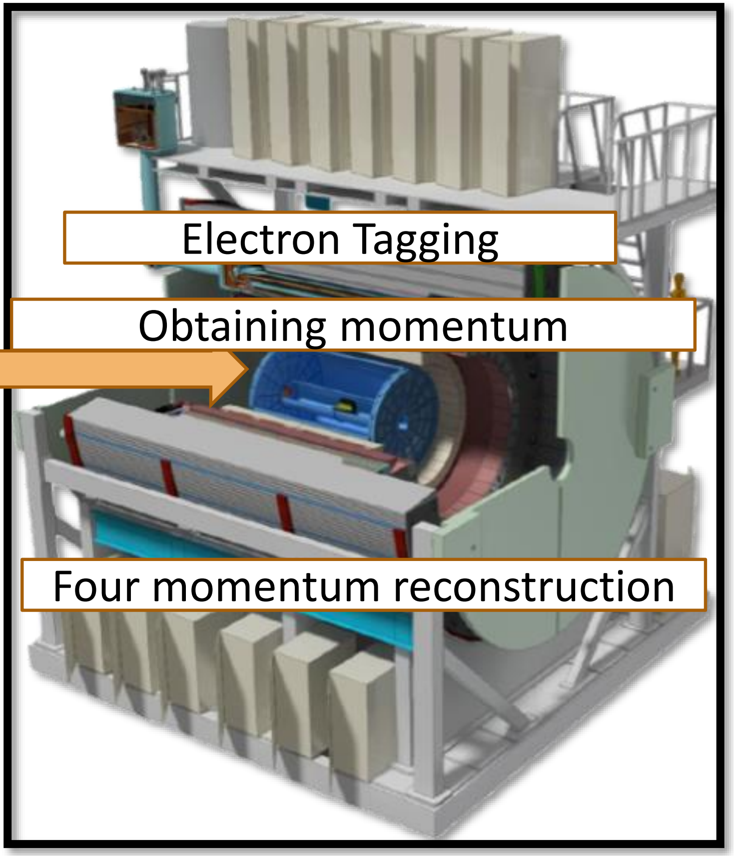
- Tag electrons using electromagnetic calorimeter
- Obtain precise momentum information using a Time Projection Chamber
- Reconstruct the 4 momentum to determine whether it is Υ(1S), Υ(2S) or Υ(3S) state.

Time Projection Chamber (TPC) at sPHENIX

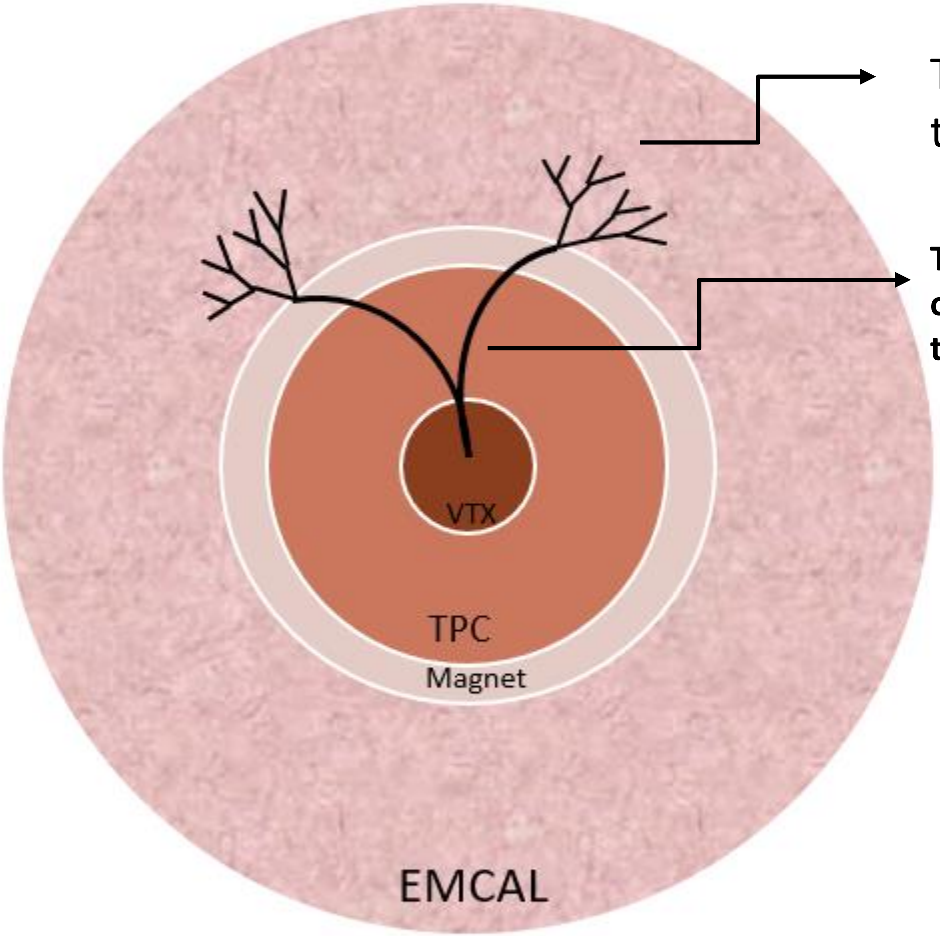
Physical Size

- 20cm < r < 78 cm (leaves ~10cm room for future PID upgrade)
- $|\eta| < 1.1$ implies 2.11 meter overall length
- Full azimuthal coverage





TPC sits in a magnetic field



The signature shower in EMCal helps tagging the tracks whether it is an electron or not

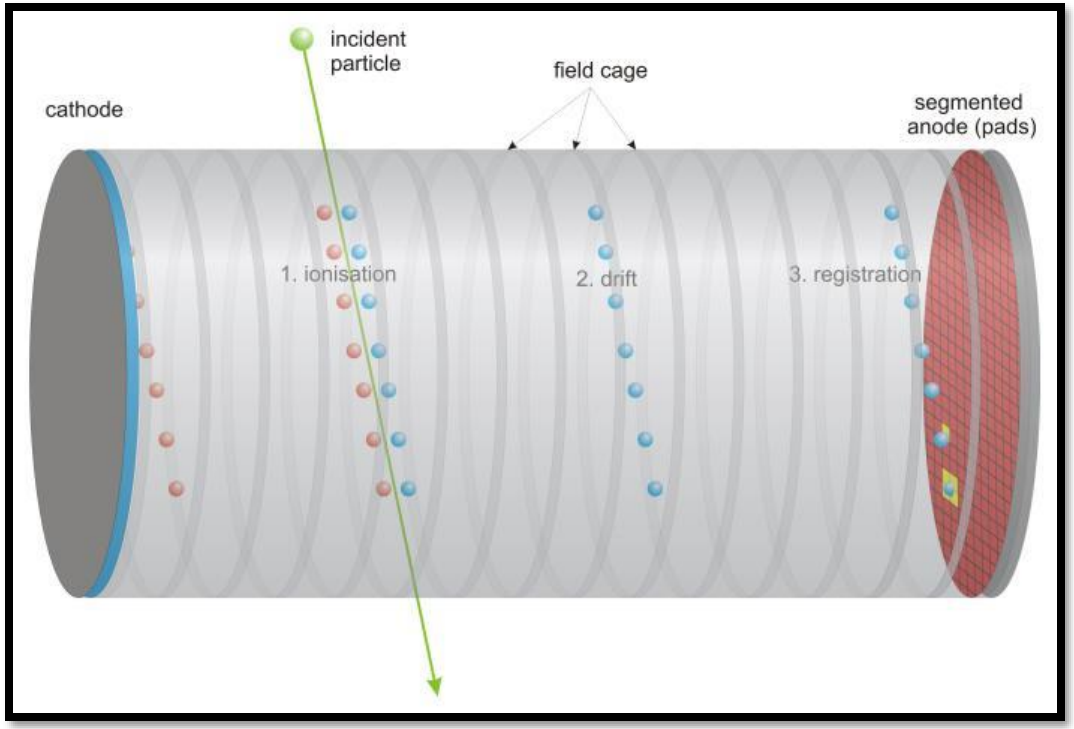
The track of a charged particle will bend in the field and the curvature will give us precise information about the momentum of the particle.

Four Momentum reconstruction which gives the mass of the decay particle and thus helps in identifying the state of Upsilon particle

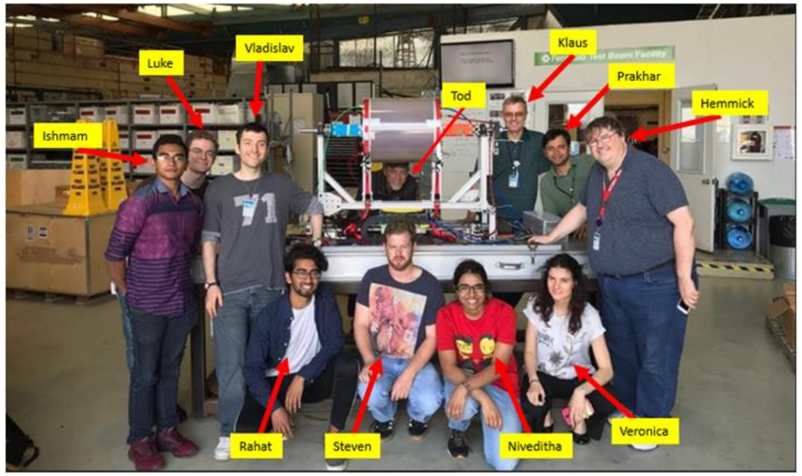
TPC – Principle of operation

The TPC is a detector subsystem which helps in mapping the track of a charged particle. Its active volume is filled with gas and as a charged particle travels through it, it ionizes the gas. The ionized electrons drift to the anode pad plane due to the imposed electric field lines.

As the sPHENIX TPC will be sitting within a magnetic field (BaBar magnet**To obtain a momentum resolution of 100MeV/c, we require a position resolution of 200**μm.



Prakhar doesn’t know to pose candidly

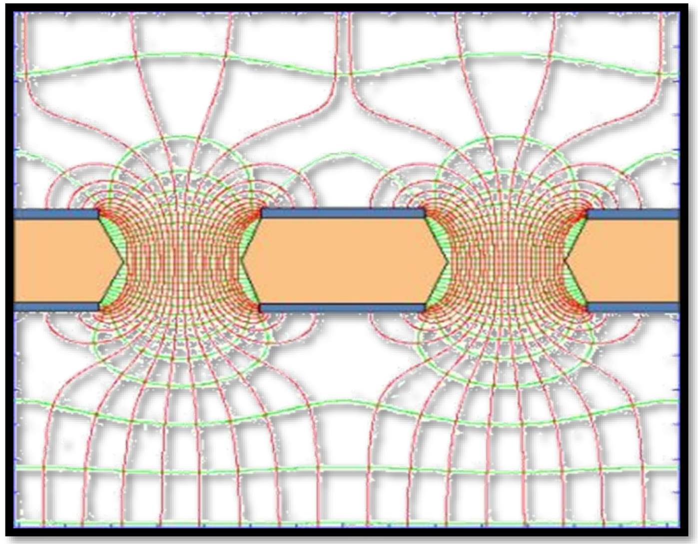


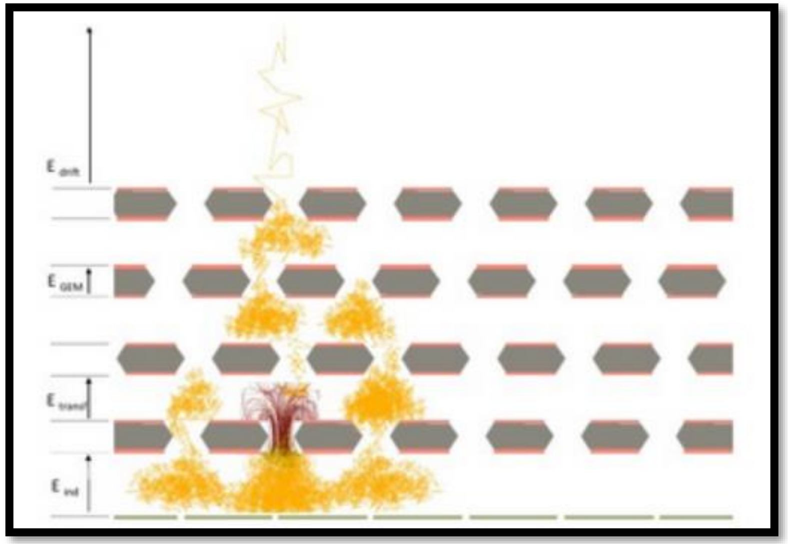
Field Cage

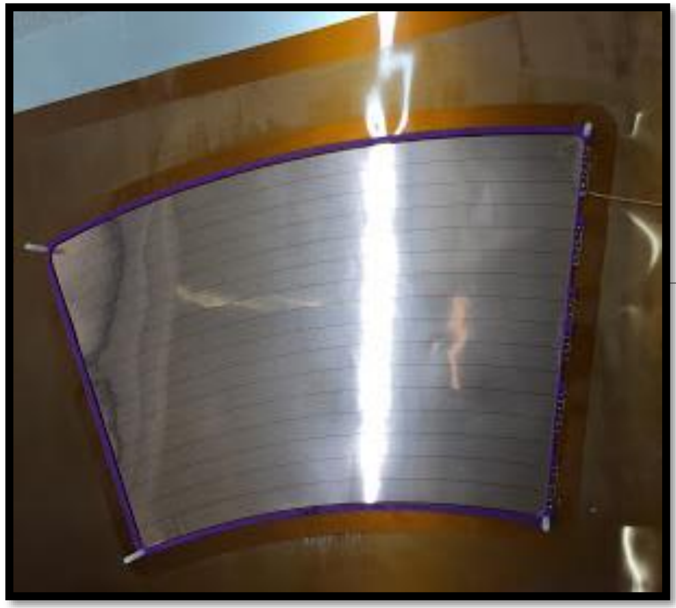
Of the prototype

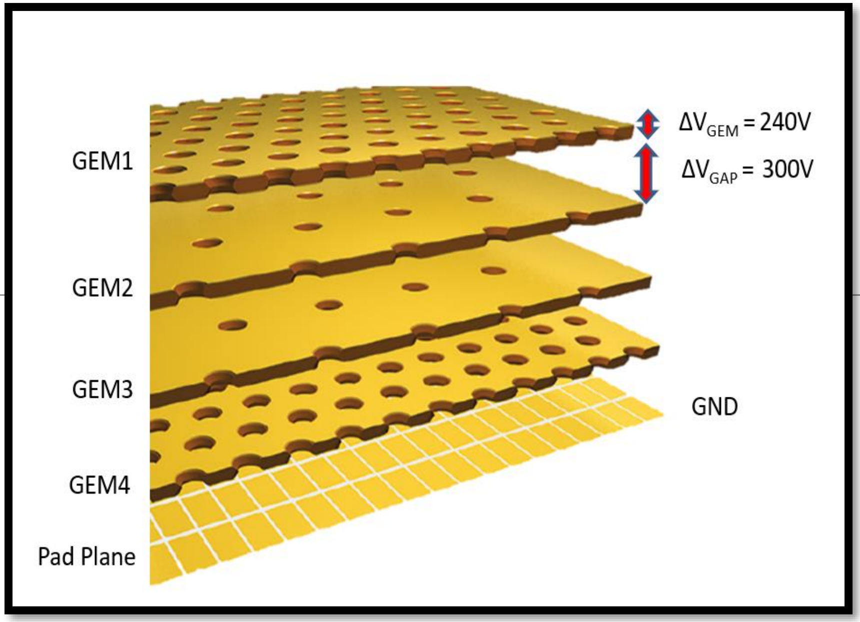
Gas Electron Multiplier

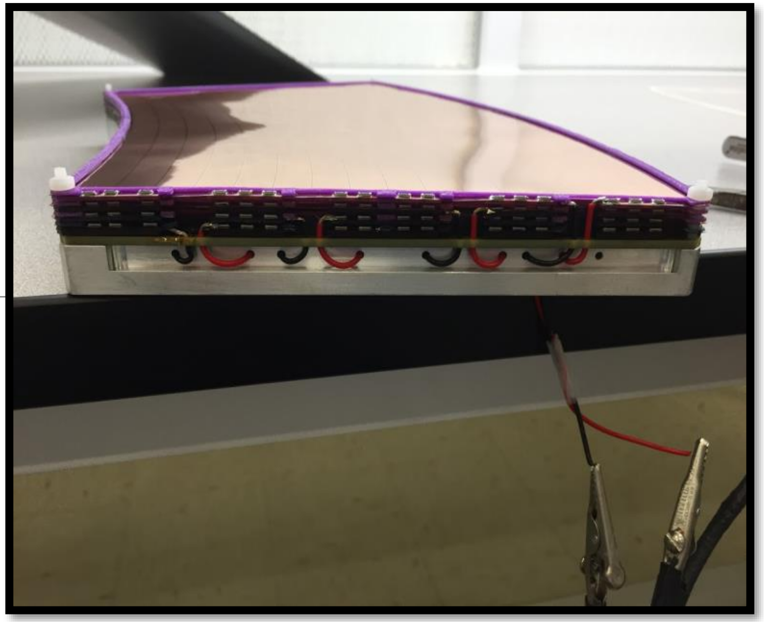
The drifted electrons from the primary ionization are too weak to produce any signal that can be measured. To produce such a signal, it needs to be amplified. The Gas Electron Multiplier (GEM) does this by guiding the electrons through a region of high electric field which avalanches the electrons







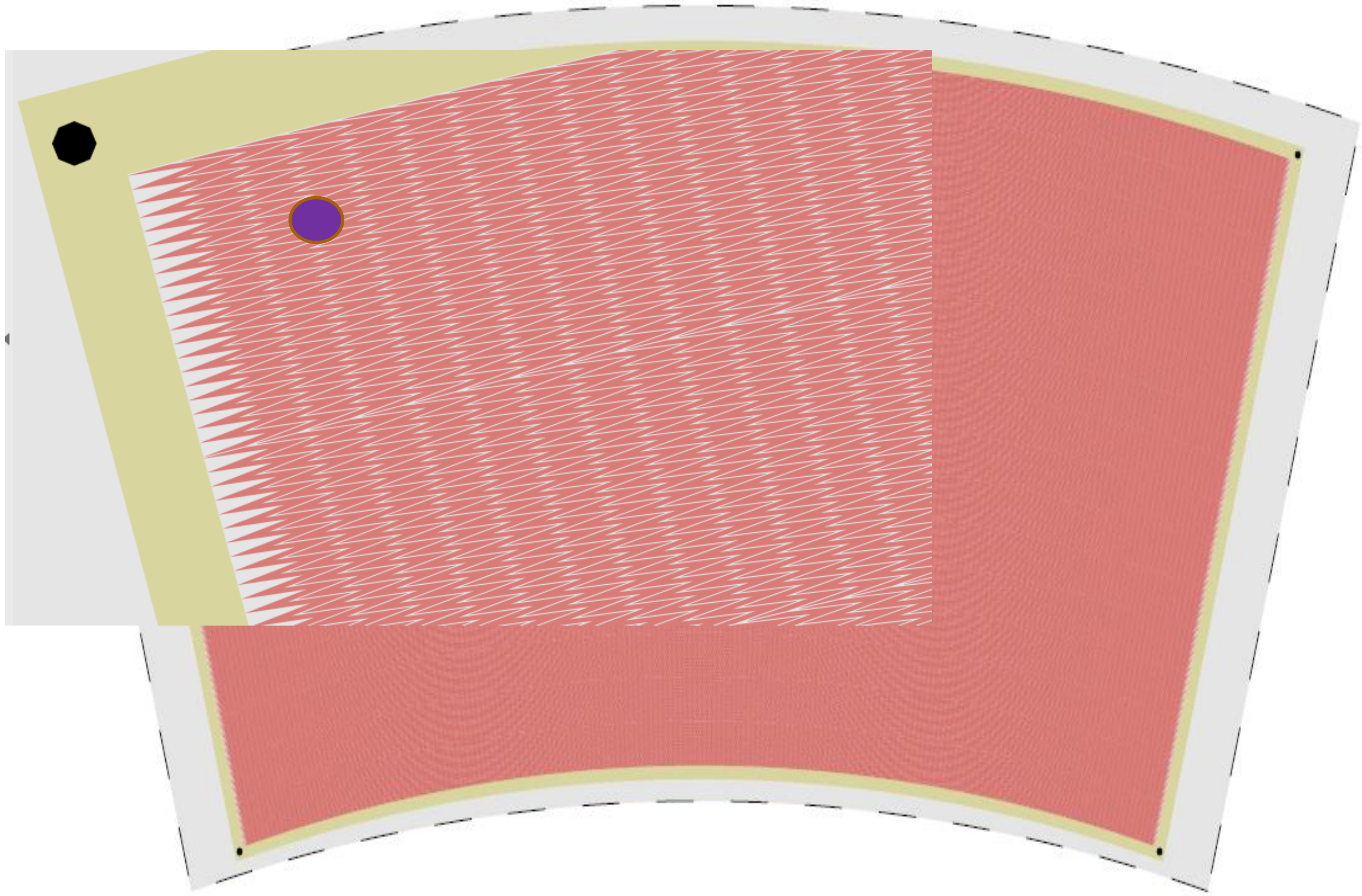




The top of the GEM is divided into 16 sectors radially and it is connected to the HV trace via a current limiting resistance of 20MΩ. The top of the GEM with copper pads for resistors and the HV trace is shown.

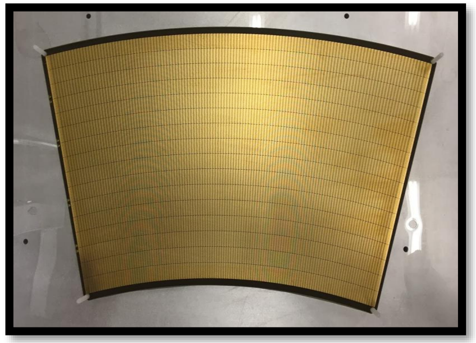
The prototype had four GEMs stacked on top of each other to provide serial amplification. Each GEM foil is voltage separated by ΔV_{GAP} and the top and bottom of the GEM is voltage separated by ΔV_{GEM} . An external High Voltage divider card supplies HV to each of these GEMs via traces on top and the bottom of each GEM

Pad Plane

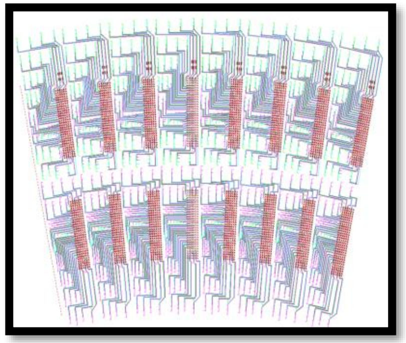


The cloud of avalanched electrons falls on a pad which is discretized in the shape of zig-zags for better resolution.
Studies have shown that these provide better resolution than rectangular pads for the same acceptance.

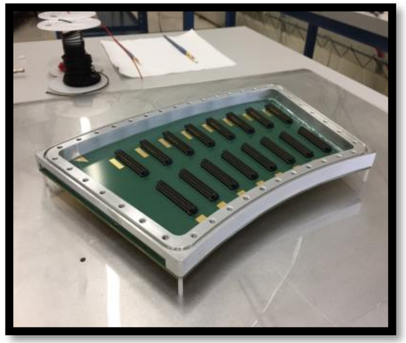
The myriads of electronics (pTPC)



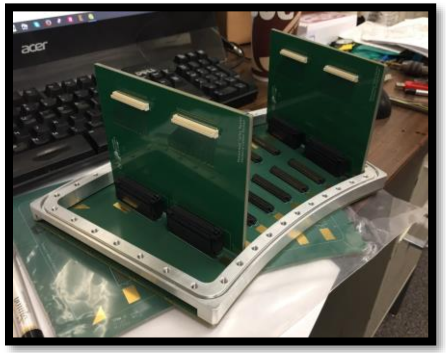
Front of Pad Plane



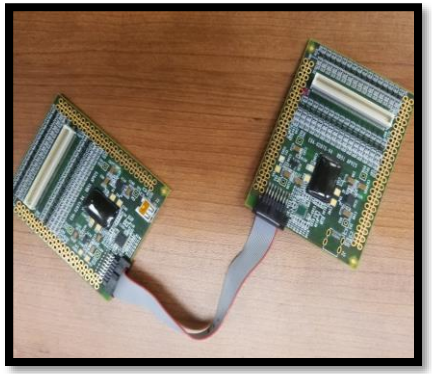
Pad Plane to SAMTEC routing



SAMTEC Connectors



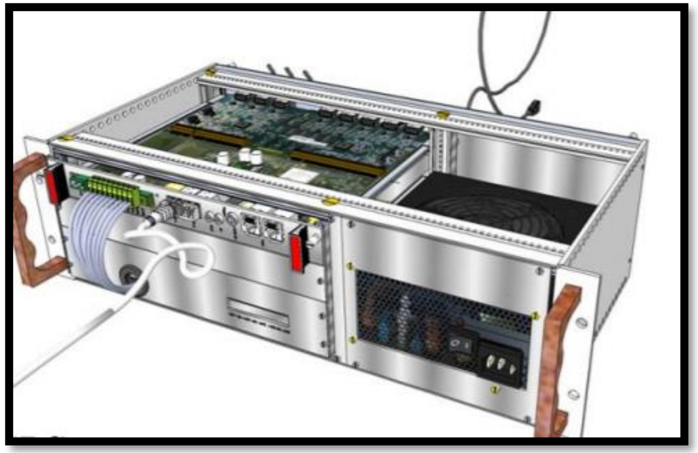
SAMTEC to Panasonic APV routing (PanSam)



Panasonic APV

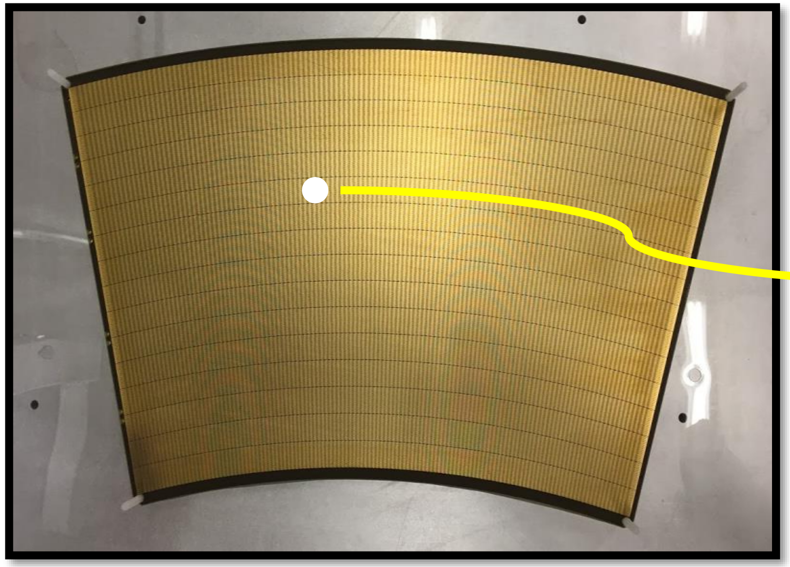
Panasonic APV connected to PANSAM

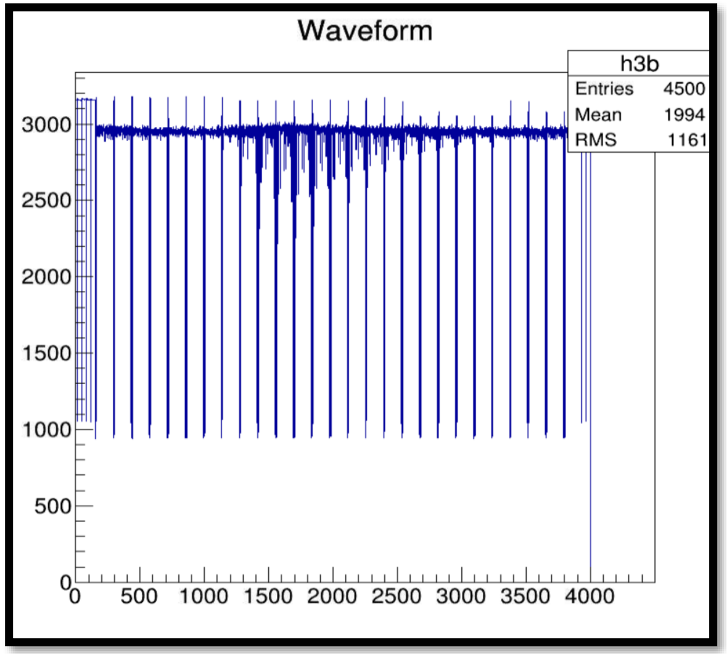
Overall Connection

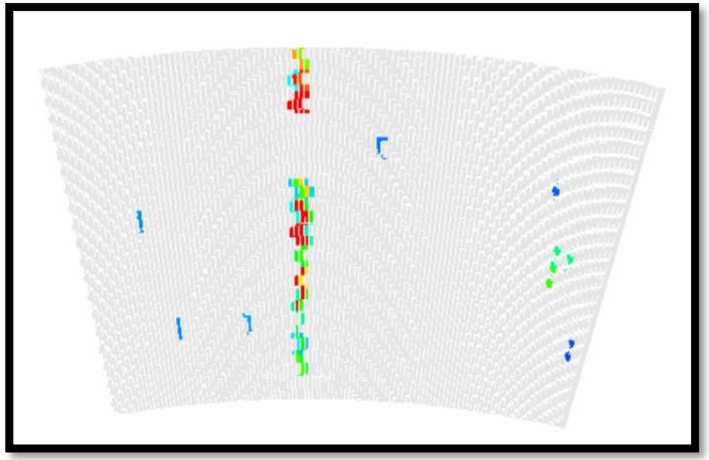


SRS crate

Basically…







Track!!

Links

Standard Model Breakdown : https://www.symmetrymagazine.org/article/the-deconstructed-standard-model-equation

QCD :

- https://www.physics.umd.edu/courses/Phys741/xji/chapter1.pdf
- https://www2.ph.ed.ac.uk/~muheim/teaching/np3/lect-qcd.pdf
- Halzen and Martin. Chapter 7
- http://web.mit.edu/physics/people/faculty/docs/wilczek_nobel_lecture.pdf

TPC:

- https://cds.cern.ch/record/1622286/files/ALICE-TDR-016.pdf
- TPC – Conceptual Design Presentations
- sPHENIX TPC internal report

Flow:

- https://indico.in2p3.fr/event/11794/contributions/6969/attachments/5682/7084/Alice_20Nov2015_Uras.pdf
- https://www.nikhef.nl/pub/services/biblio/theses_pdf/thesis_C_Perez-Lara.pdf

APPENDIX

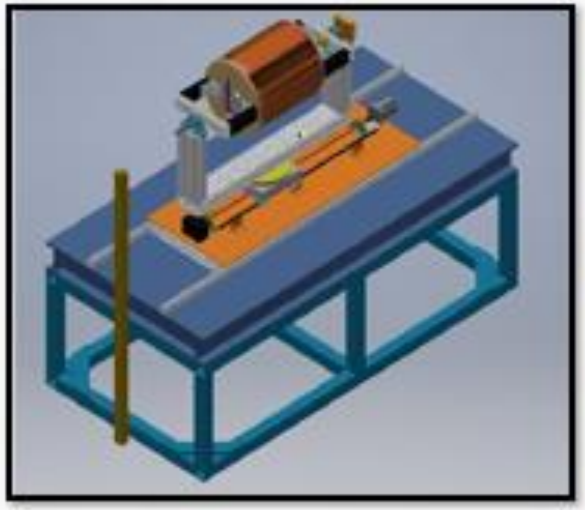
Detector Requirement & Test Beam Purpose

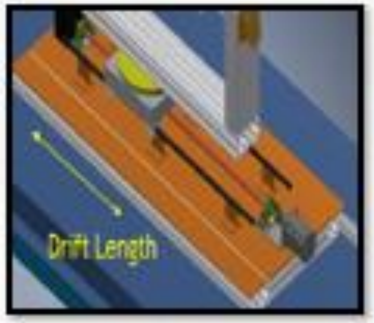
The required momentum resolution of 100 MeV/c can be achieved if we have a position resolution better than 200 μm. The total position resolution is given by

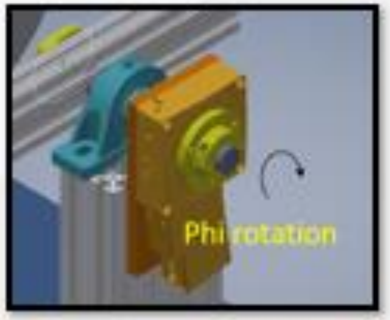
$$\sigma^2{}_{tot} = \sigma^2{}_{int} + \frac{D^2{}_T L}{N_{eff}} + \sigma^2{}_{sc}$$

Where, σ_{int} is intrinsic resolution (at zero drift) verified by GEM chambers in ILC to be ~70μm and σ_{sc} is the resolution due to the space charge term and detailed simulations place its value as ~50μm. The purpose of the test beam is the plot $\sigma^2{}_{tot}$ as a function of drift length and use the slope at zero magnetic field to obtain effective number of electrons (N_{eff}), which can then be extrapolated for 1.4T magnetic field.

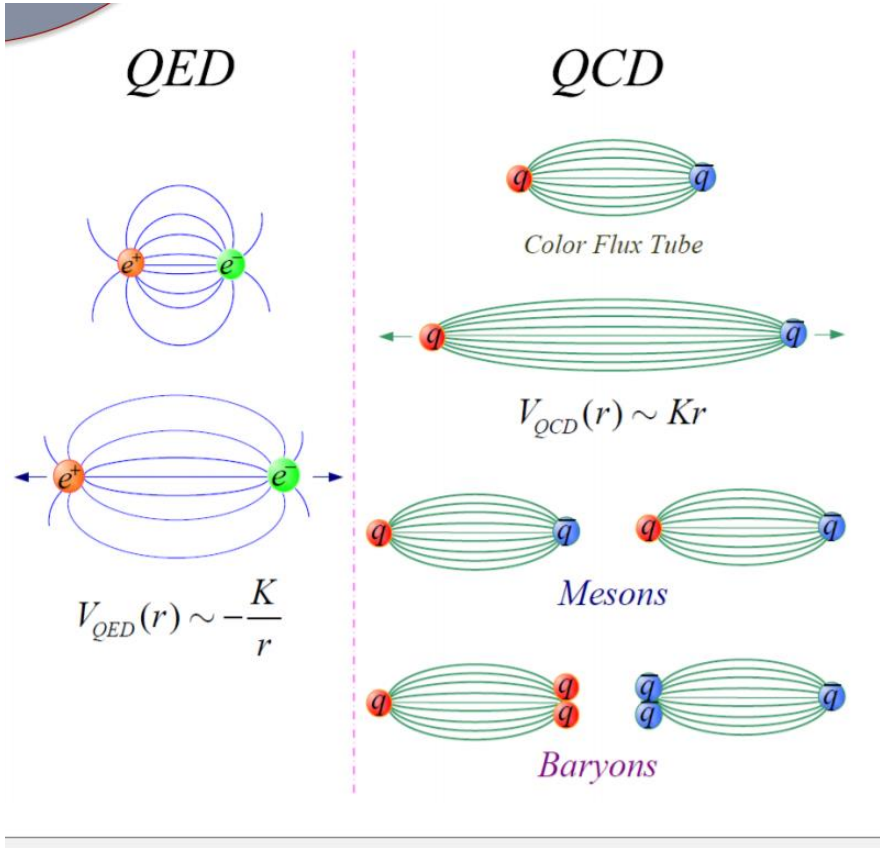
Prototype Stage and final setup







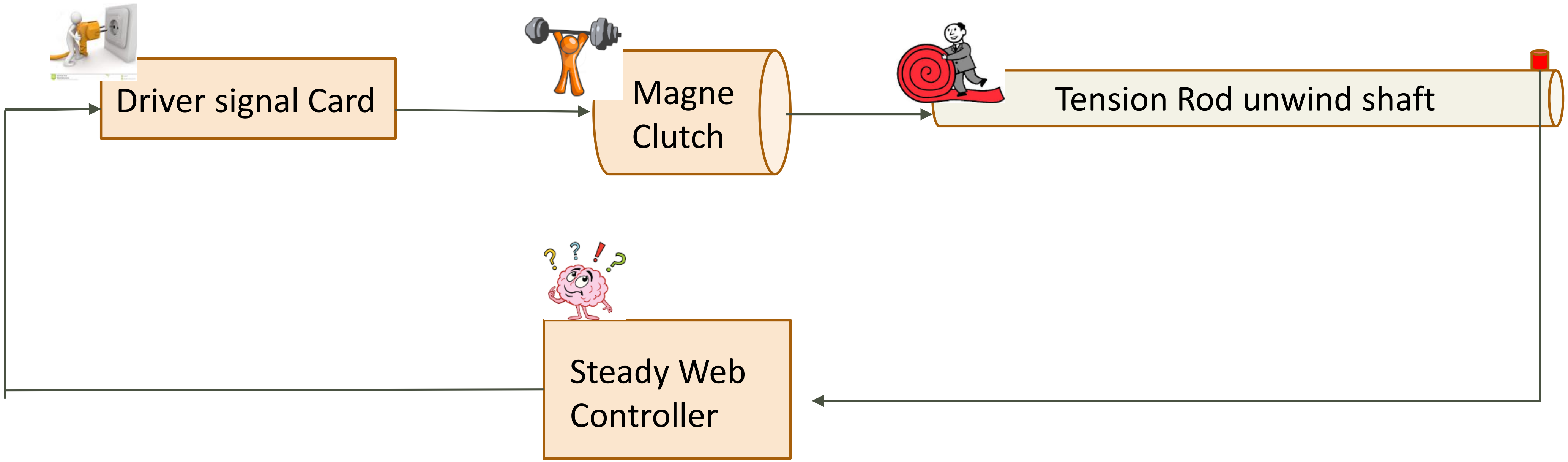
Inventor Model and actual picture of the Final setup. The entire setup has three degrees of freedom. The drift length is the most important as it helps in the study of position resolution. To mimic real tracks which have wide possibility of eta and momentum, our detector also has motors for controlled rotation along eta and phi direction.



QED
QCD
Color Flux Tube
$V_{QCD}(r) \sim Kr$
Mesons
Baryons
$V_{QED}(r) \sim -\frac{K}{r}$

Electrical Layout

Kapton unwind tension generating assembly



Electrical Layout

Scrap winder assembly