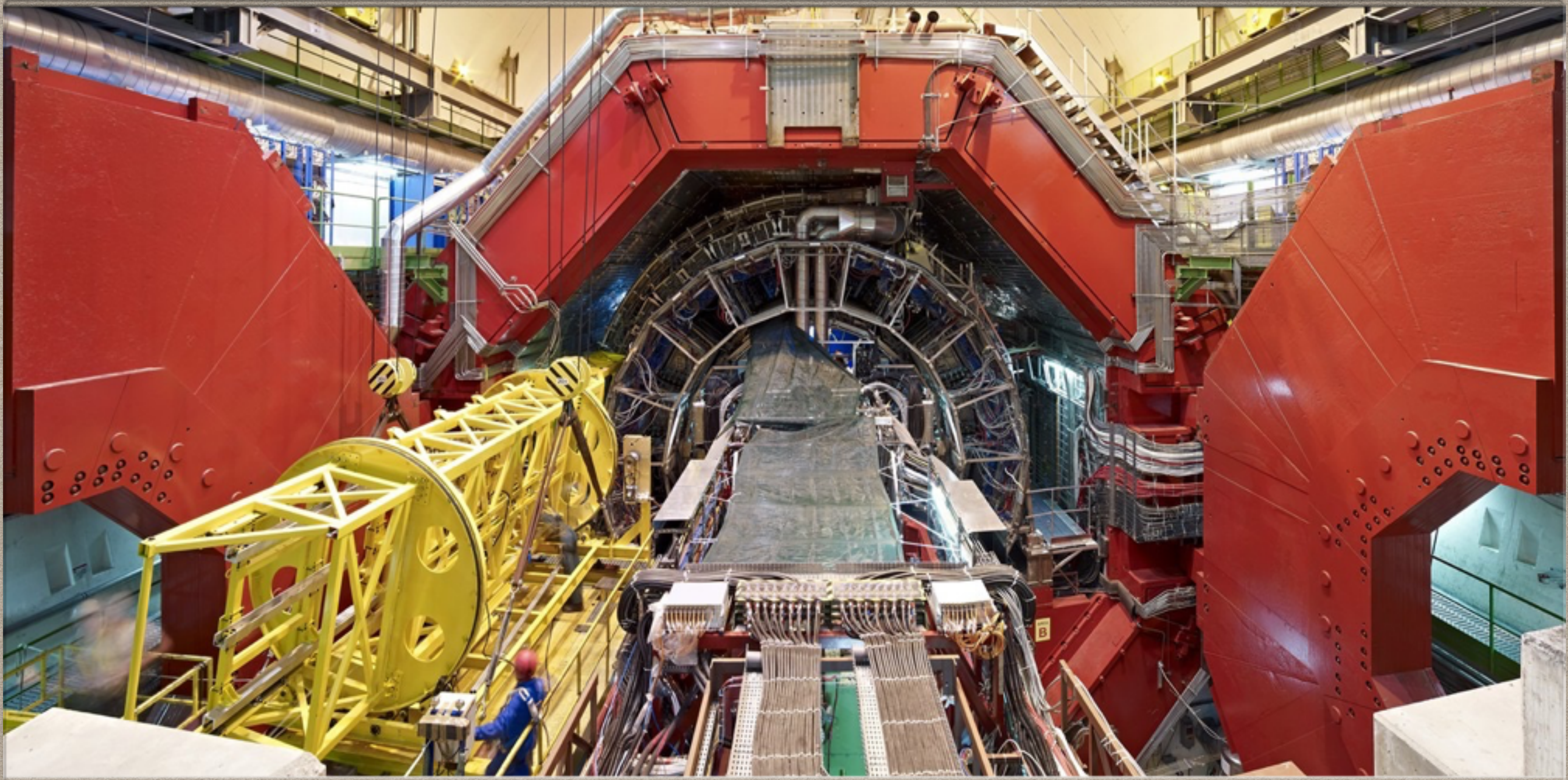
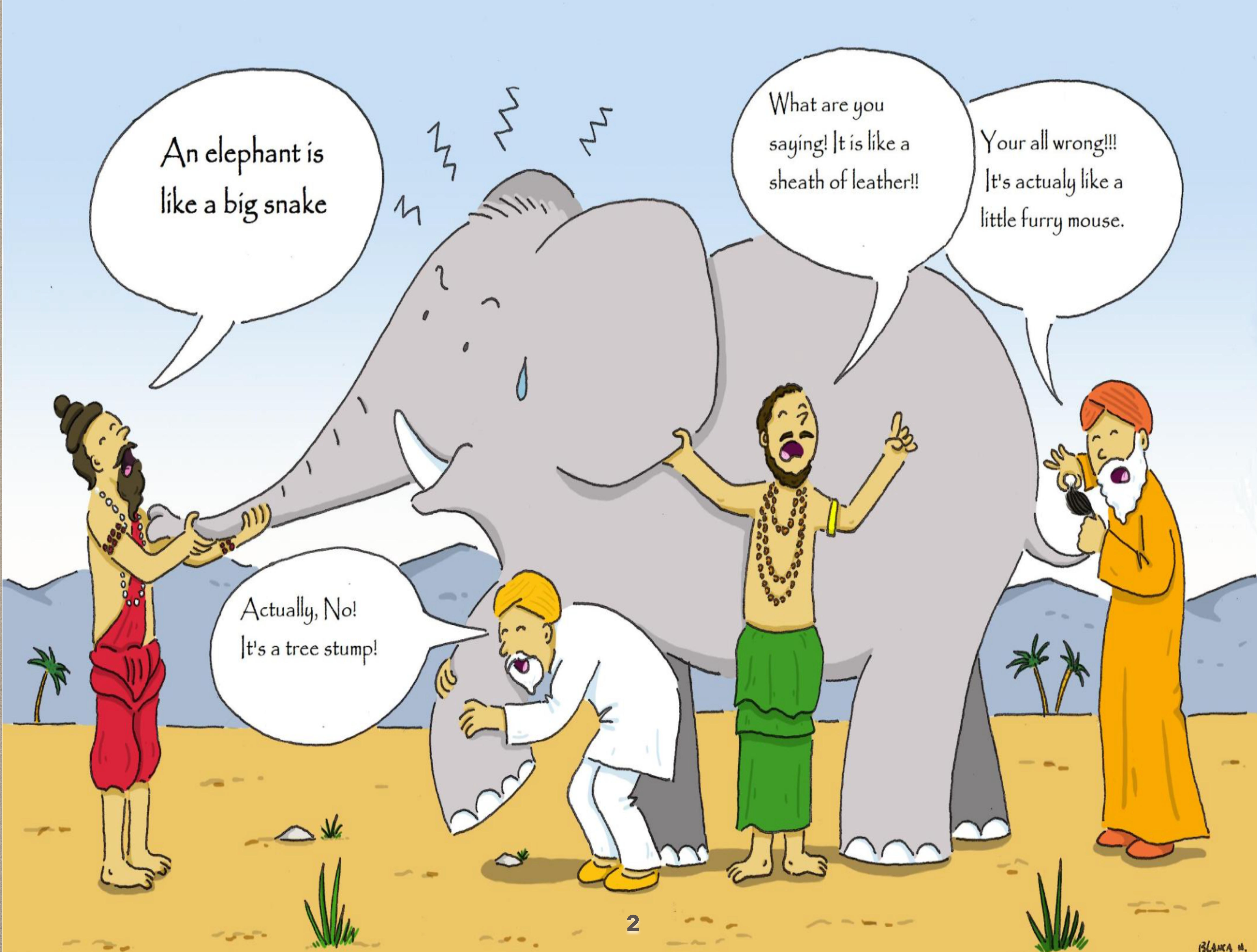
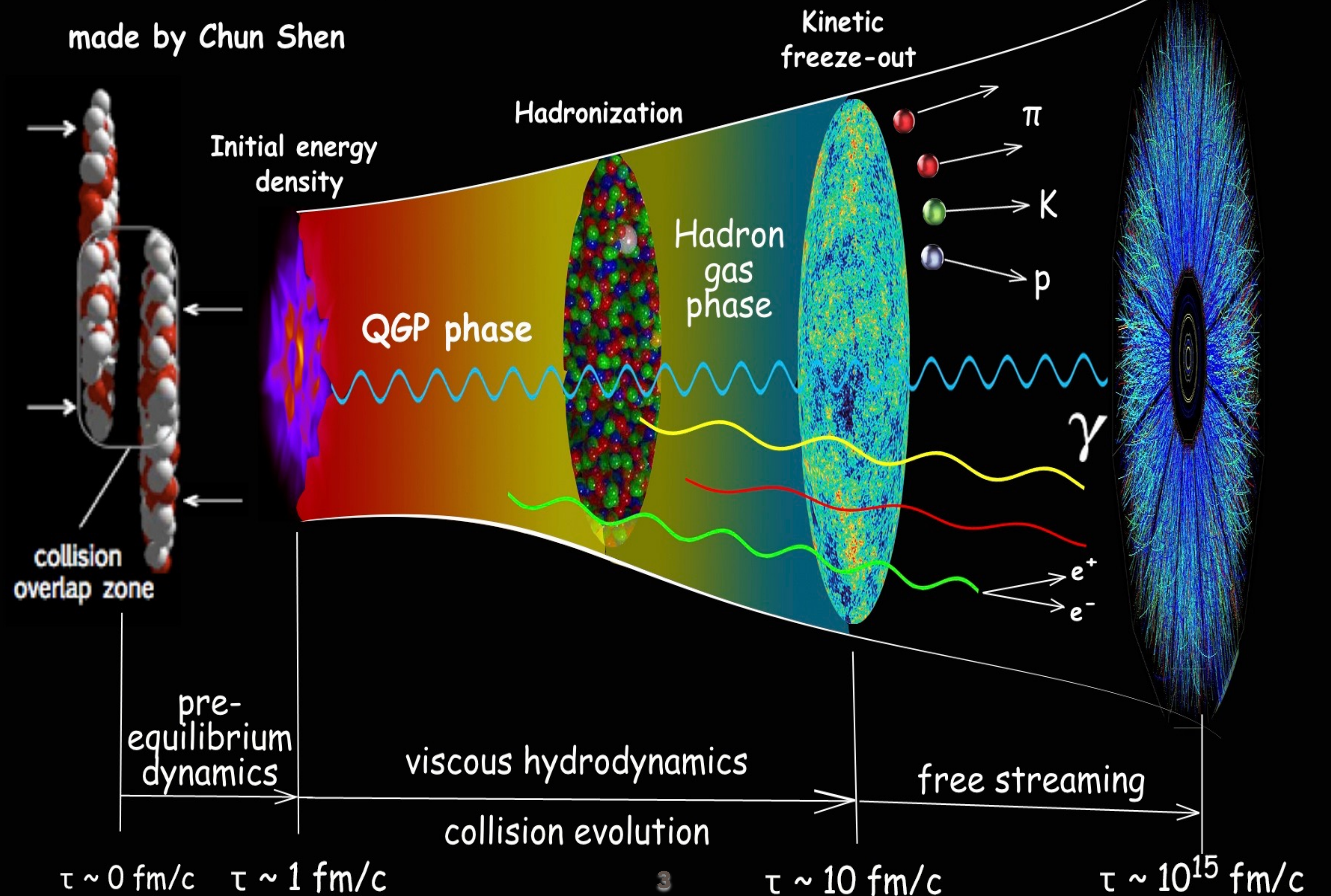


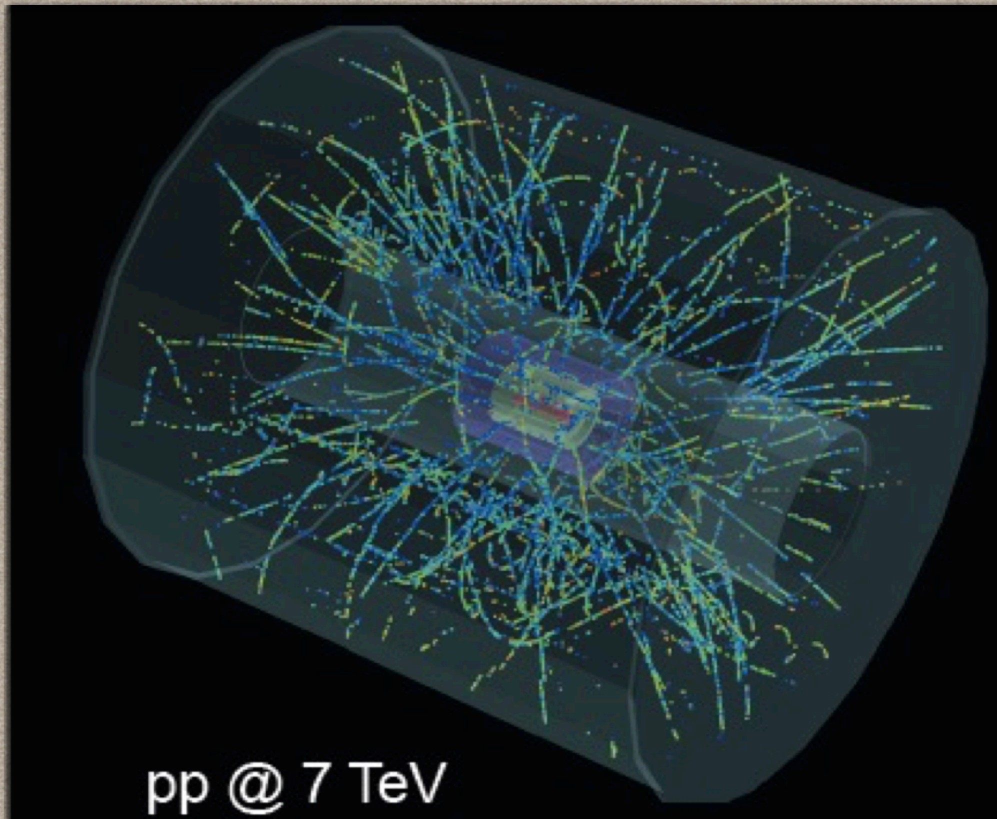
CURRENT AND FUTURE PROSPECT OF HEAVY ION PHYSICS

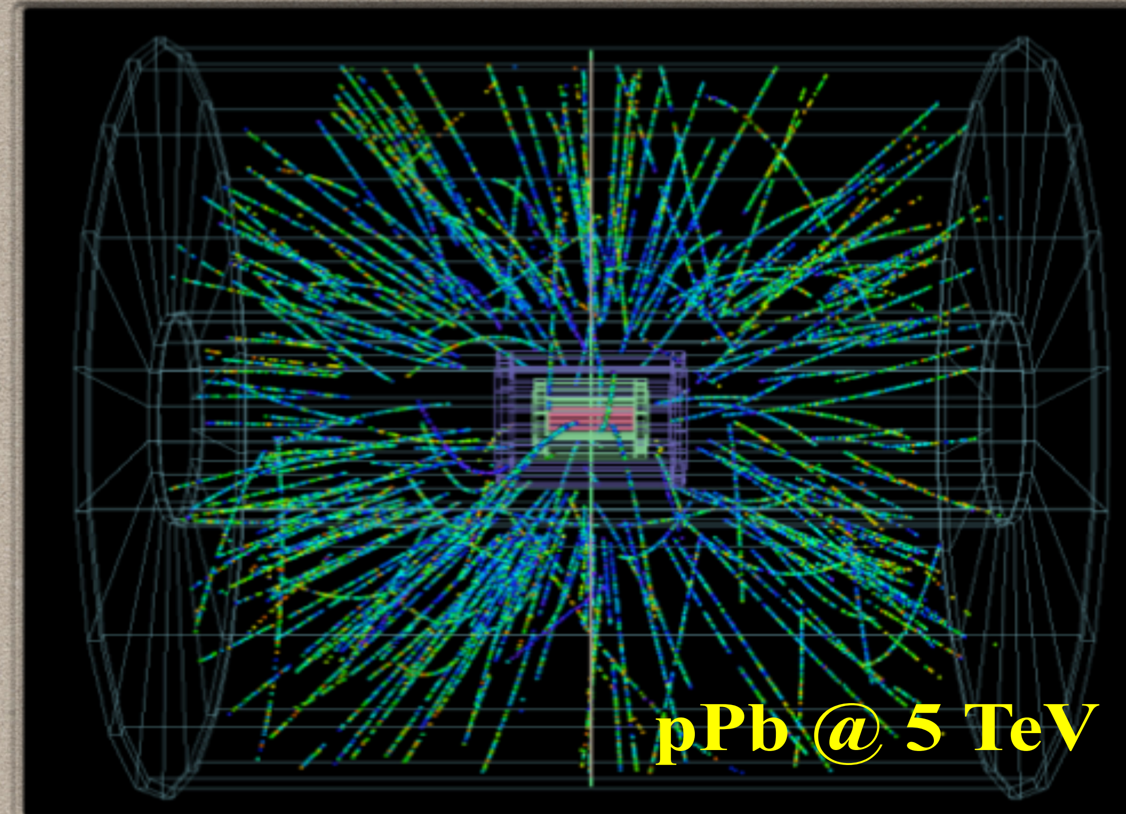
IN-KWON YOO (PUSAN NAT'L UNIVERSITY)

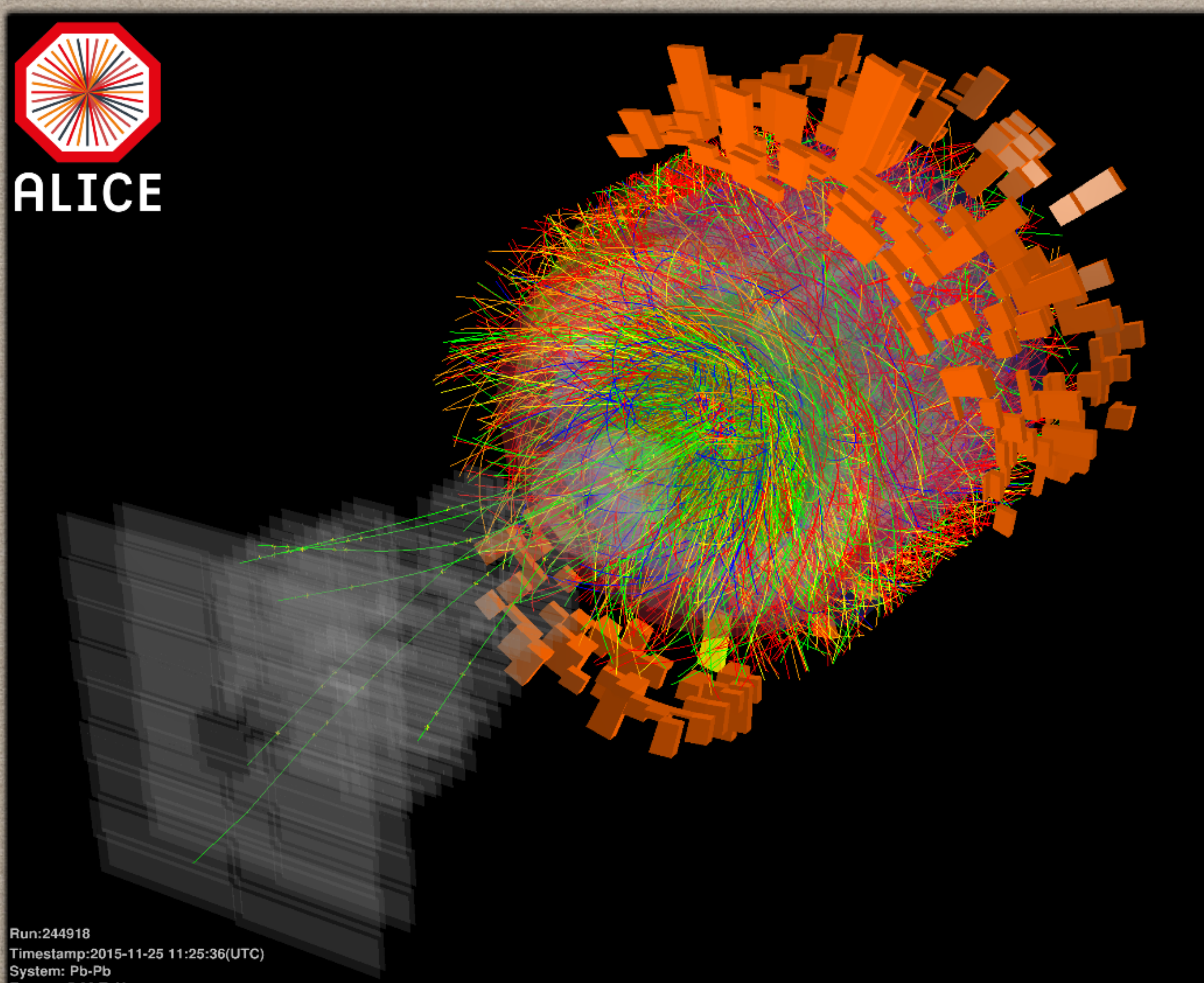

An elephant is like a big snake
Actually, No! It's a tree stump!
What are you saying! It is like a sheath of leather!!
Your all wrong!!! It's actualy like a little furry mouse.

Relativistic Heavy-Ion Collisions





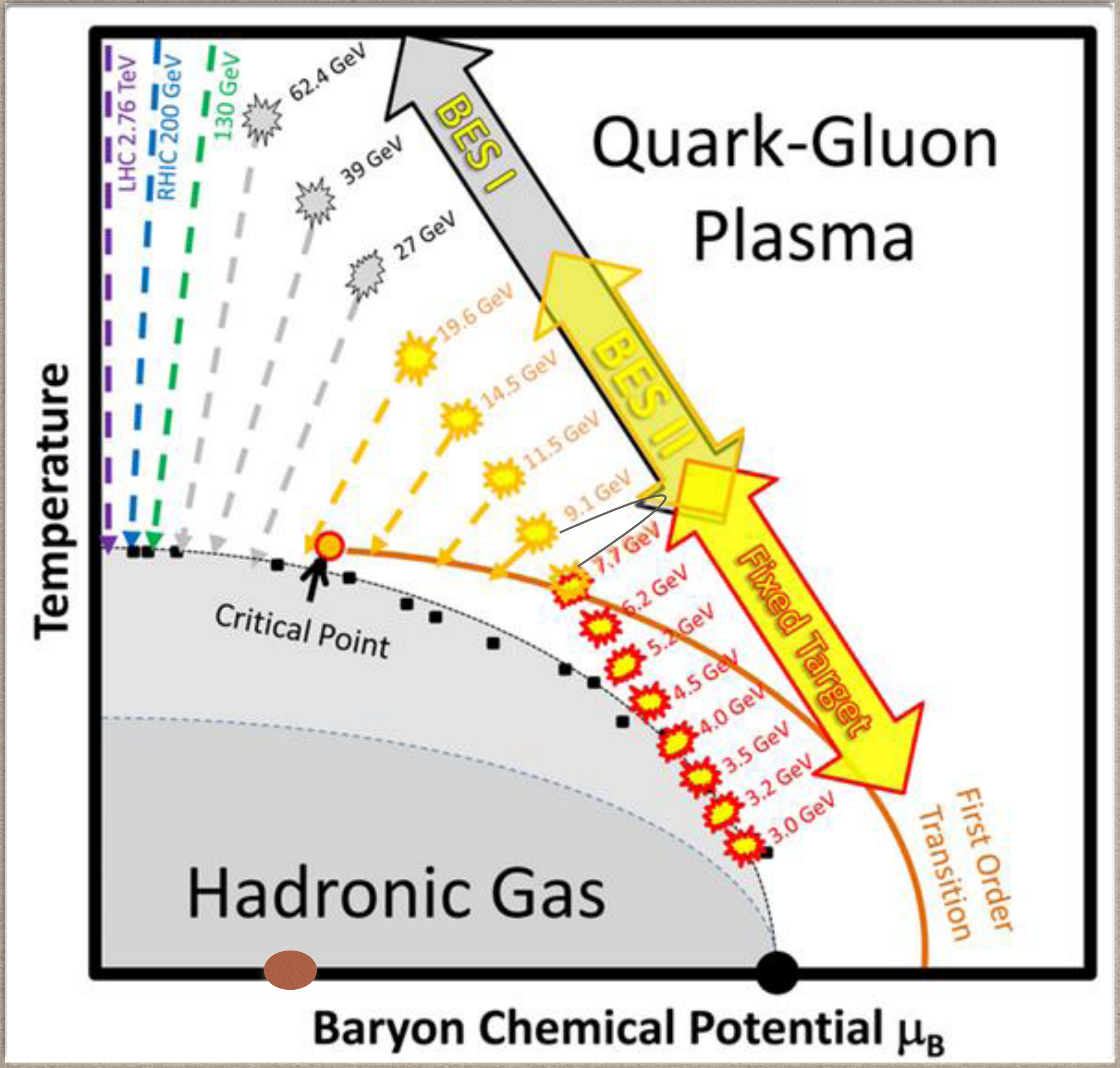




PbPb $\neq$ 208$\otimes$208 pp

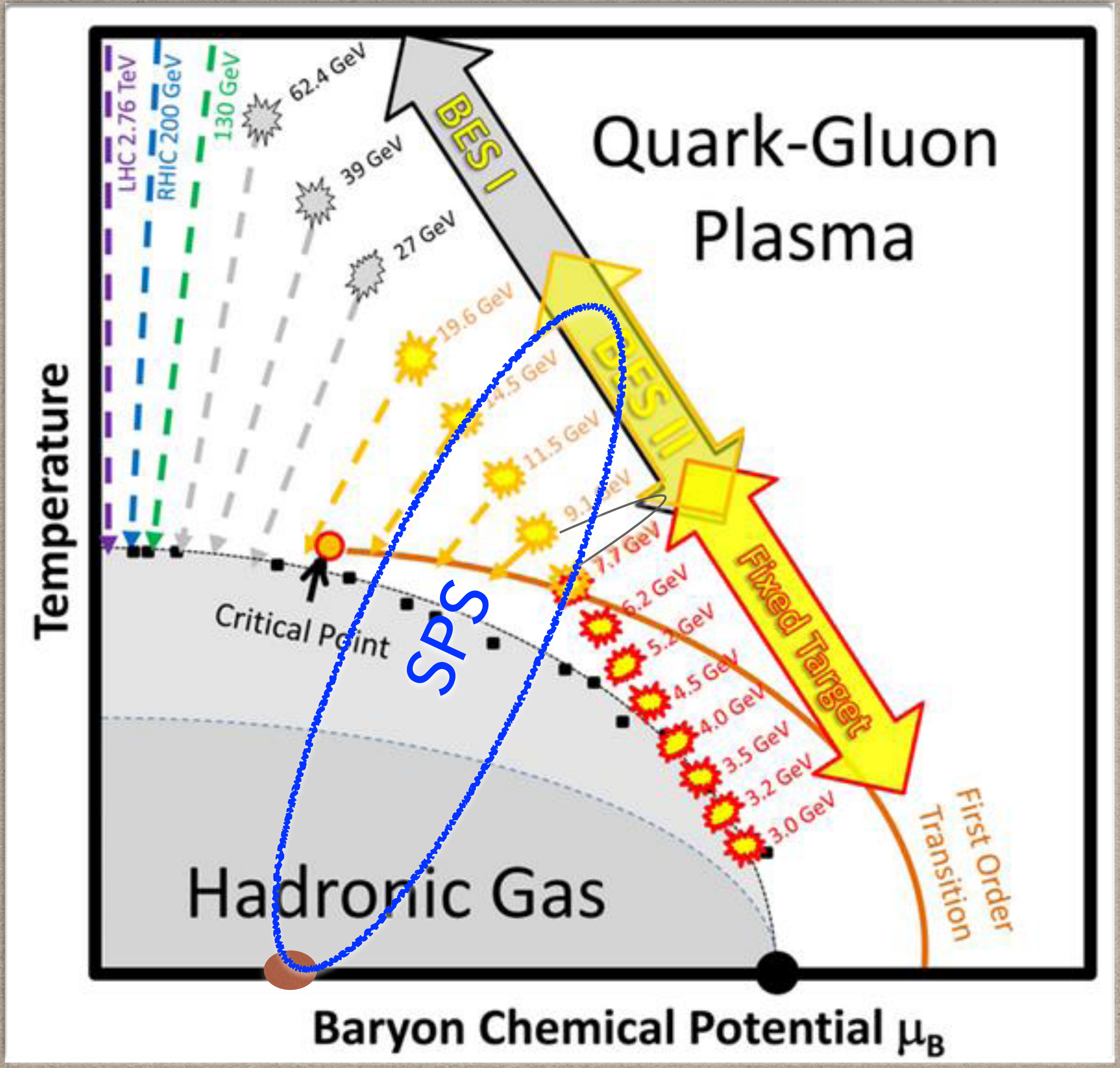
1990s

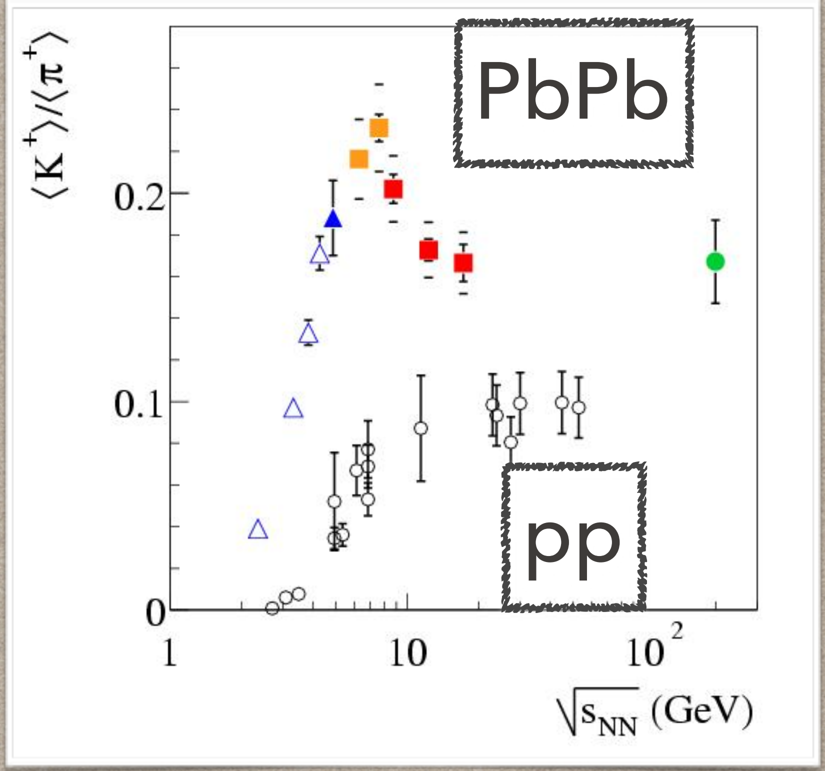
EXPLORING QCD PHASE I (SPS)



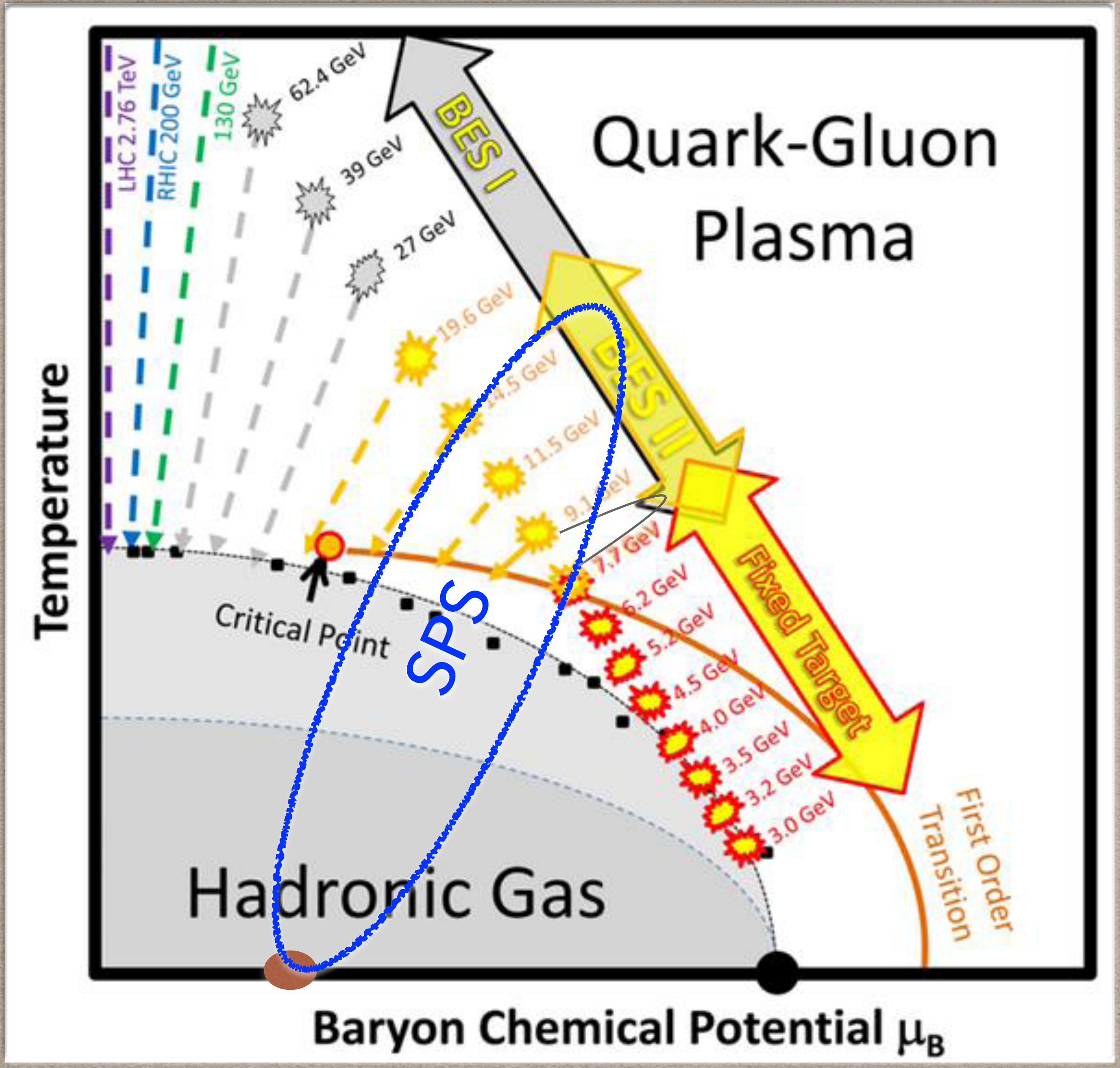
EXPLORING QCD PHASE I (SPS)

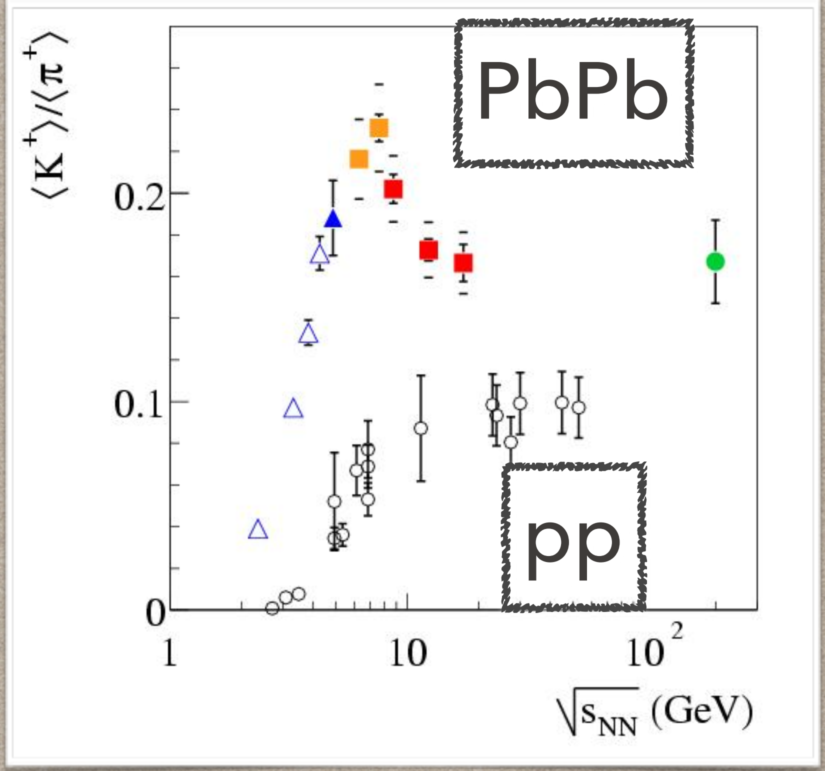
1990s

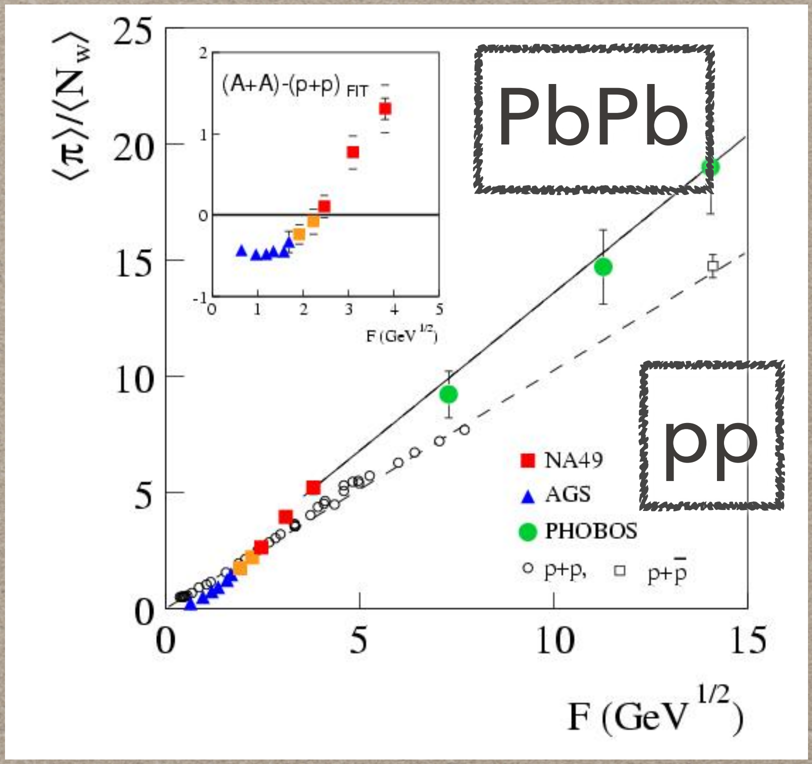




EXPLORING QCD PHASE I (SPS)

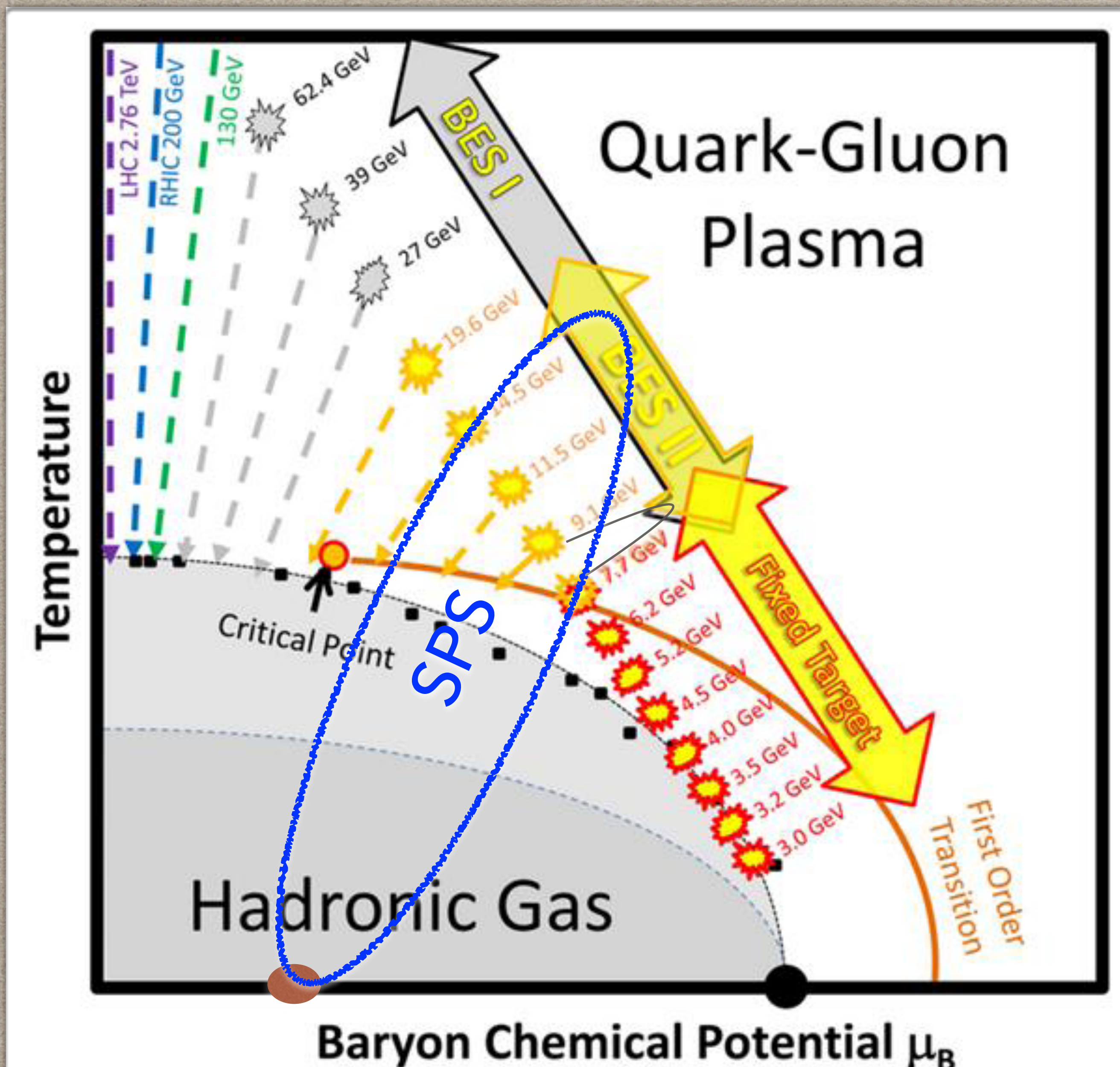


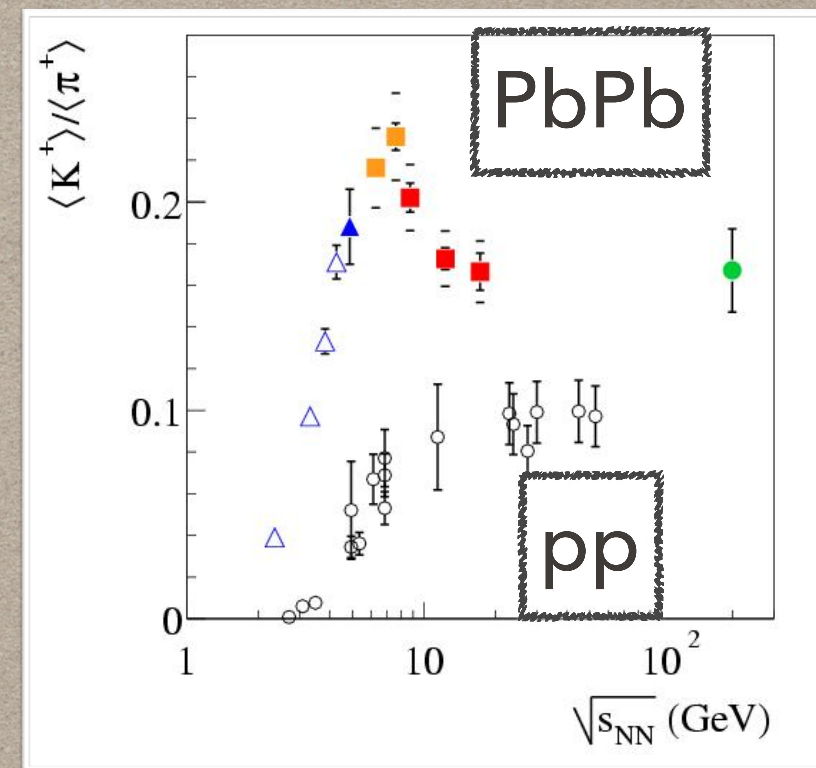


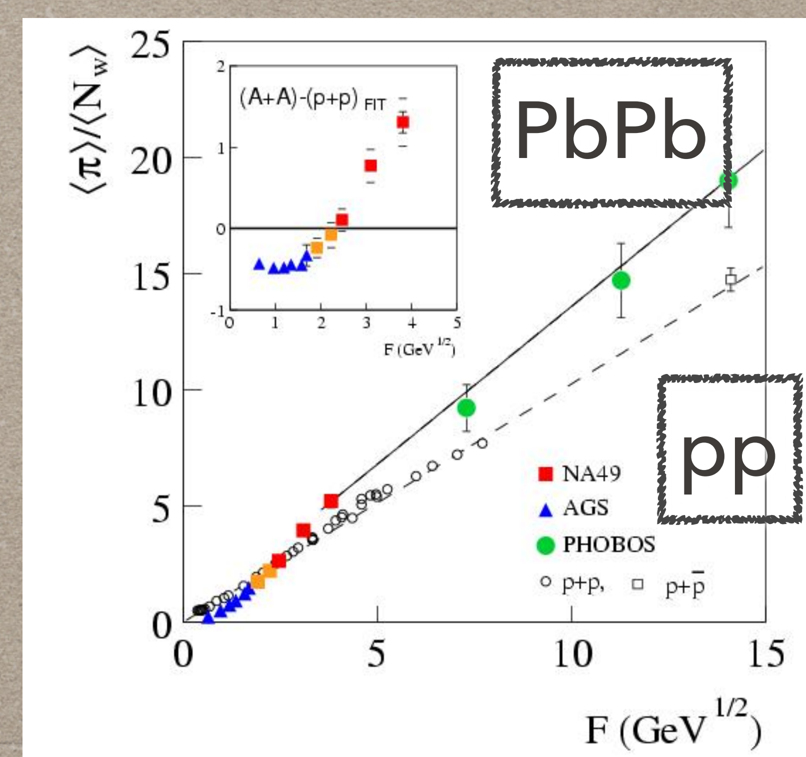


1990s

EXPLORING QCD PHASE I (SPS)

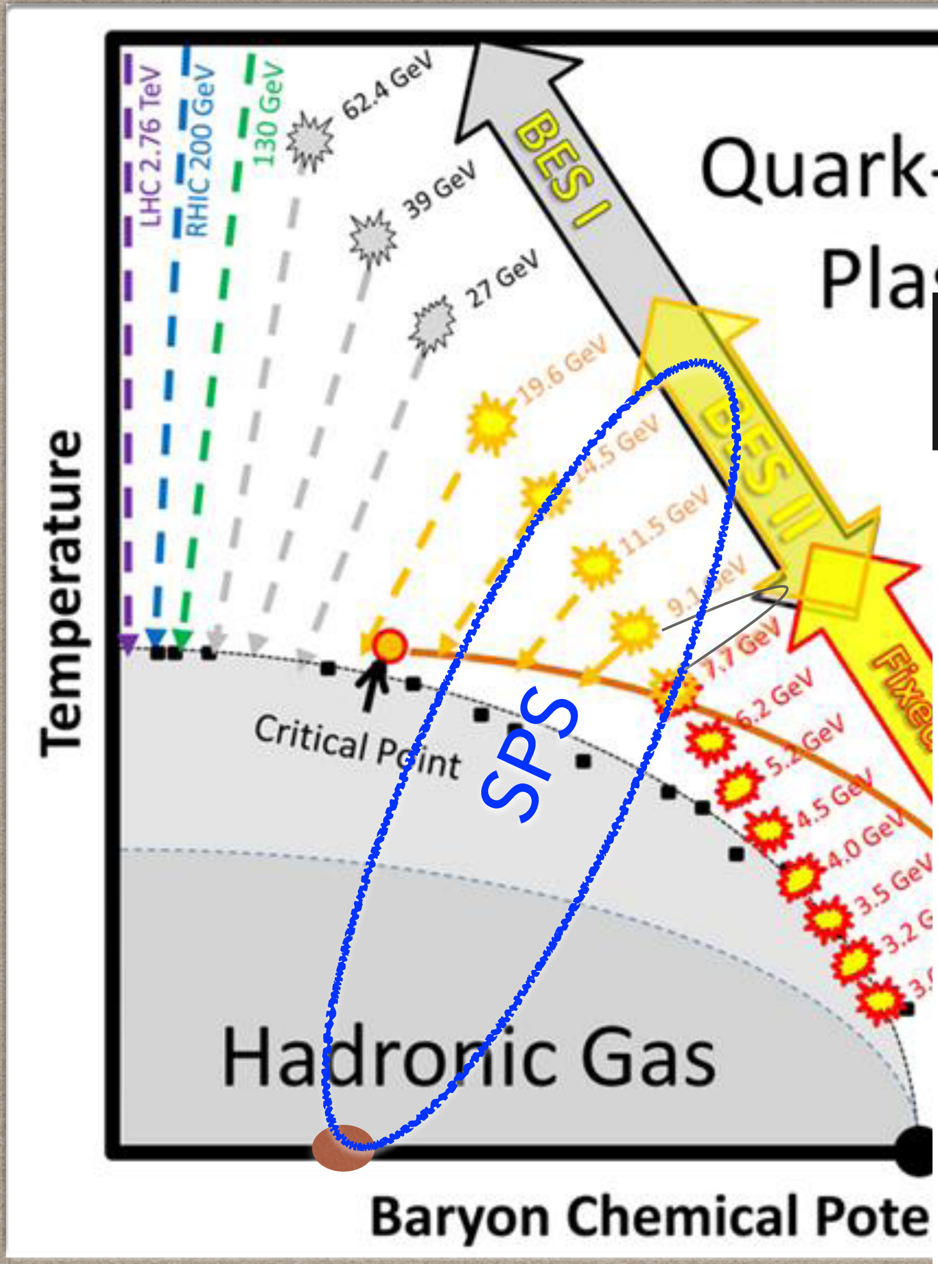


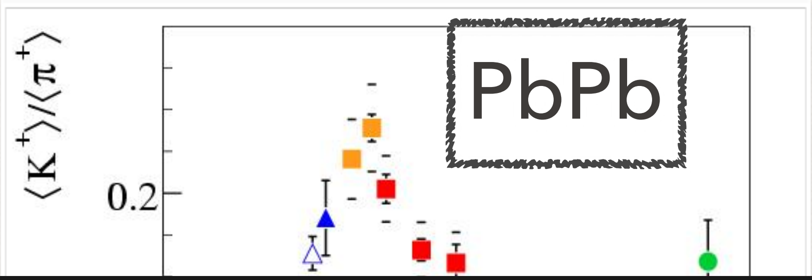




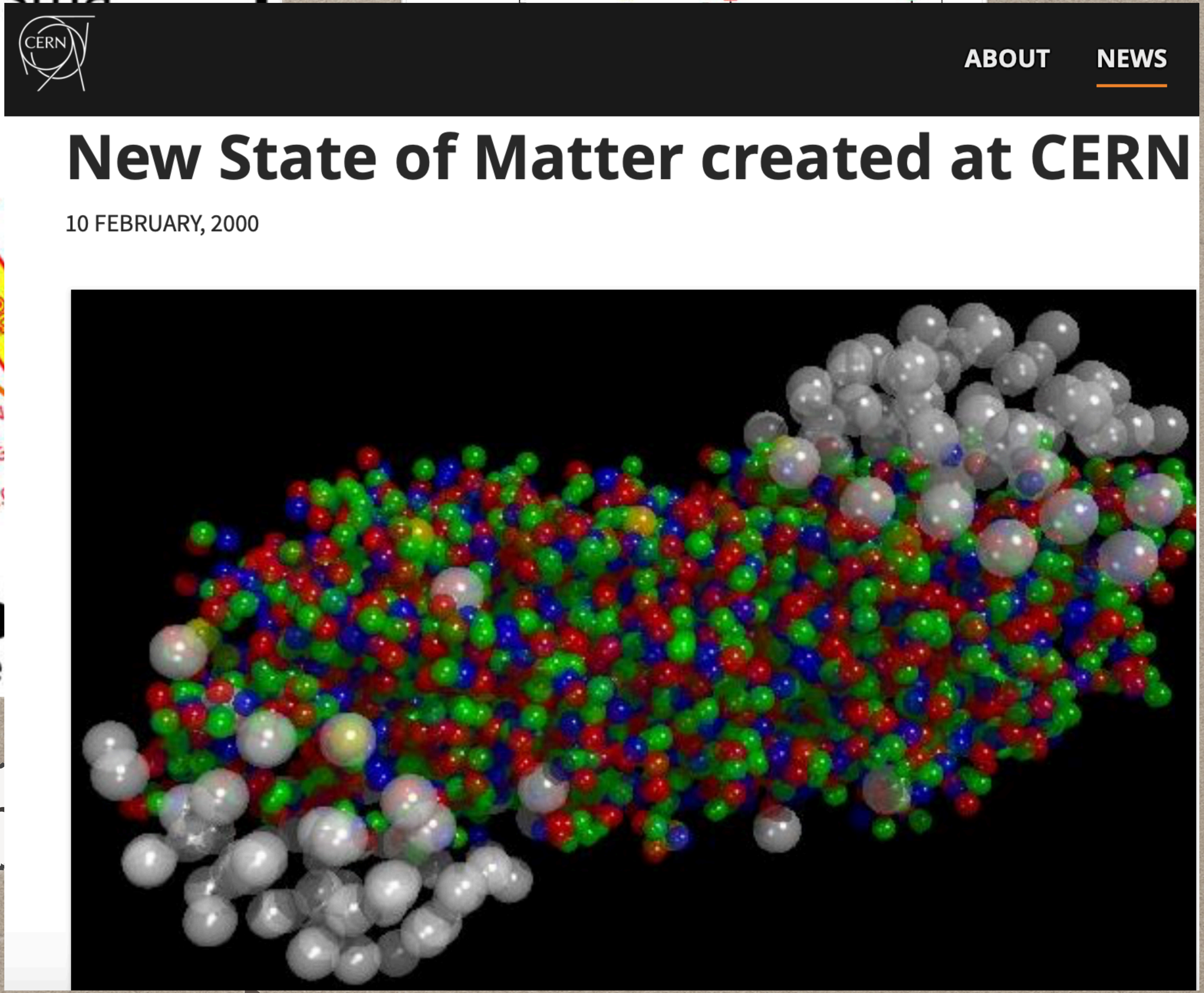
Onset of Deconfinement?

EXPLORING QCD PHASE I (SPS)

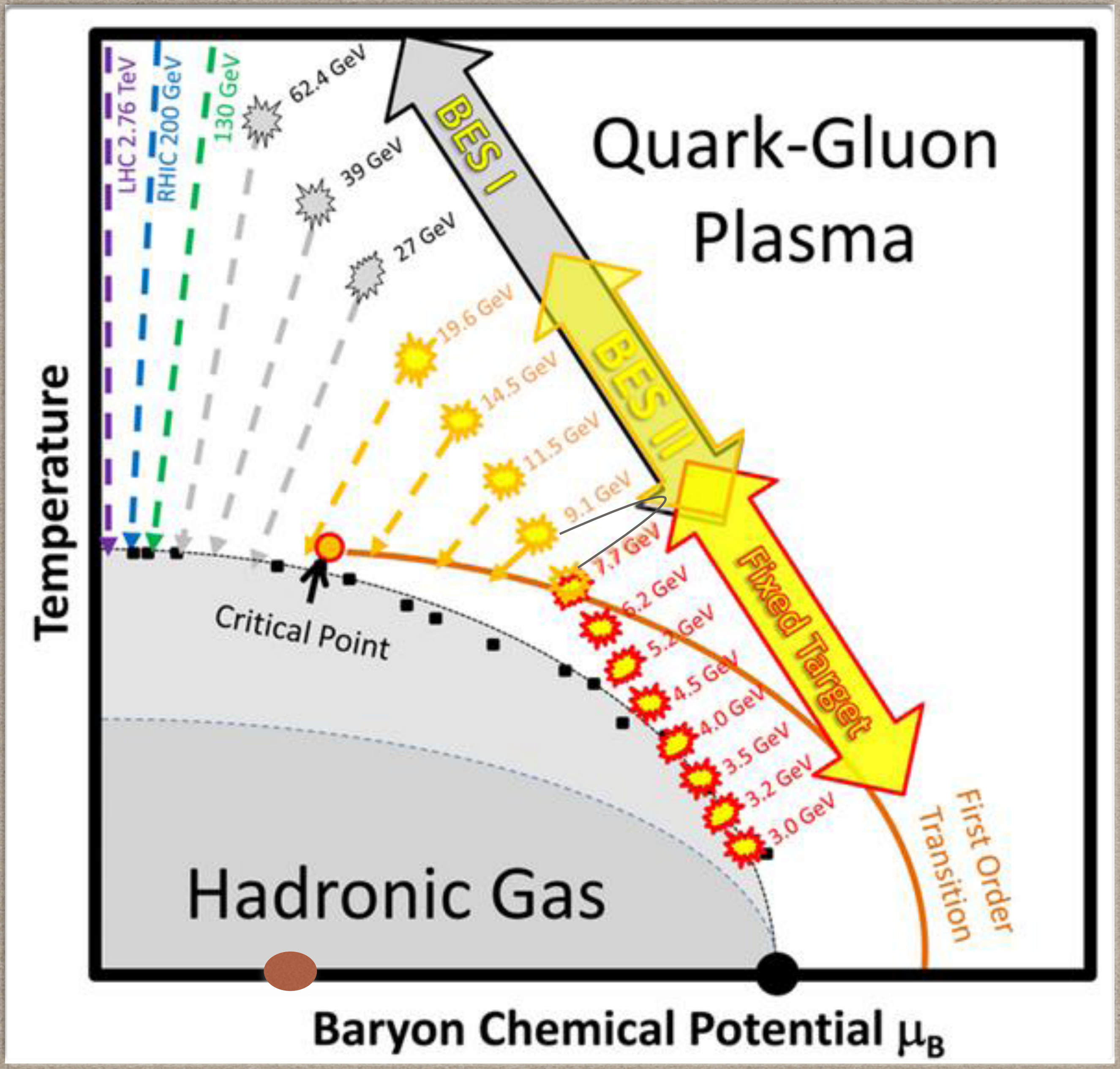




Onset of Deconfiner

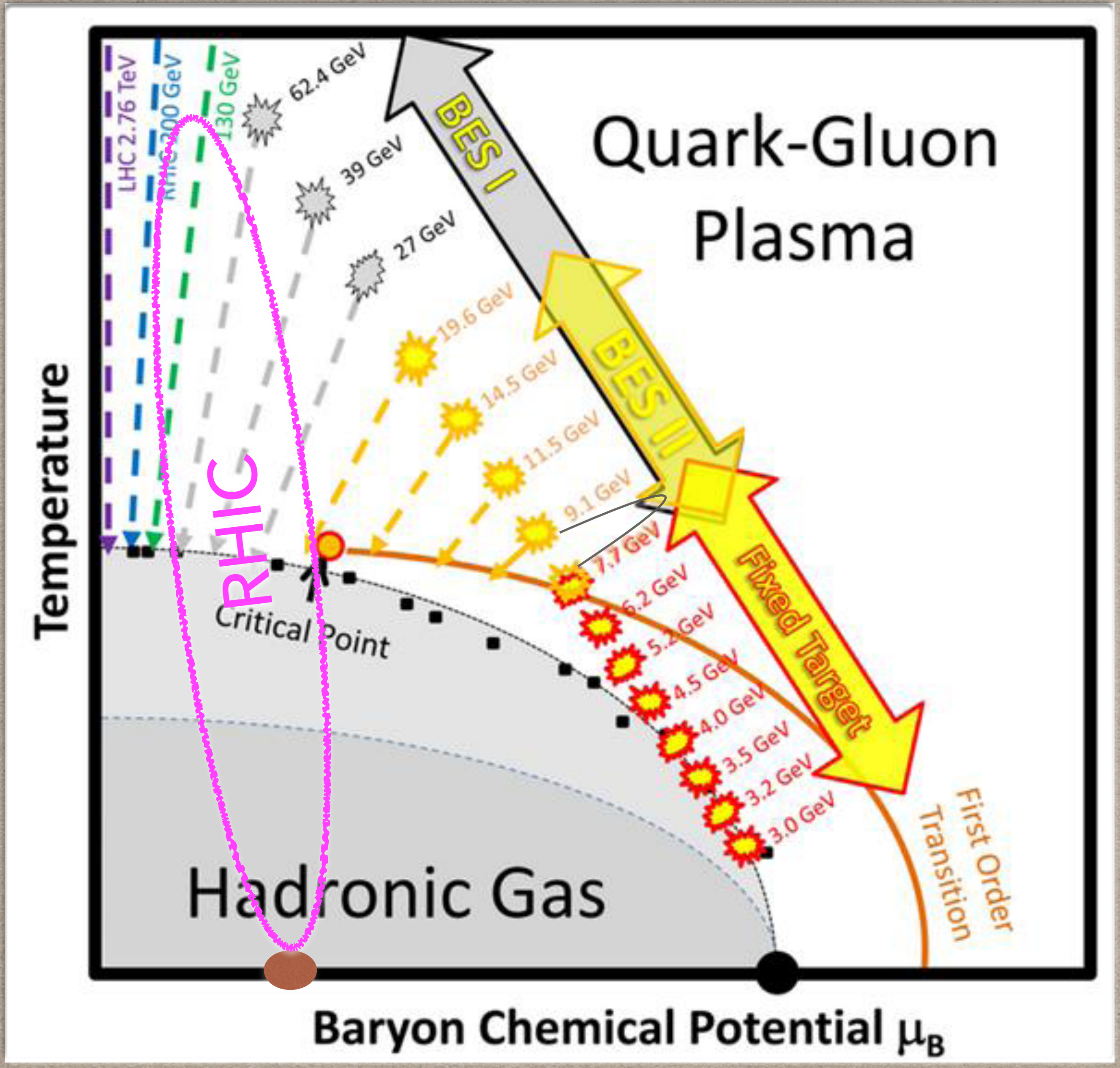


EXPLORING QCD PHASE II (RHIC)

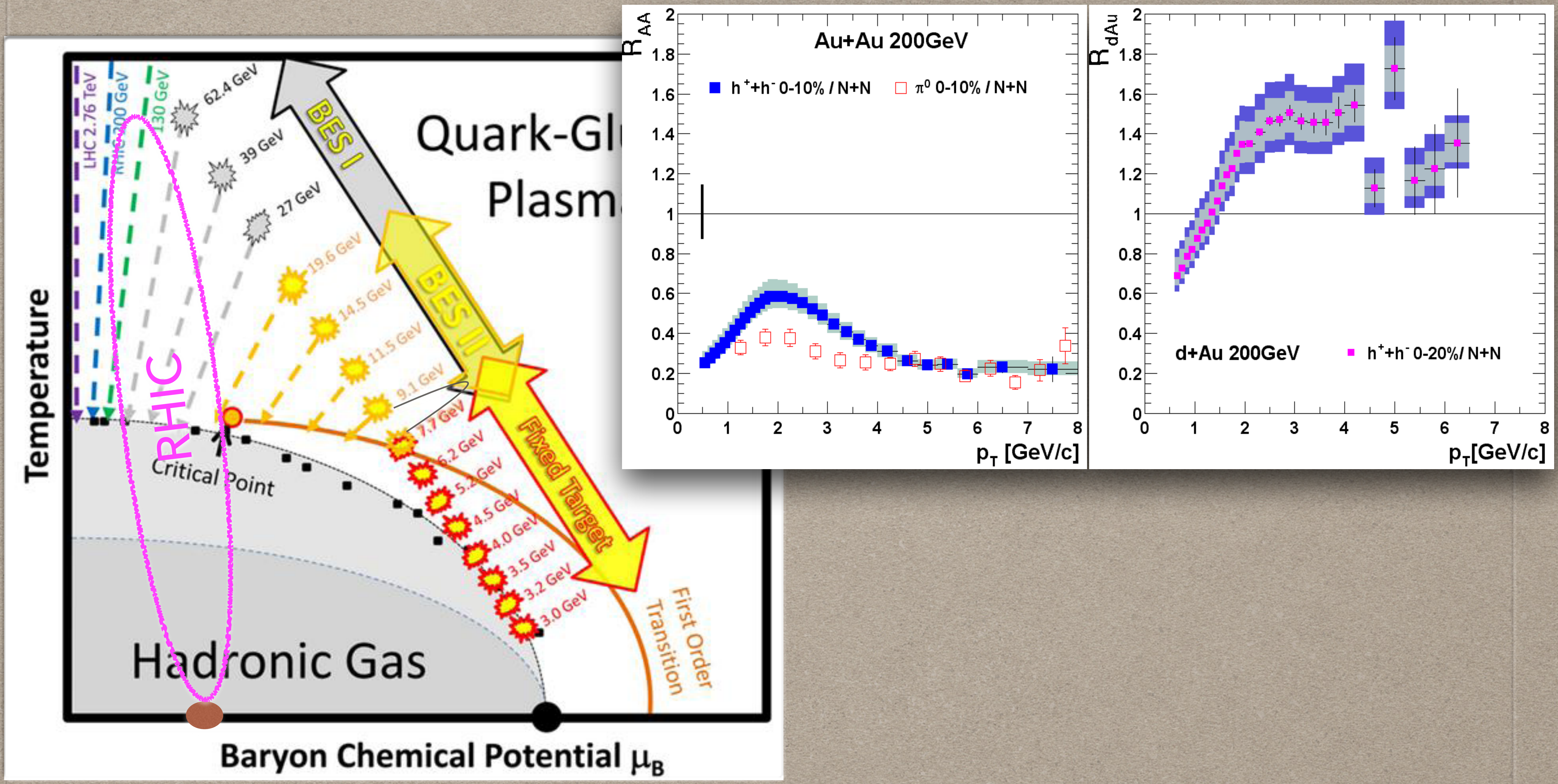


EXPLORING QCD PHASE II (RHIC)

2000s

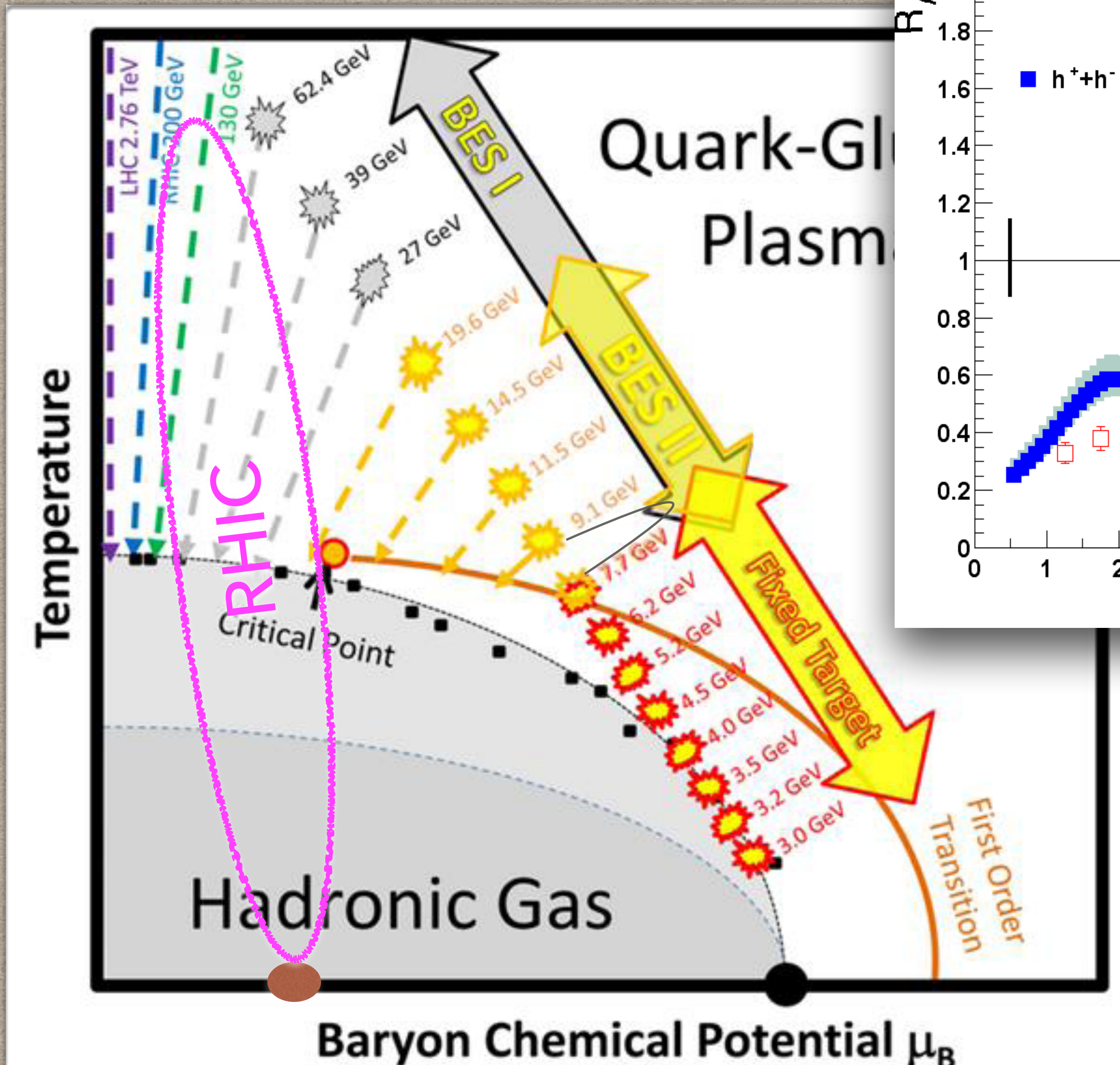


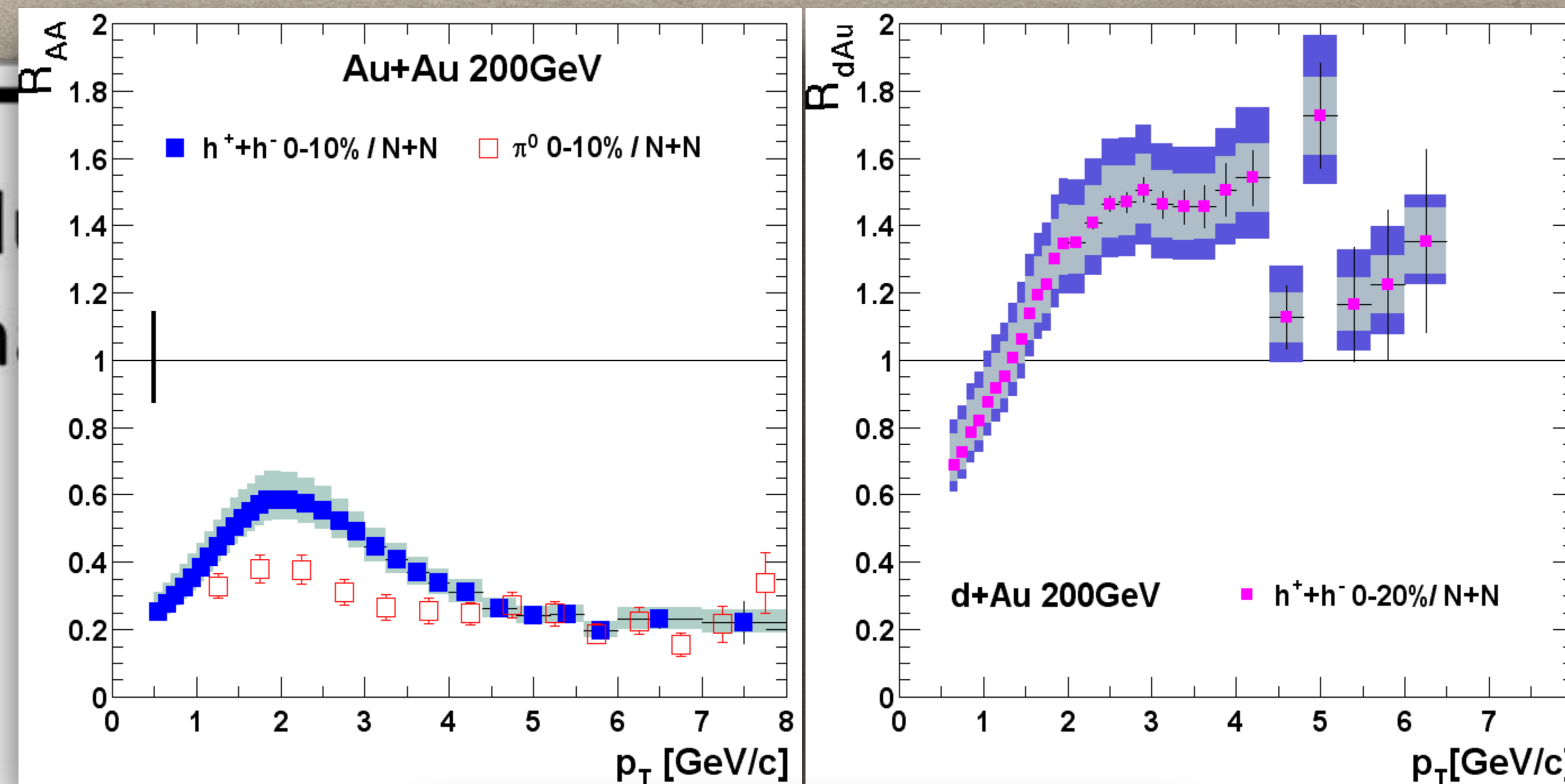
EXPLORING QCD PHASE II (RHIC)

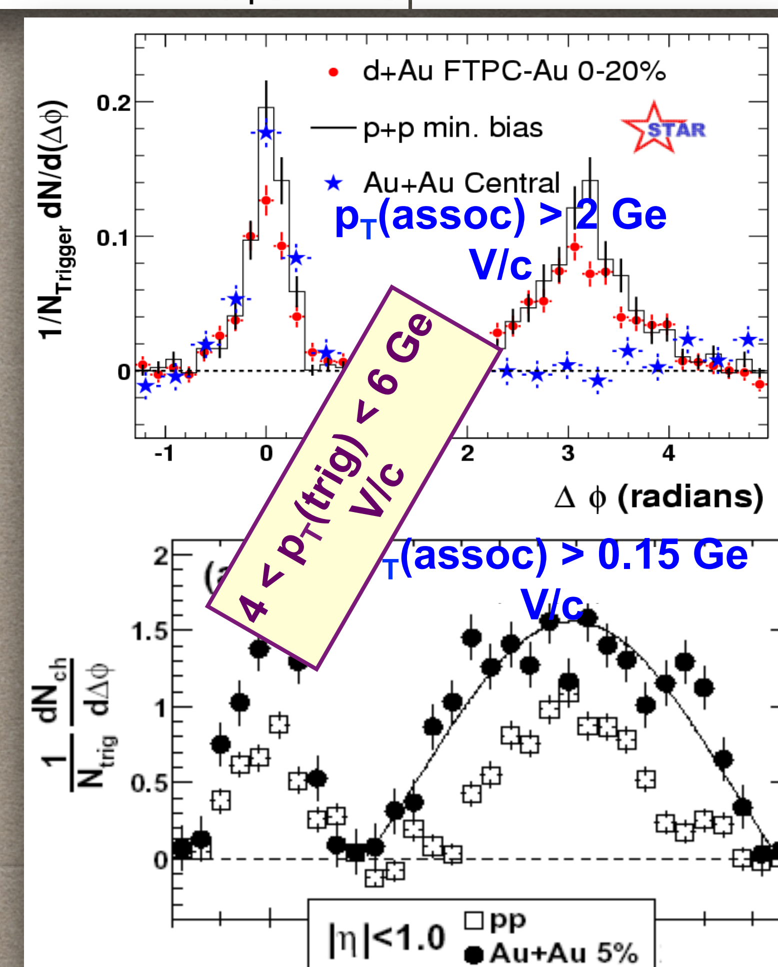


2000s

EXPLORING QCD PHASE II (RHIC)

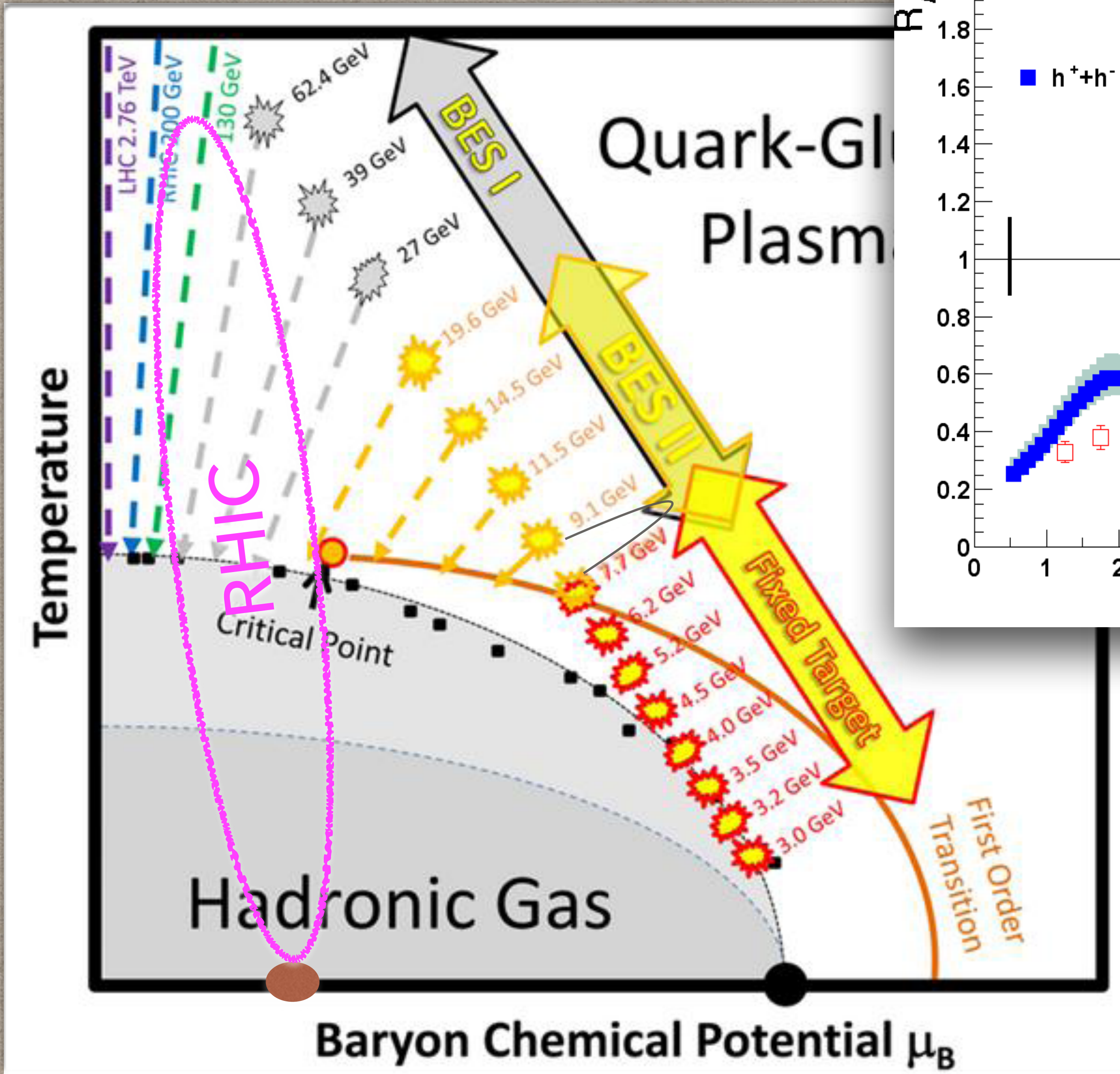


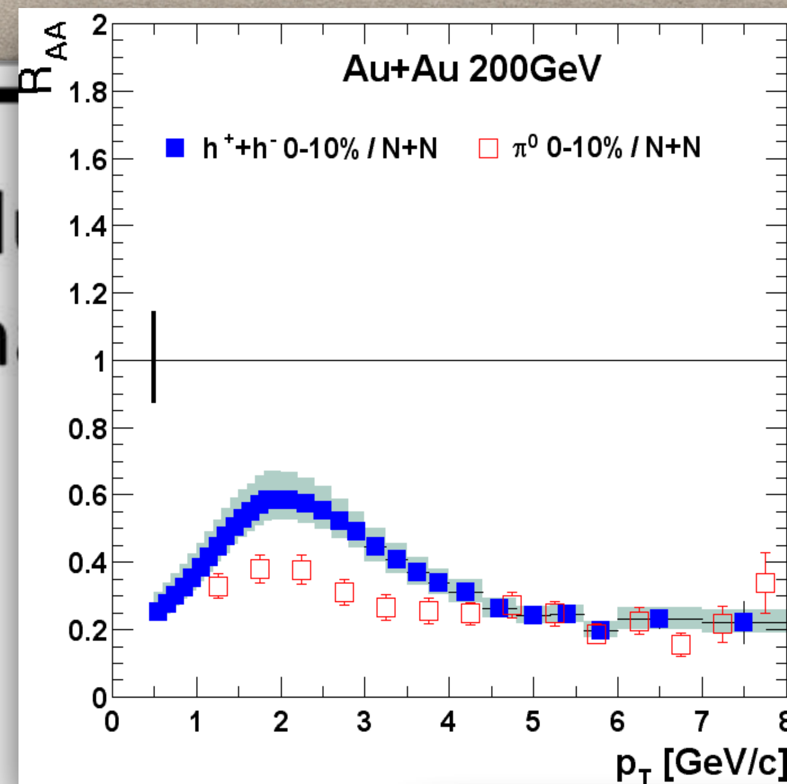


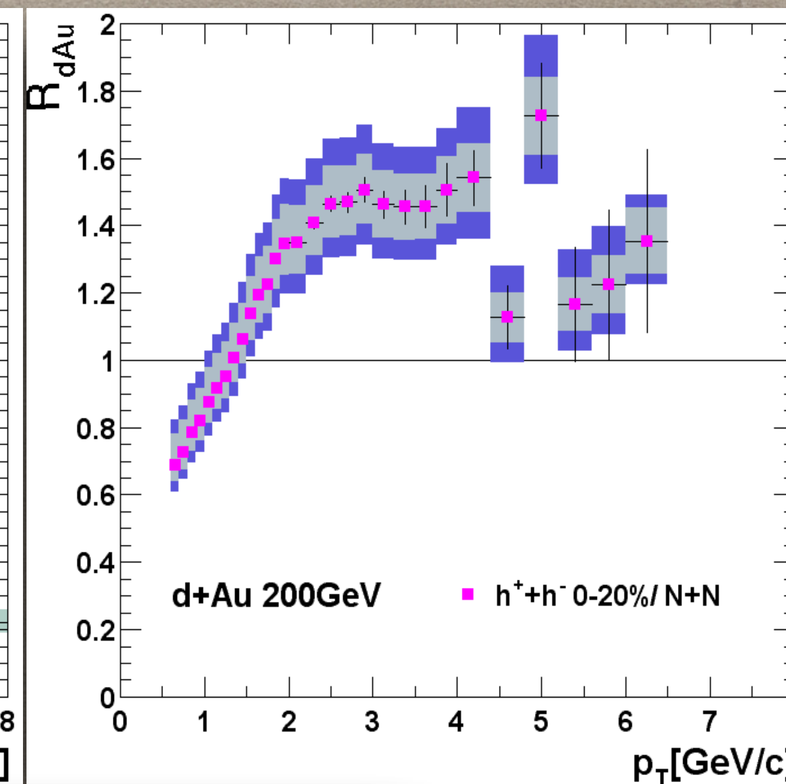


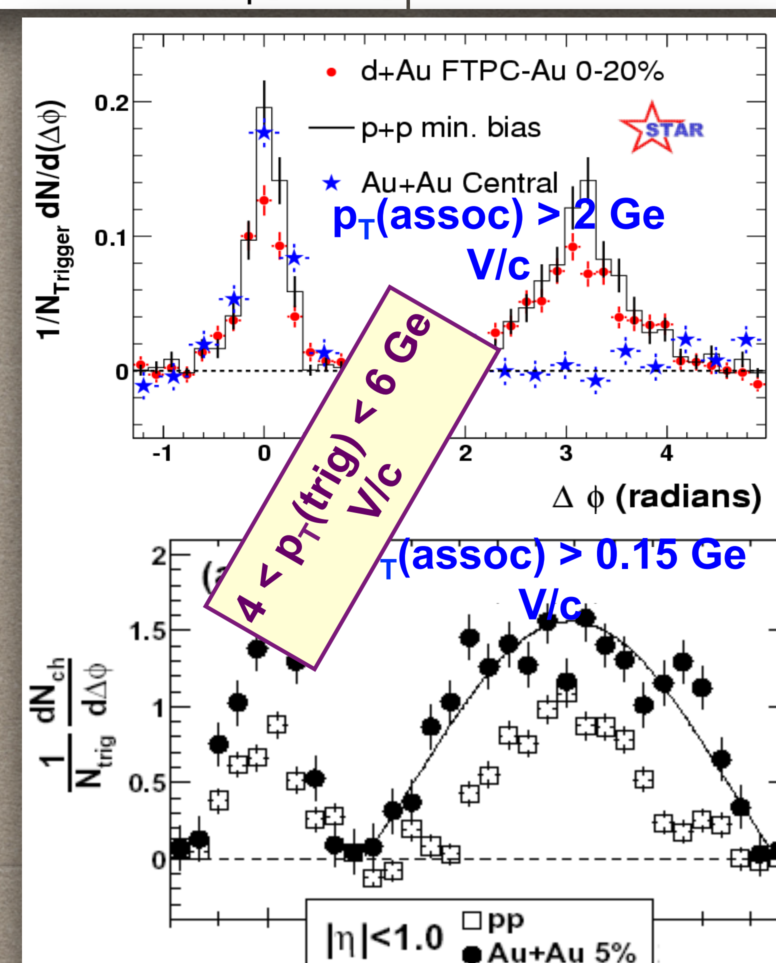
EXPLORING QCD PHASE II (RHIC)

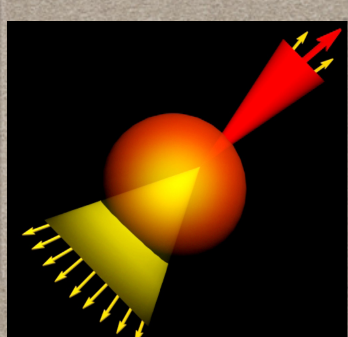
2000s



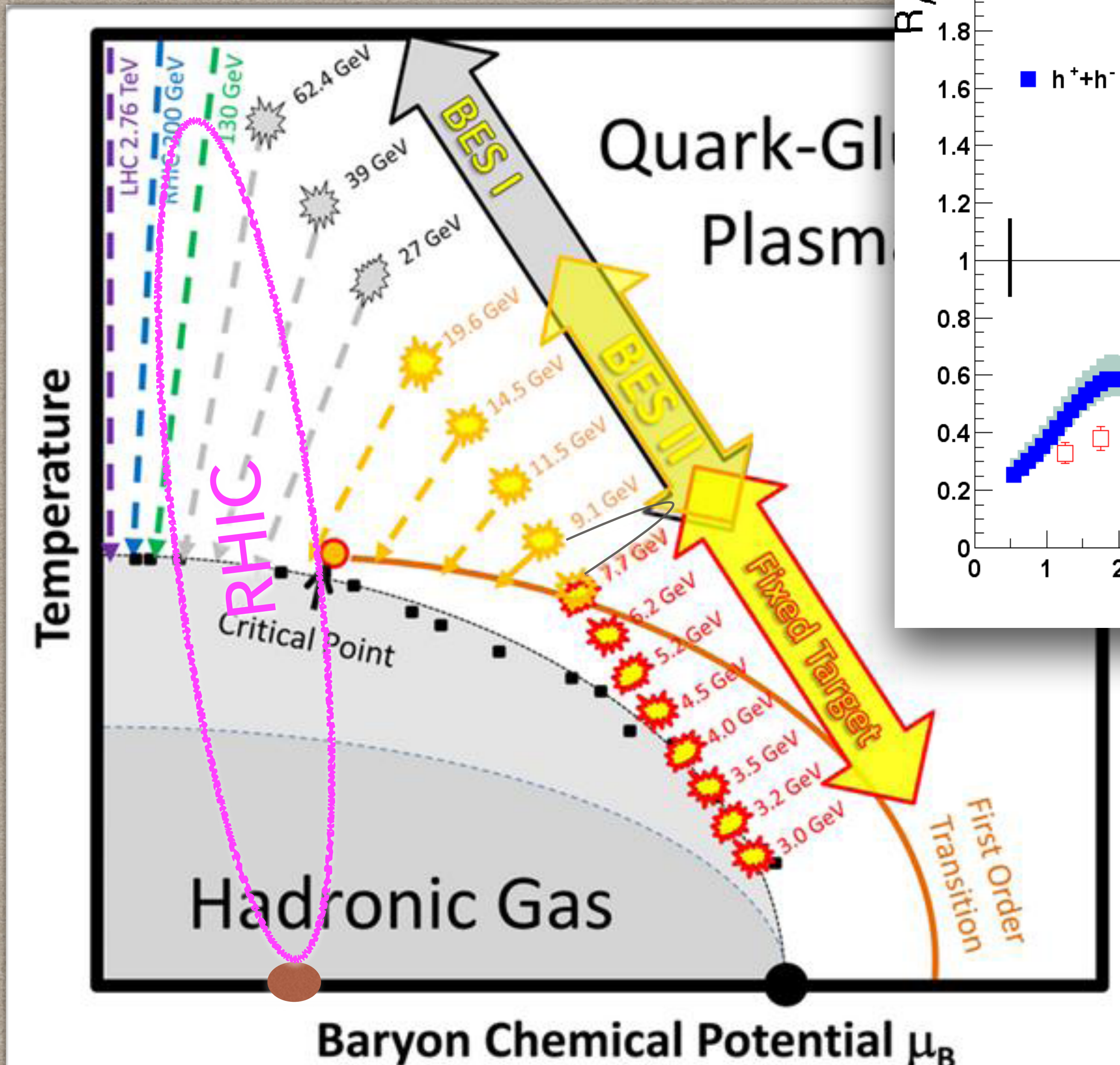


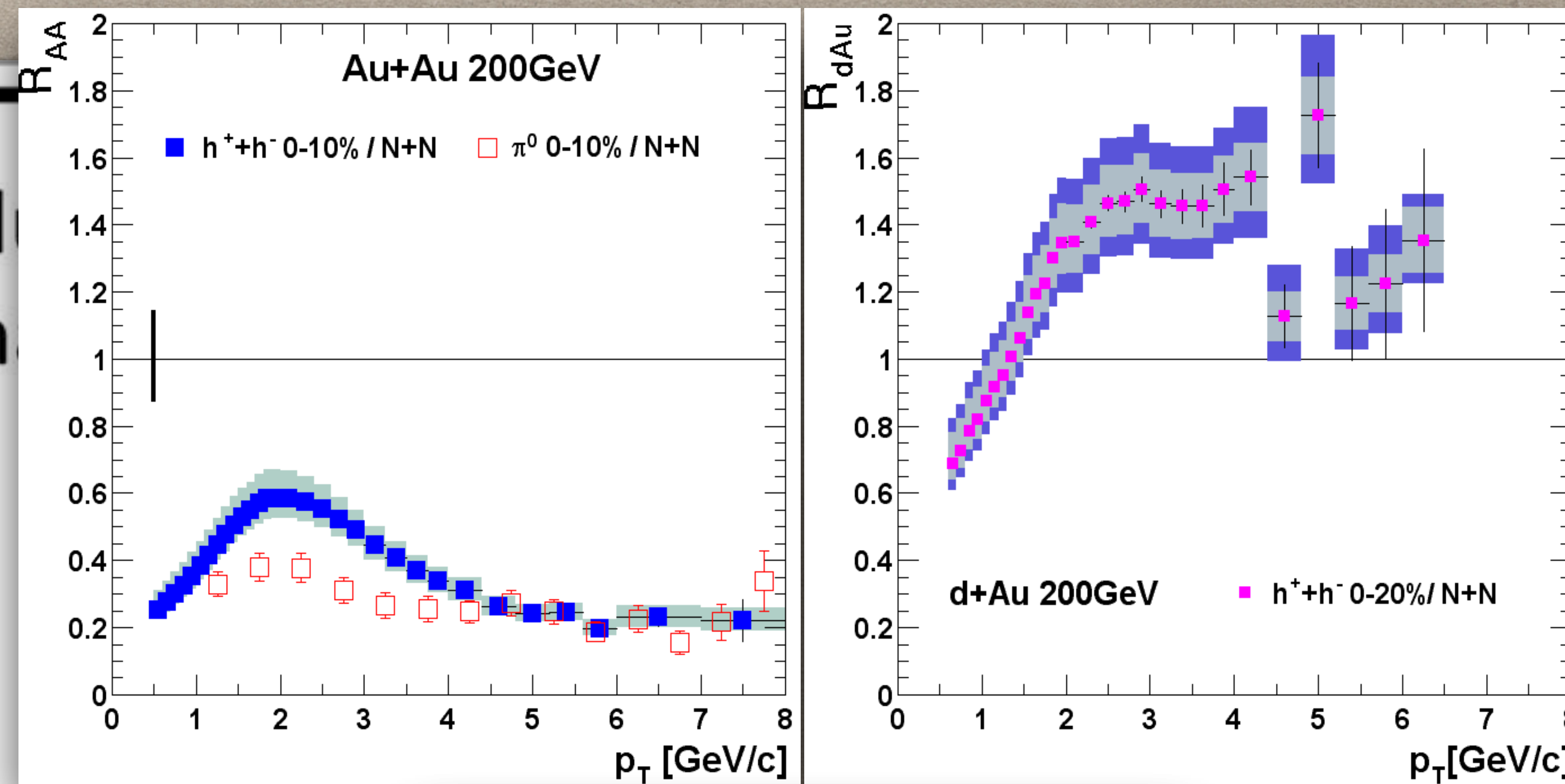


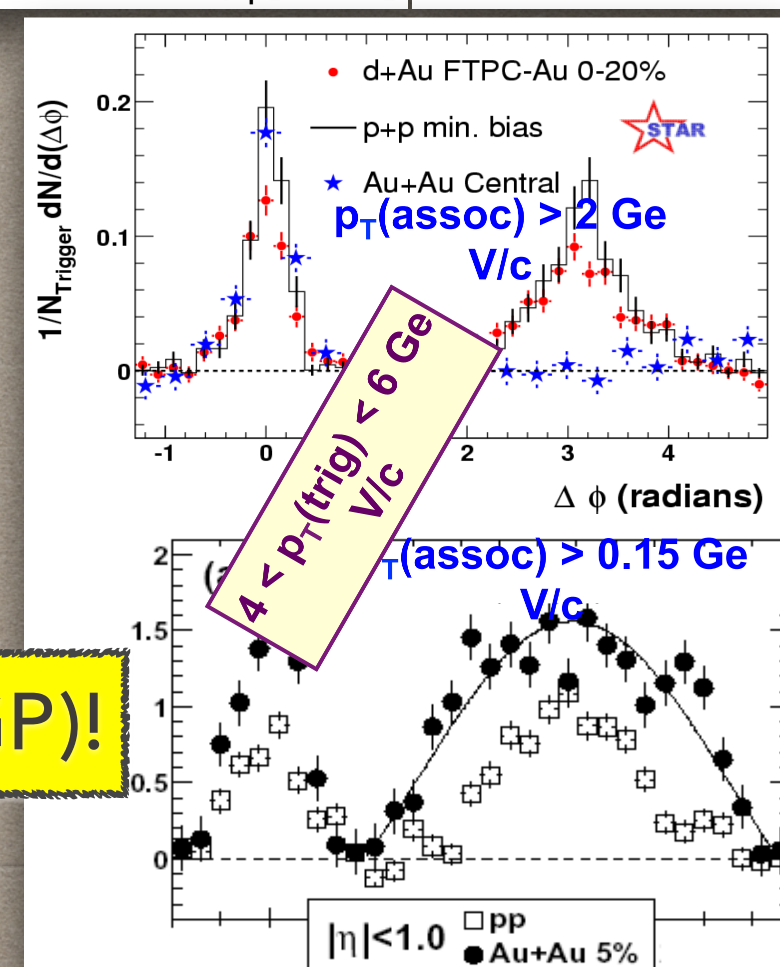




EXPLORING QCD PHASE II (RHIC)

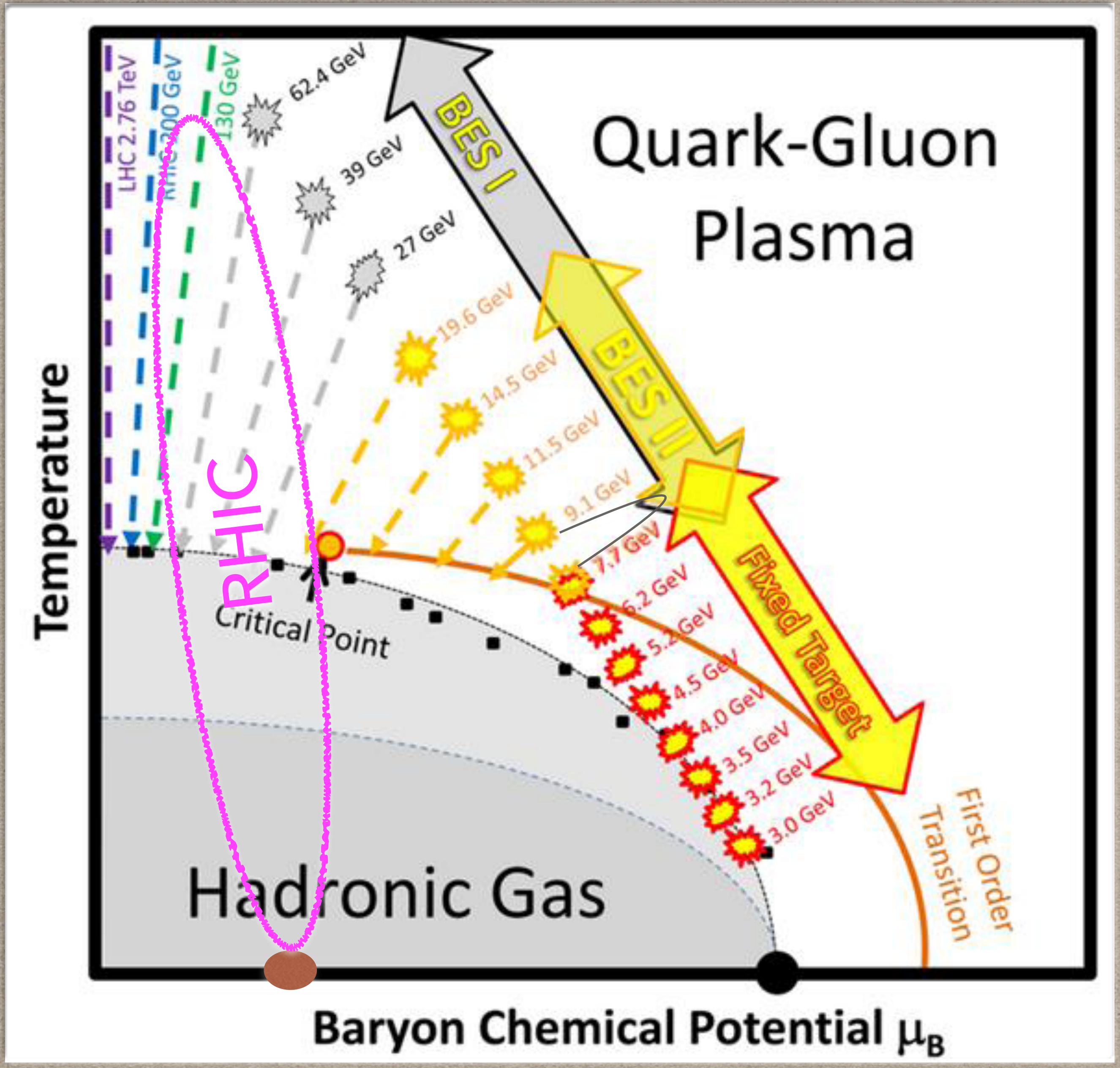




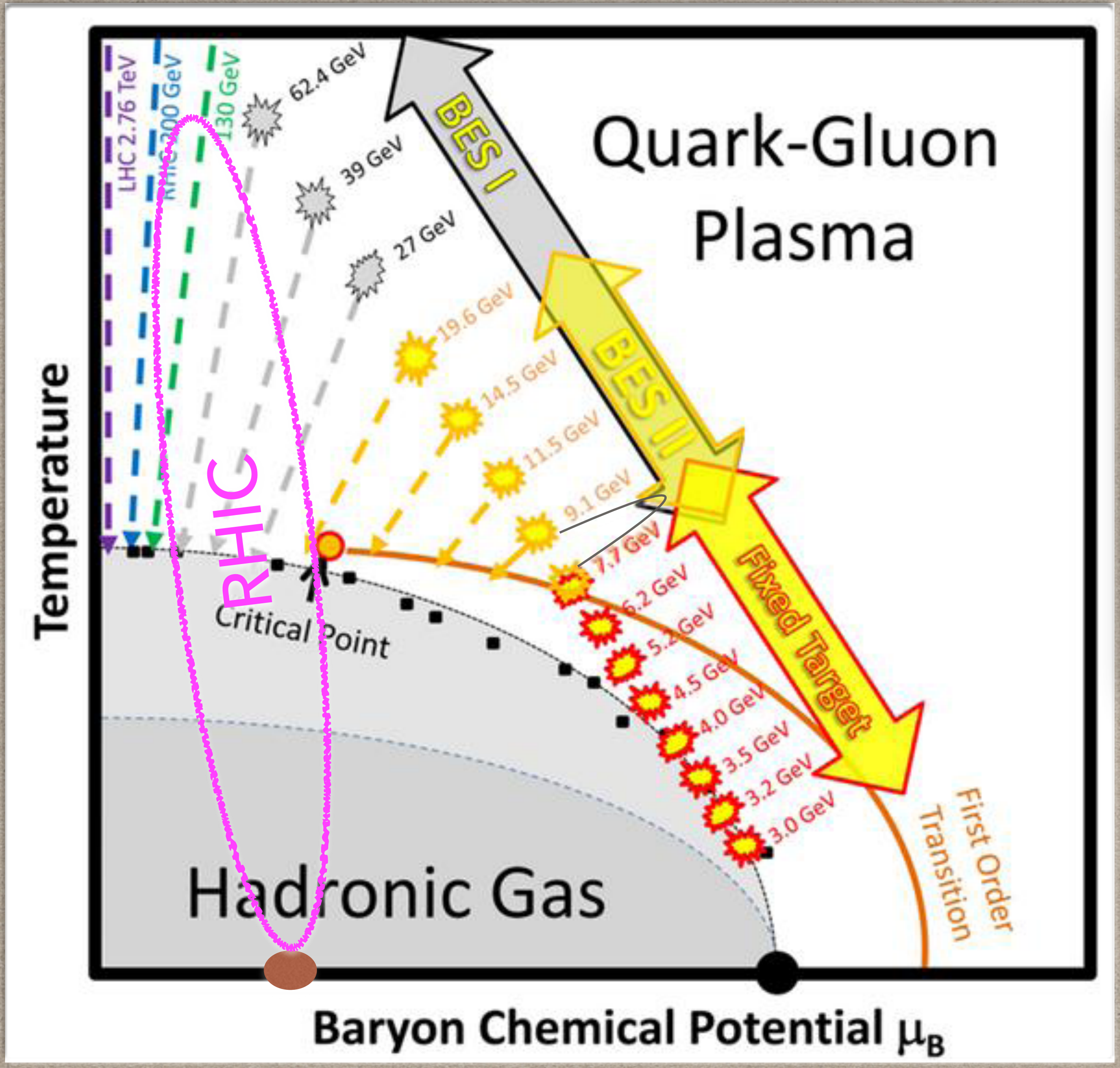


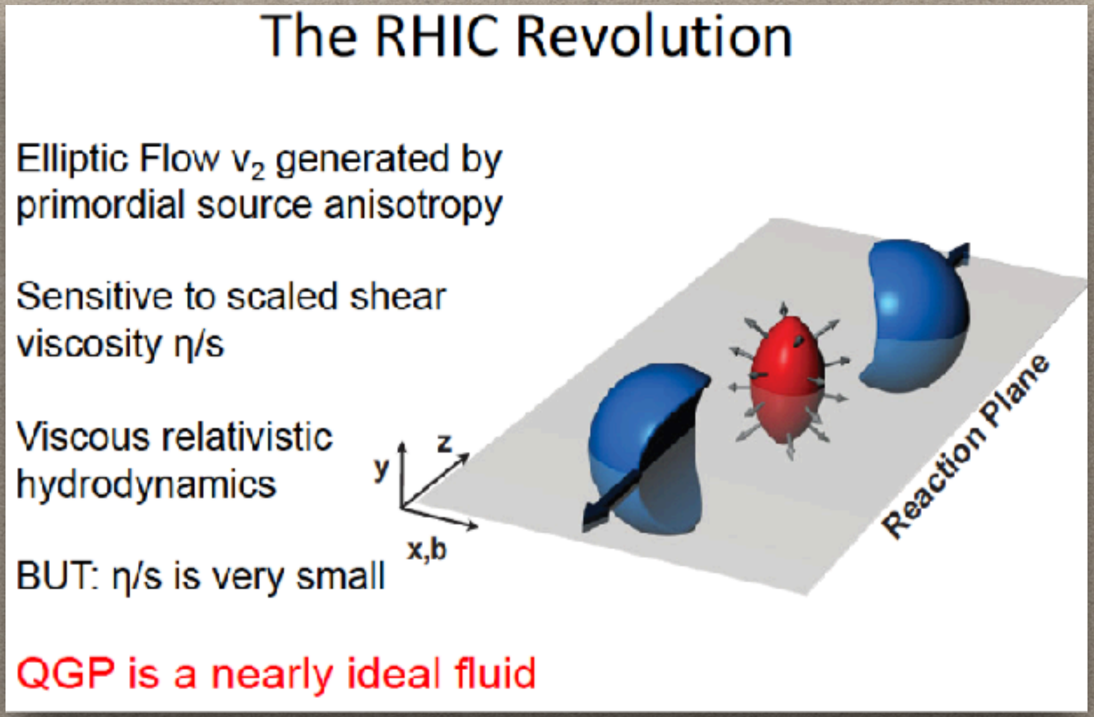
Strongly interacting Matter (QGP)!

EXPLORING QCD PHASE II (RHIC)



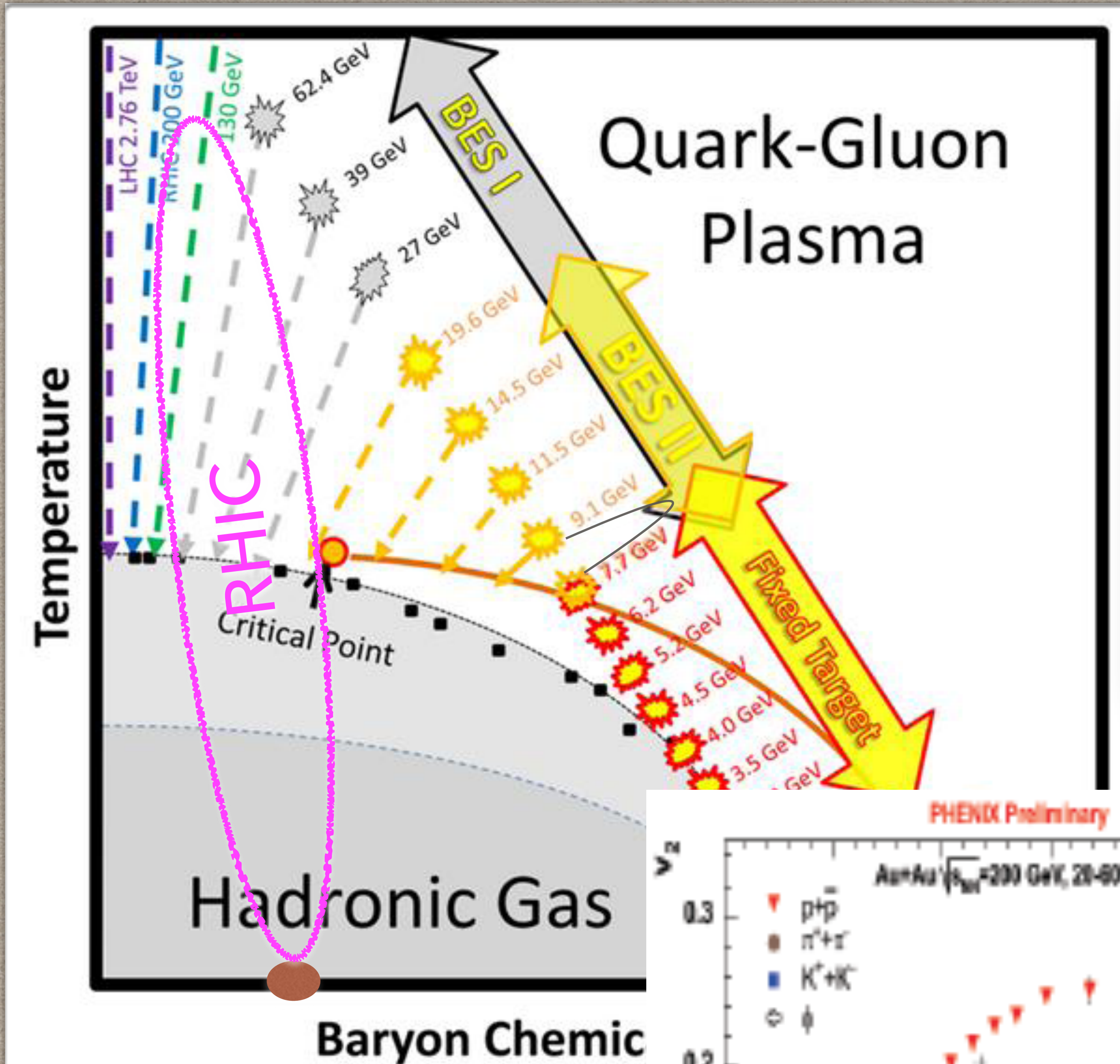
EXPLORING QCD PHASE II (RHIC)





2000s

EXPLORING QCD PHASE II (RHIC)



The RHIC Revolution

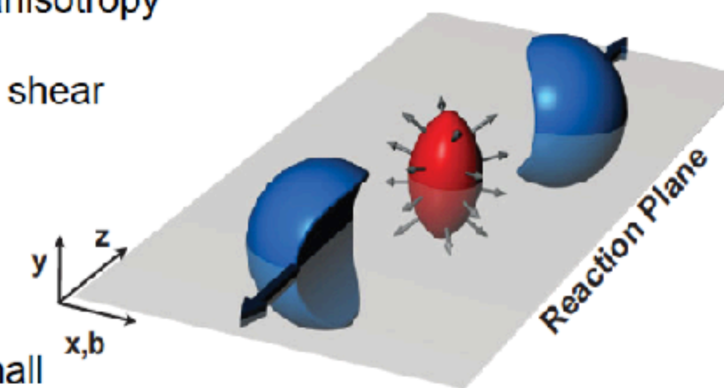
Elliptic Flow v_2 generated by primordial source anisotropy

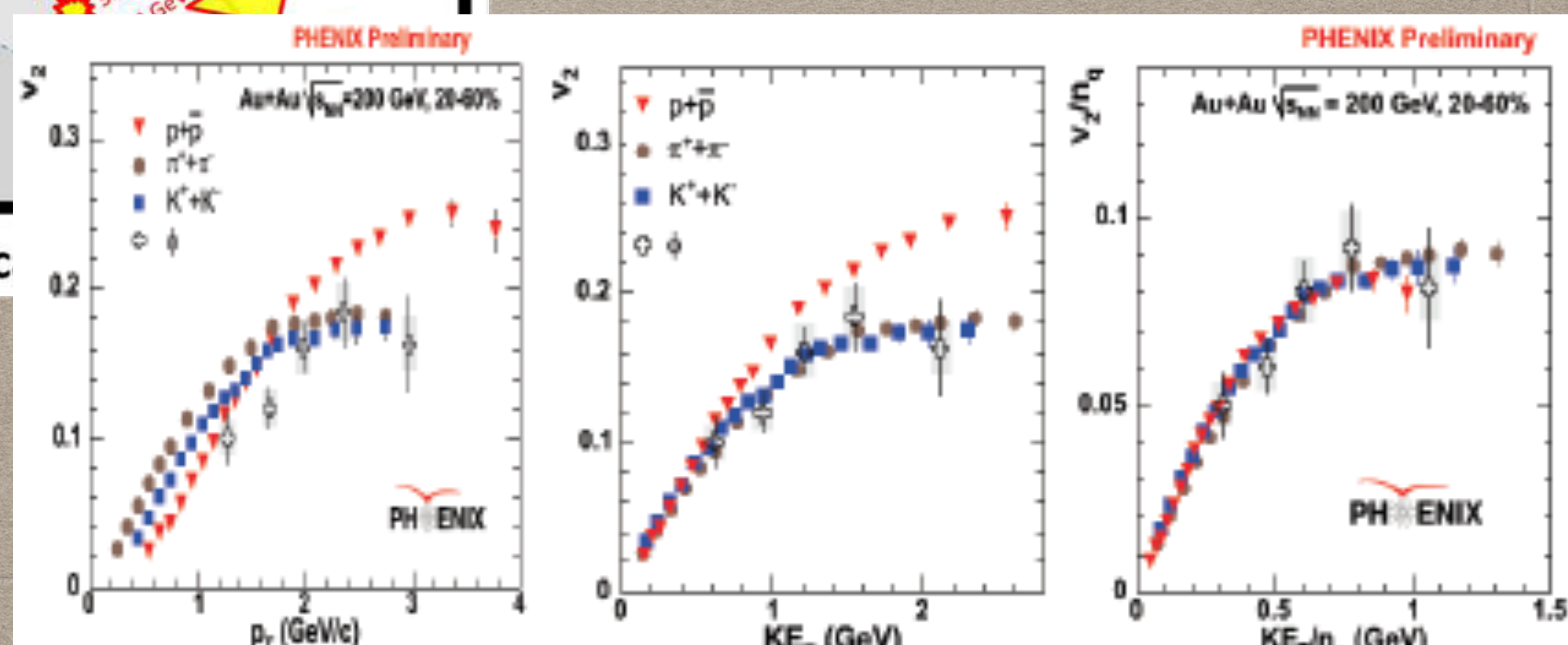
Sensitive to scaled shear viscosity η/s

Viscous relativistic hydrodynamics

BUT: η/s is very small

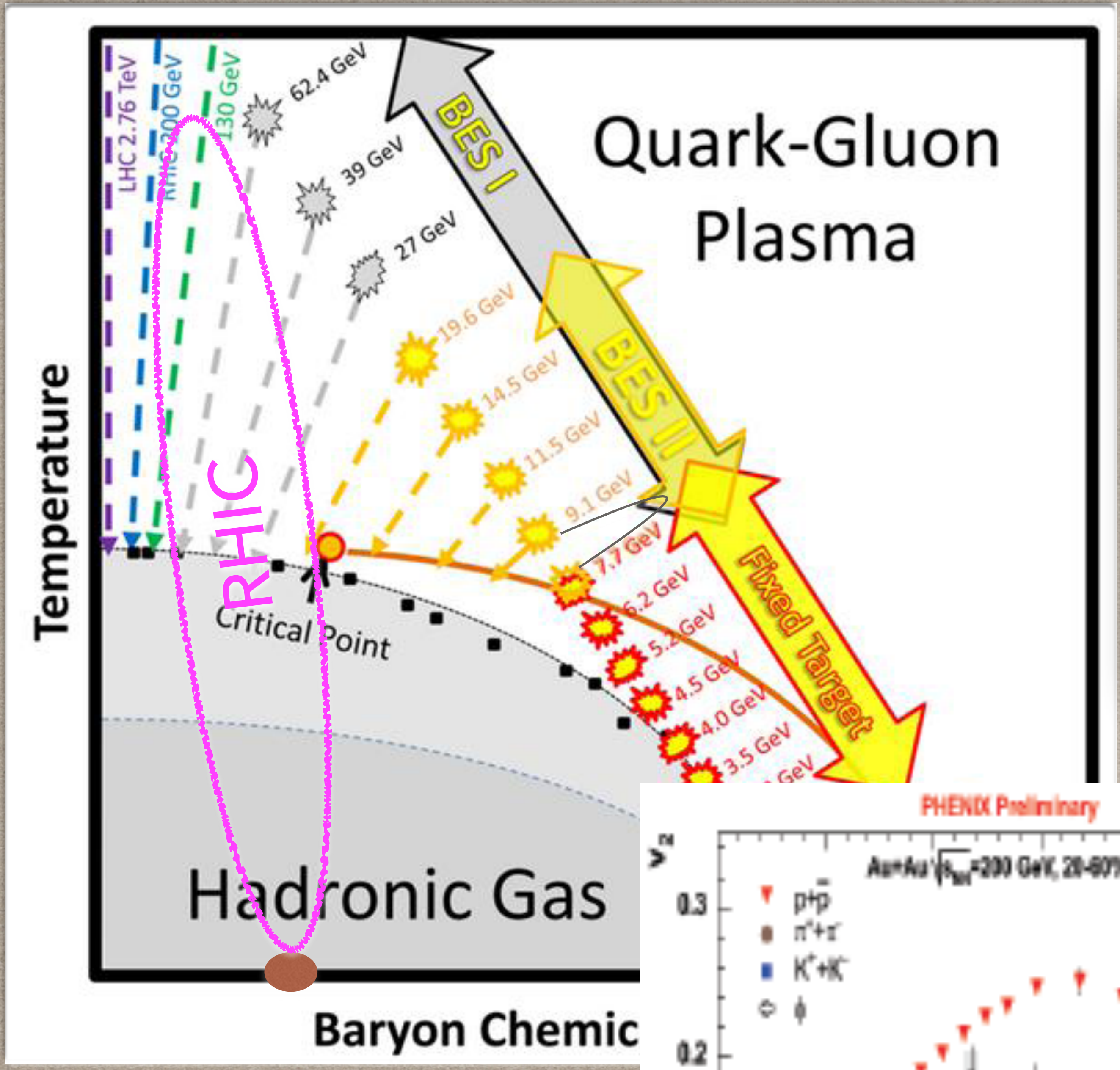
QGP is a nearly ideal fluid

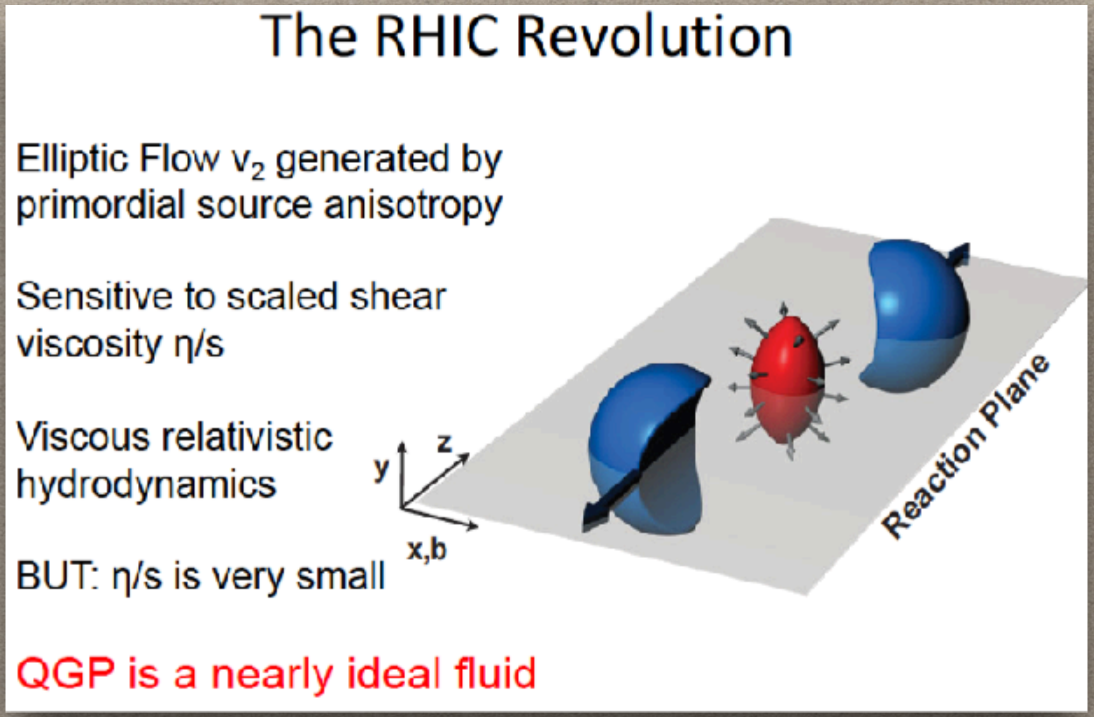


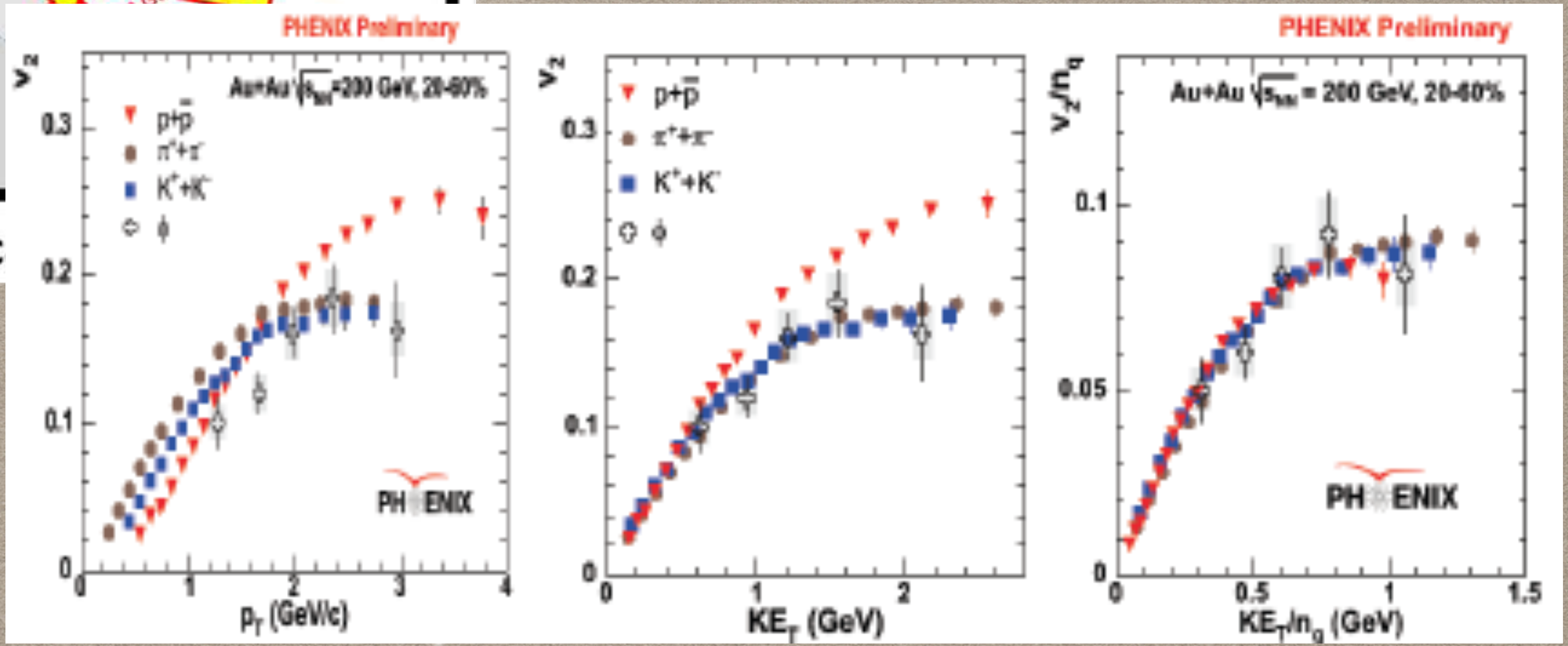


EXPLORING QCD PHASE II (RHIC)

2000s



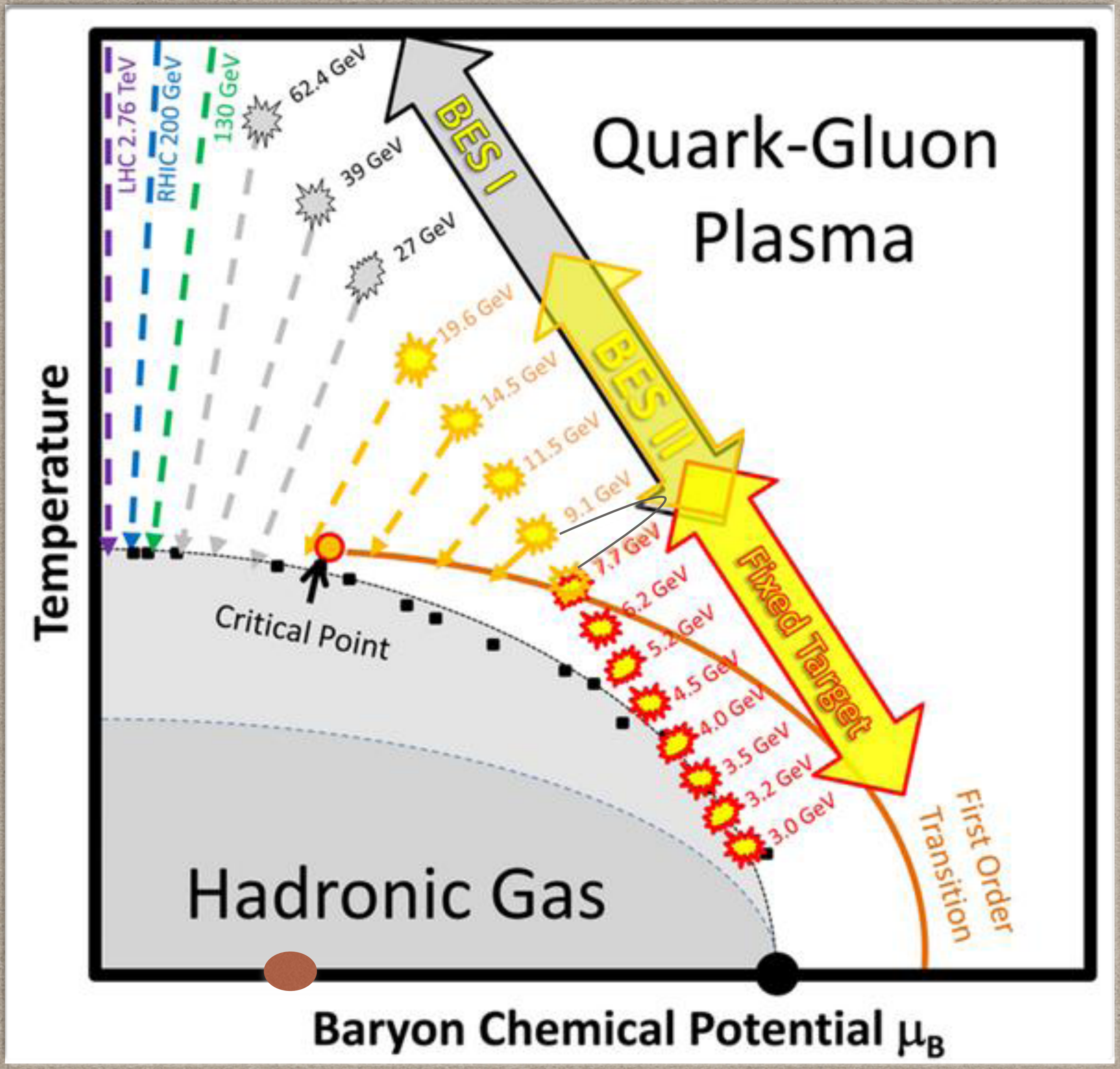




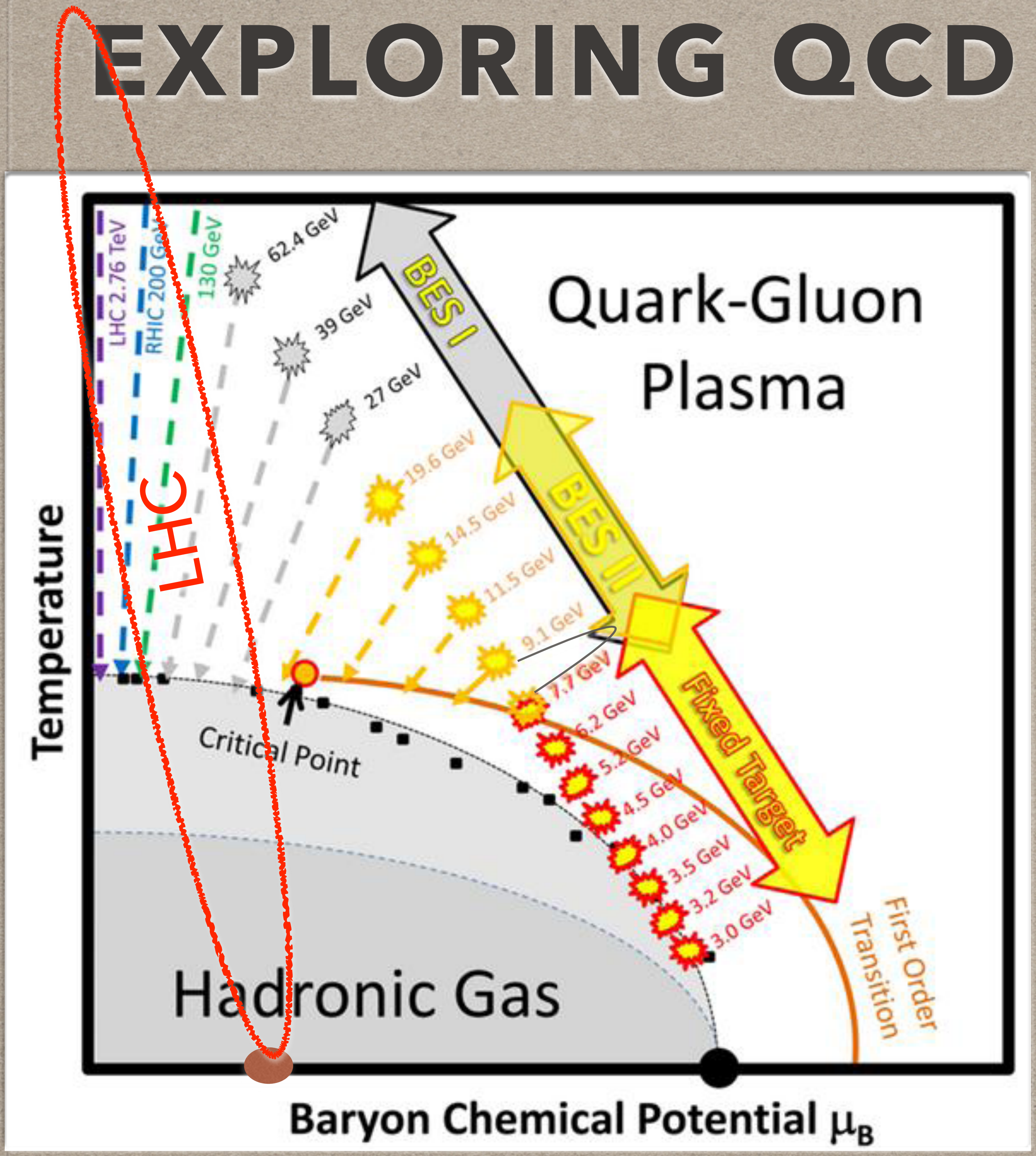
even ideal fluid!

EXPLORING QCD PHASE III (LHC)

2010s

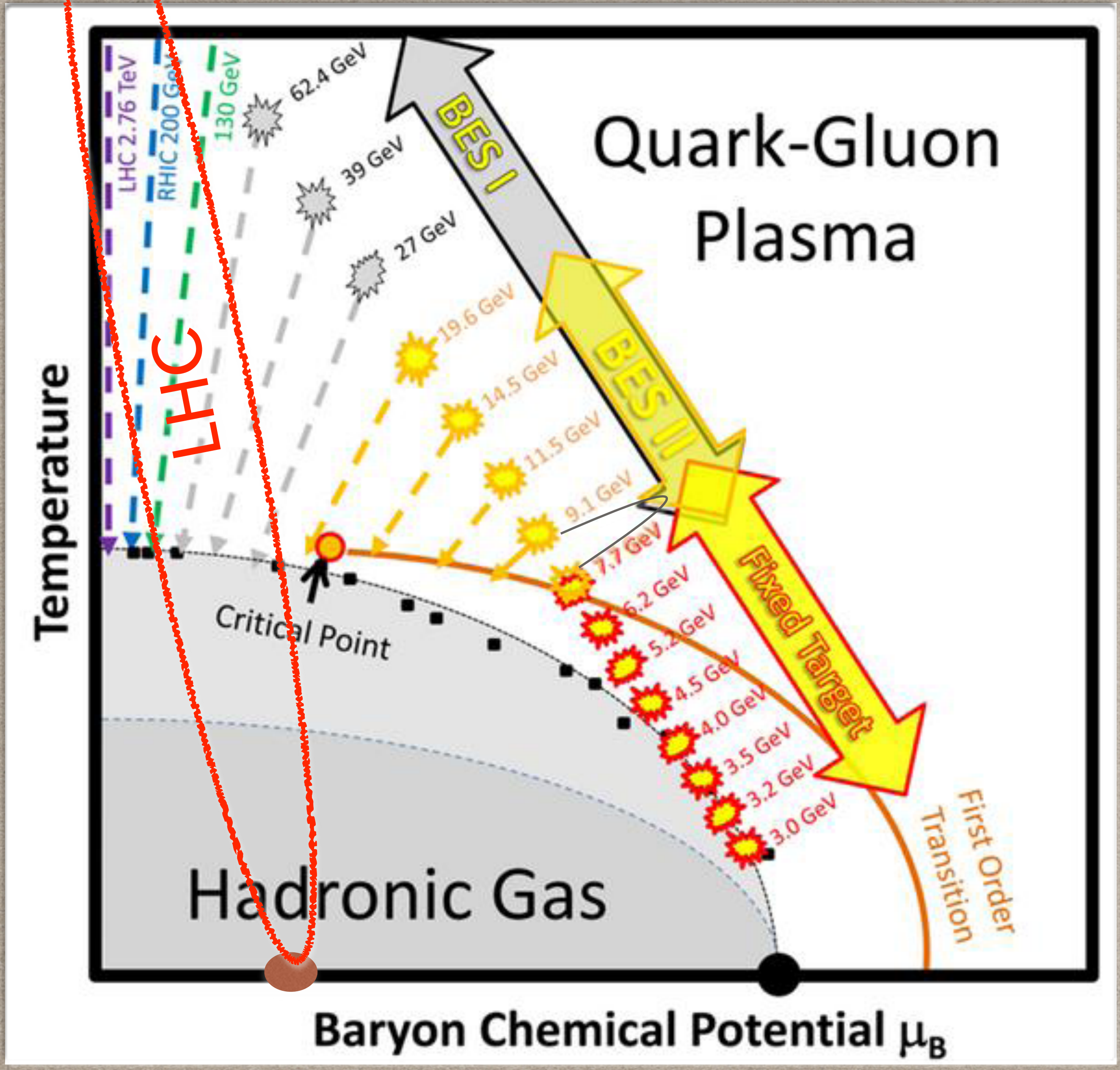


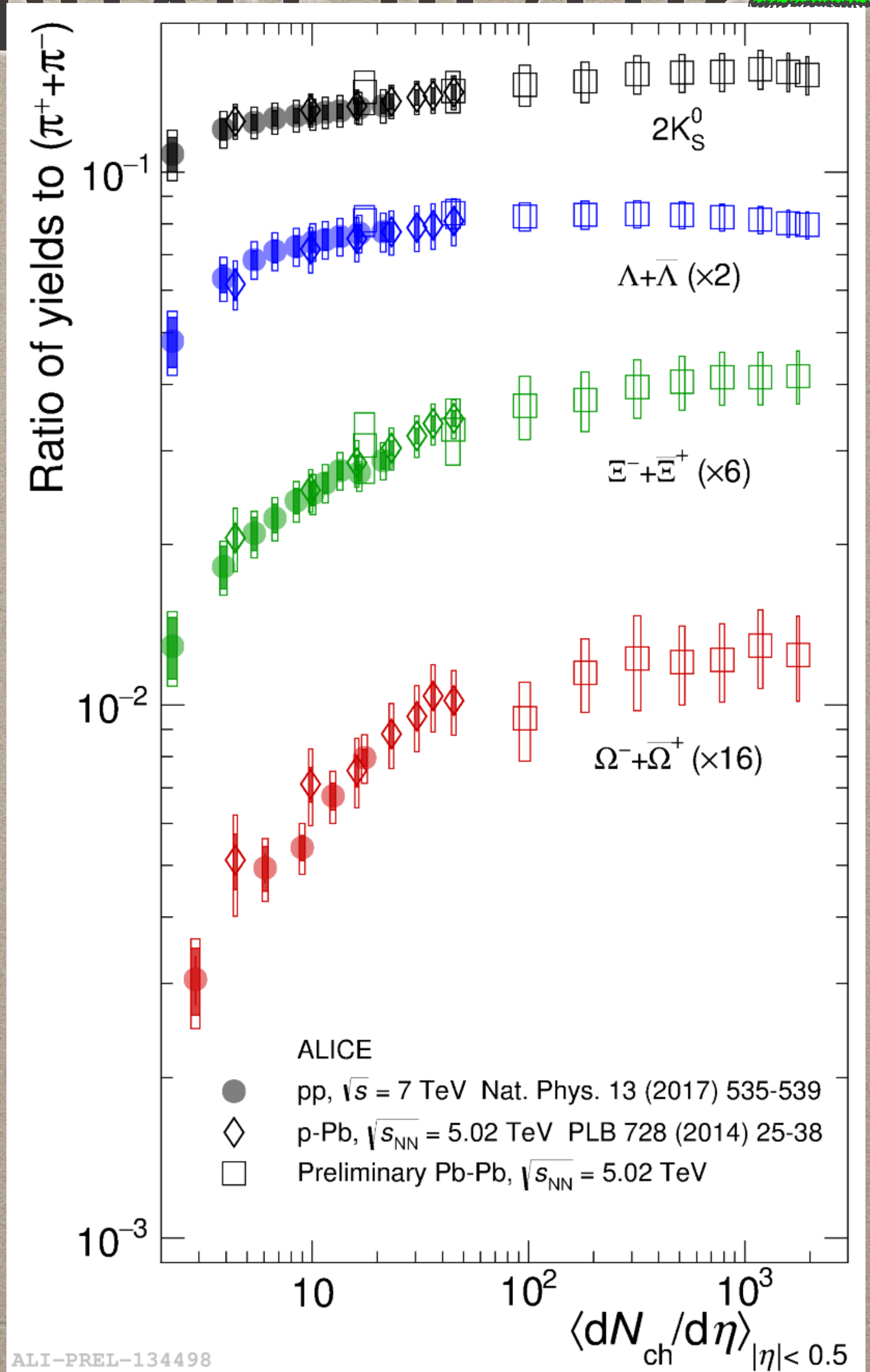
EXPLORING QCD PHASE III (LHC)



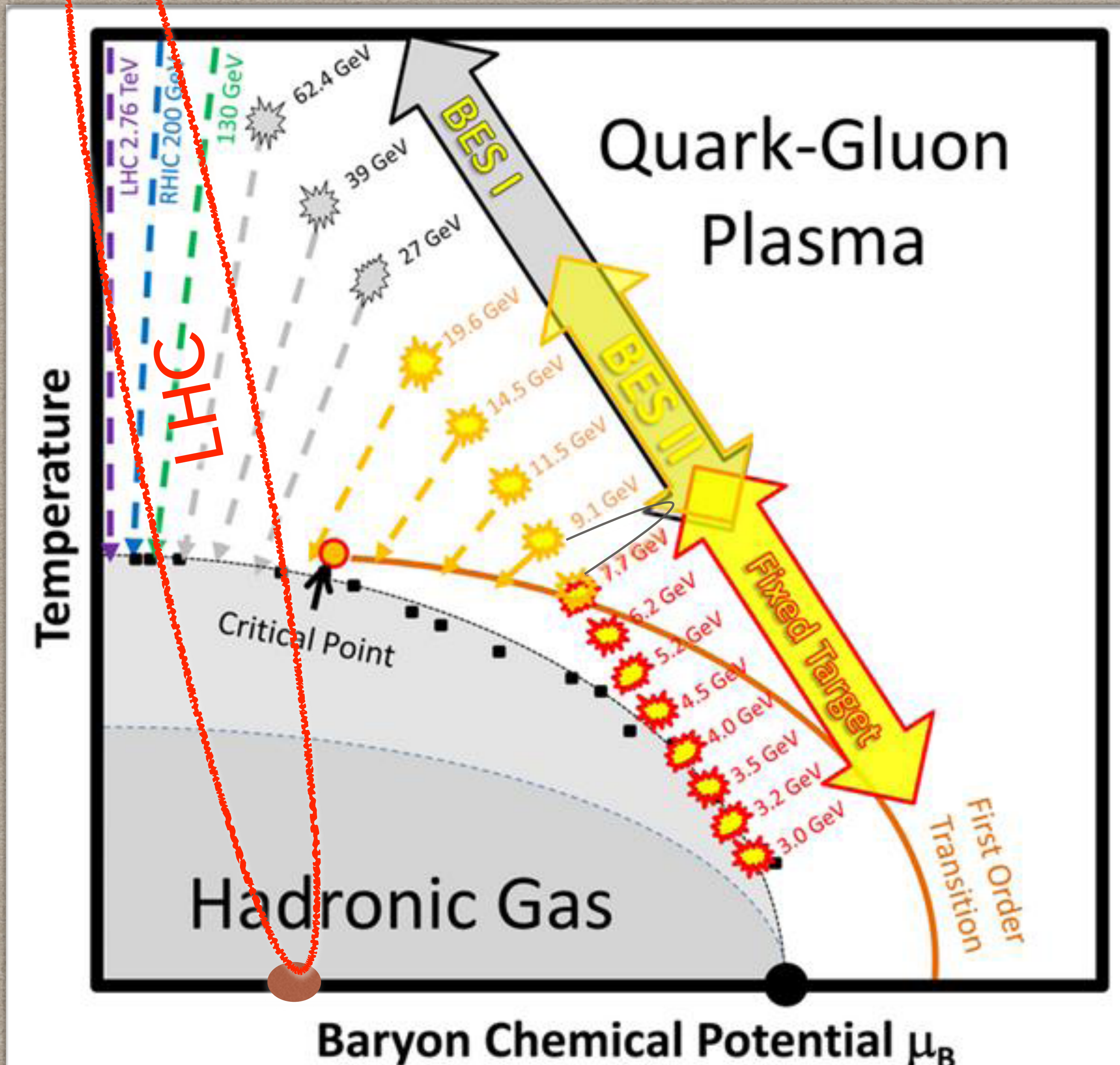
EXPLORING QCD PHASE III (LHC)

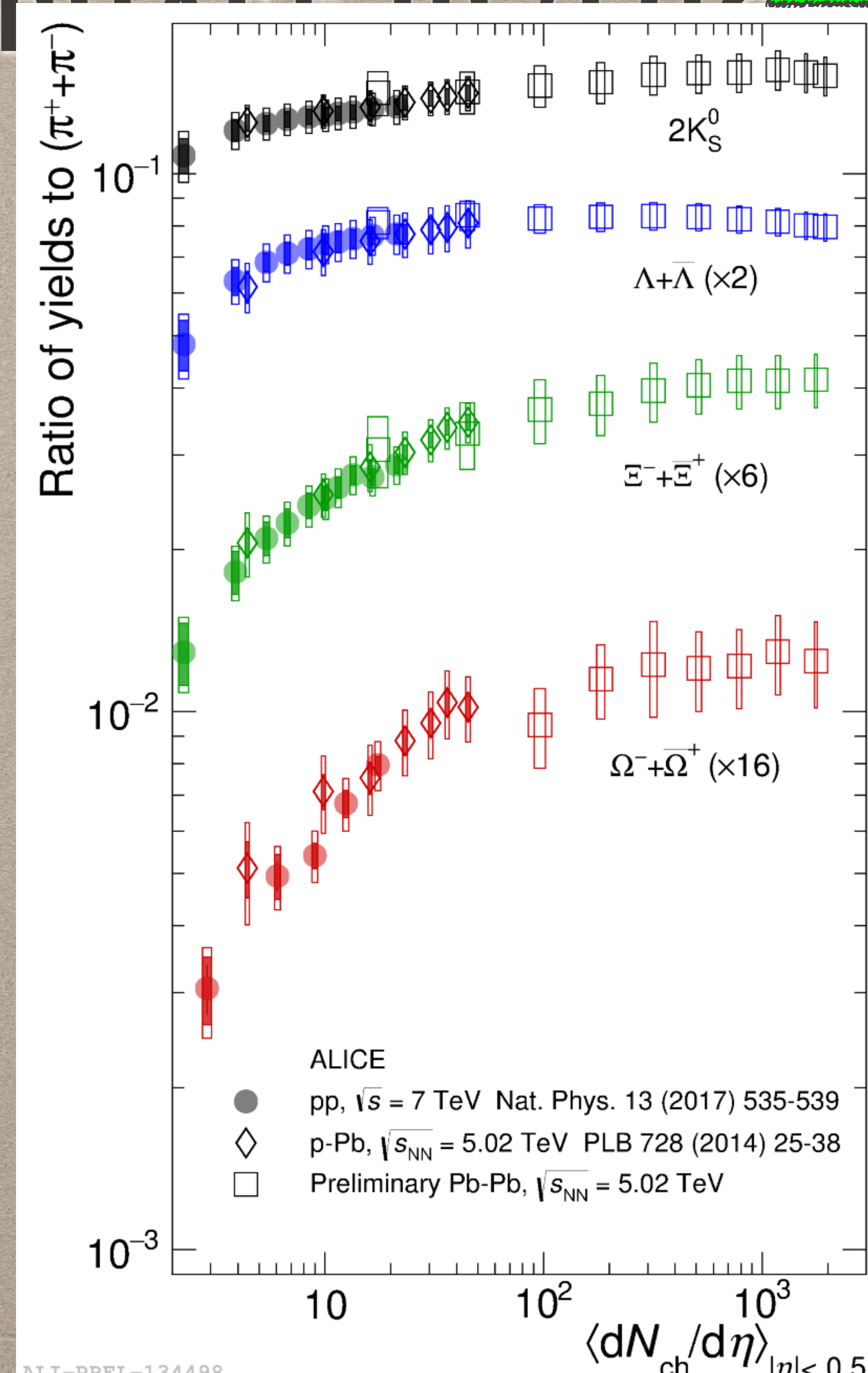
2010s





EXPLORING QCD PHASE III (LHC

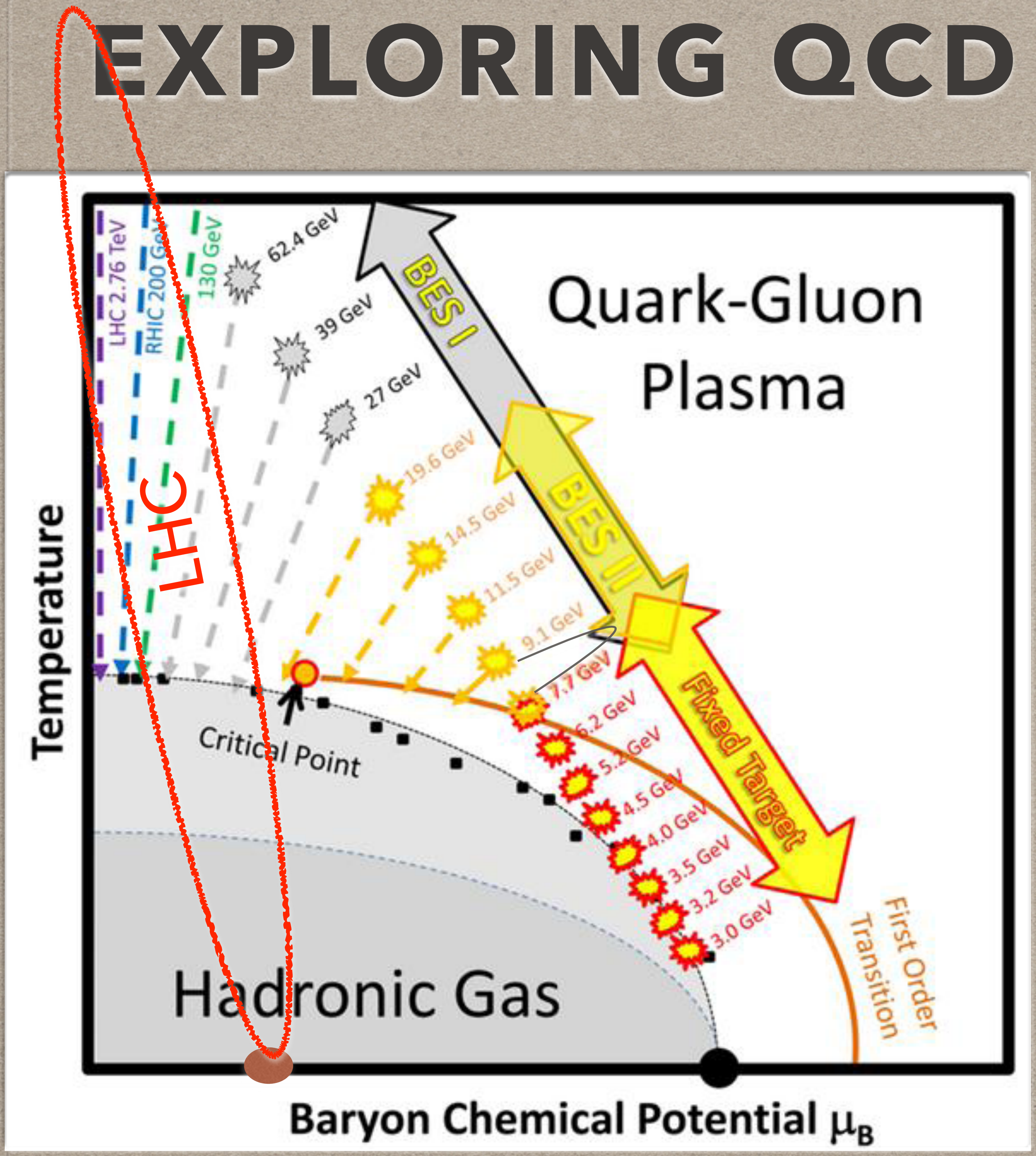




smooth evolution!
from pp to PbPb

2010s

EXPLORING QCD PHASE III (LHC)



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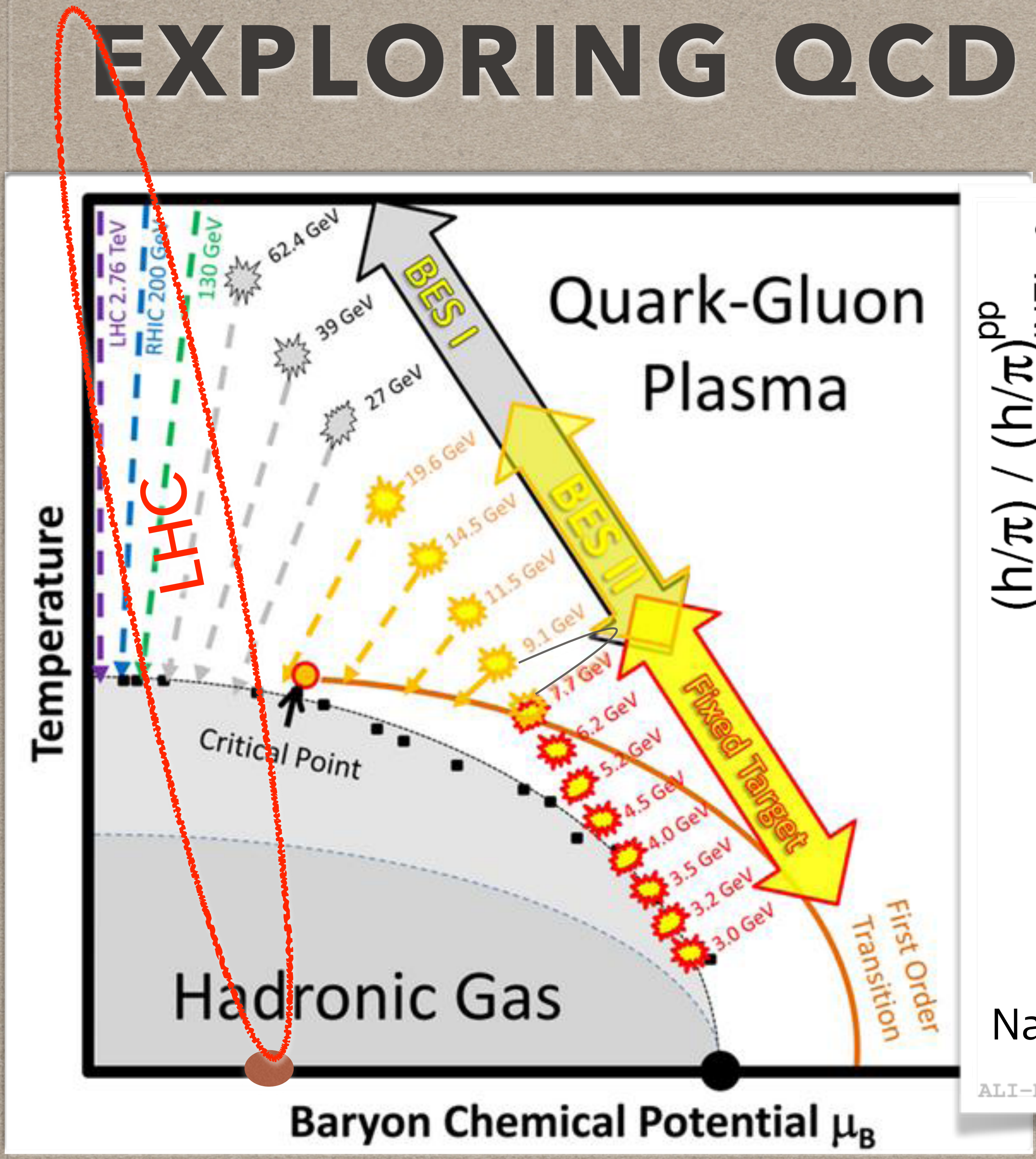
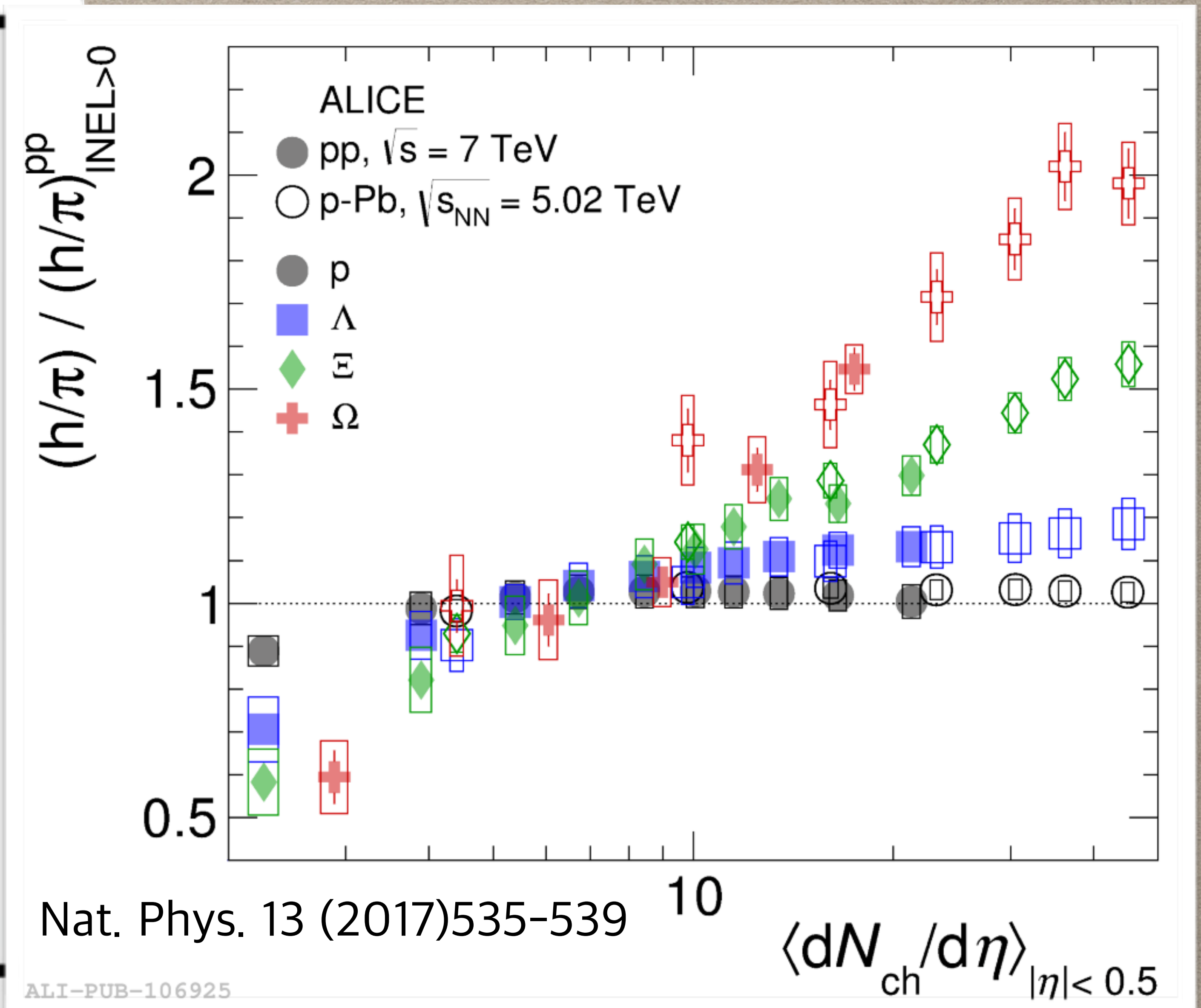
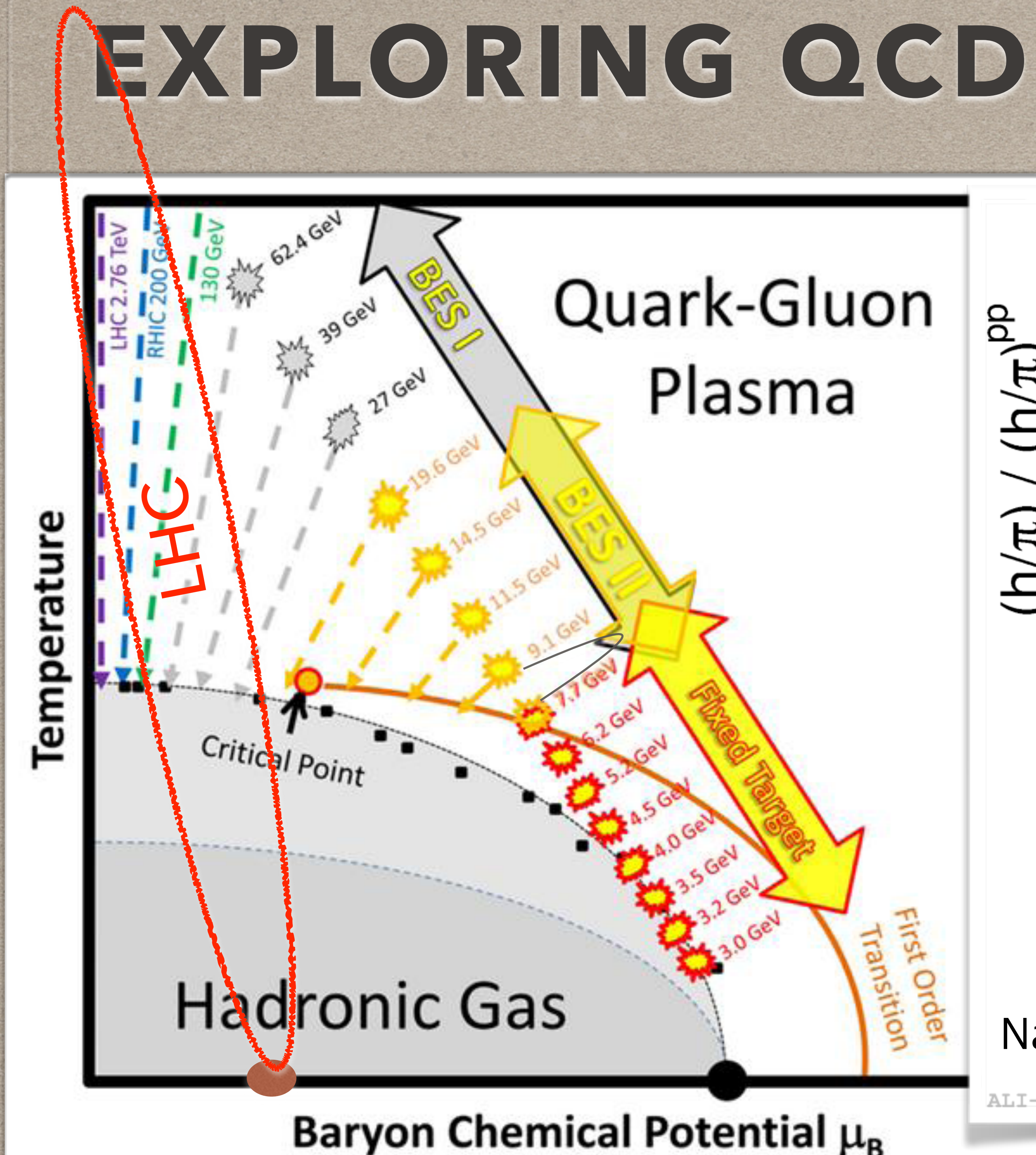
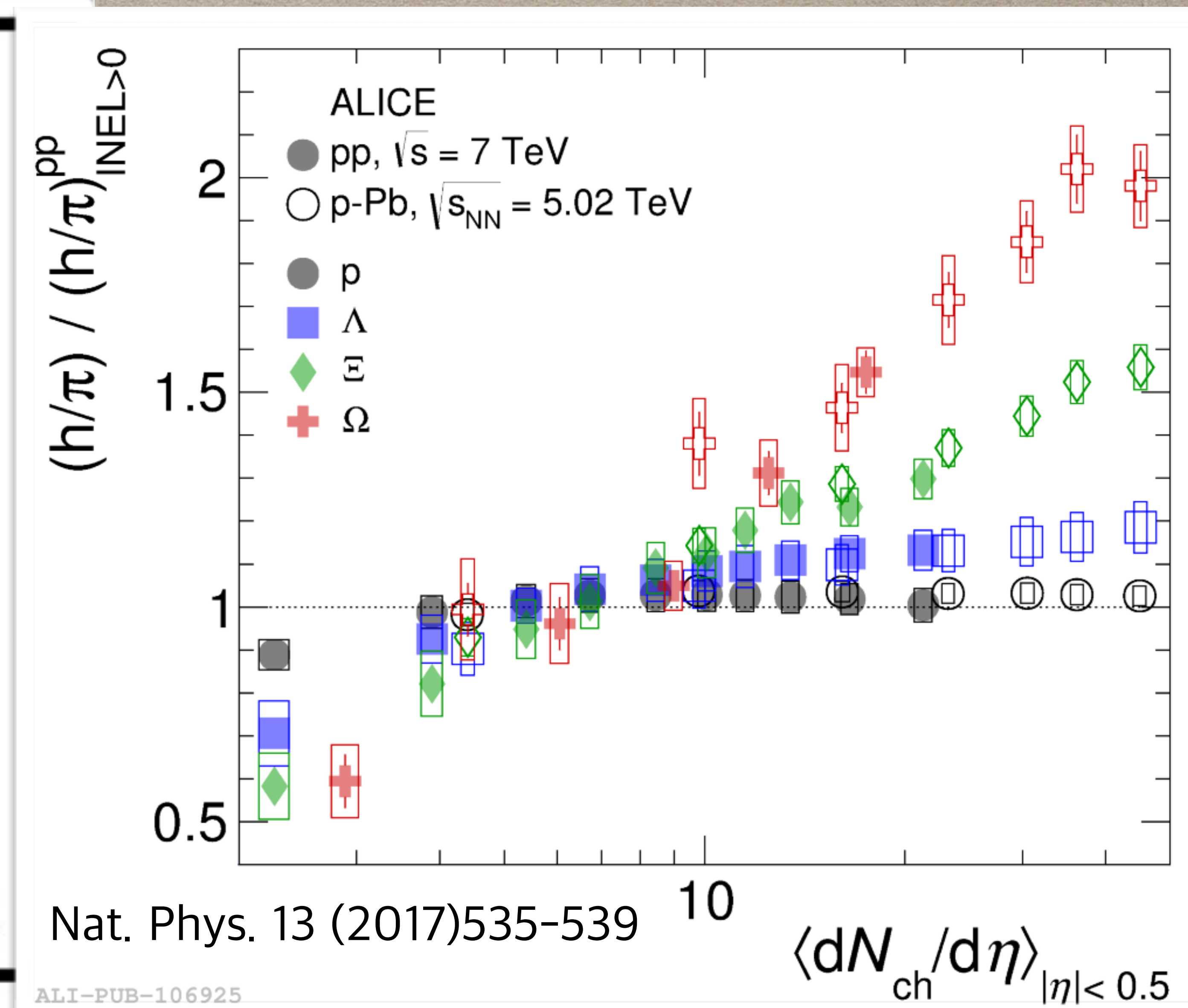




smooth evolution!
from pp to PbPb

EXPLORING QCD PHASE III (LHC)





smooth evolution! from pp to PbPb

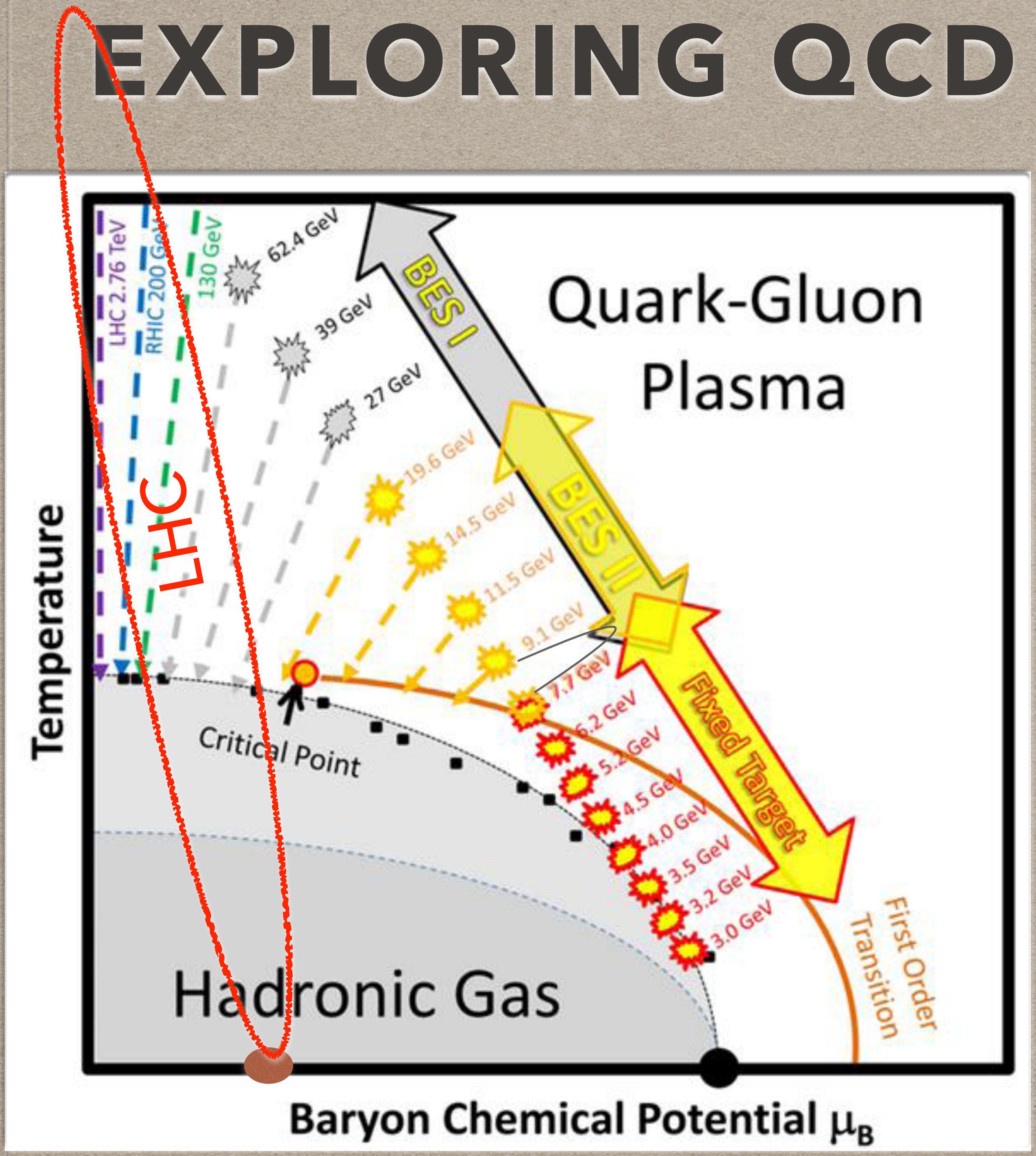
Multiplicity = Universal Variable for the collisions

- Energy, System don't matter!

➡Attention to the small system!

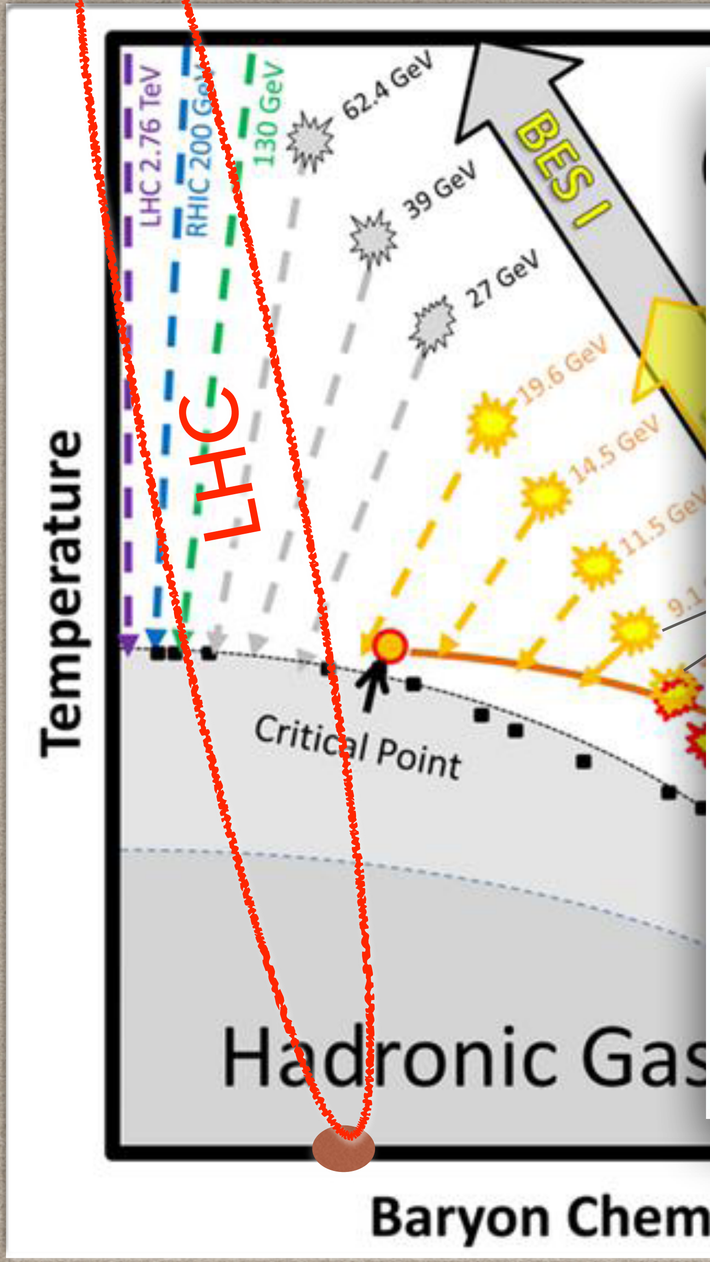
EXPLORING QCD PHASE III (LHC)

2010s



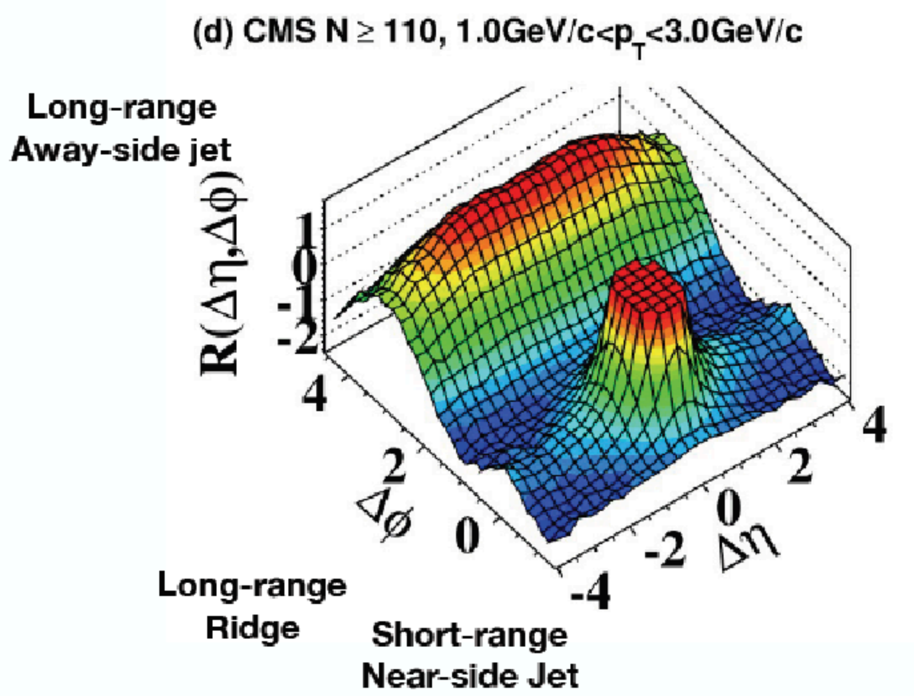
2010s

EXPLORING QCD PHASE III (LHC)



Ridge in High Multiplicity pp

CMS, JHEP 09 (2010) 091



Collectivity in small systems

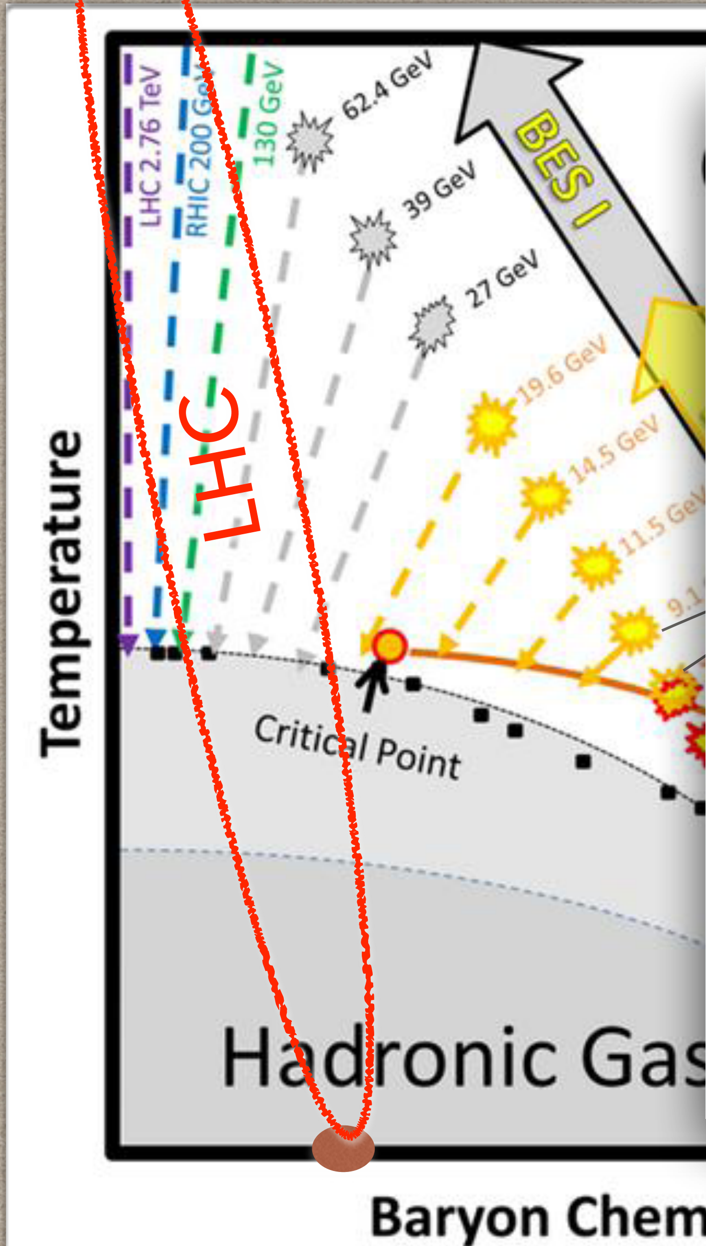
~ year 2005: sQGP signature
~ year 2010: sQGP in pp as well?

ridge includes v_2 + higher orders

Li Yi (Shandong University) 6

2010s

EXPLORING QCD PHASE III (LHC)



Ridge in High Multiplicity pp

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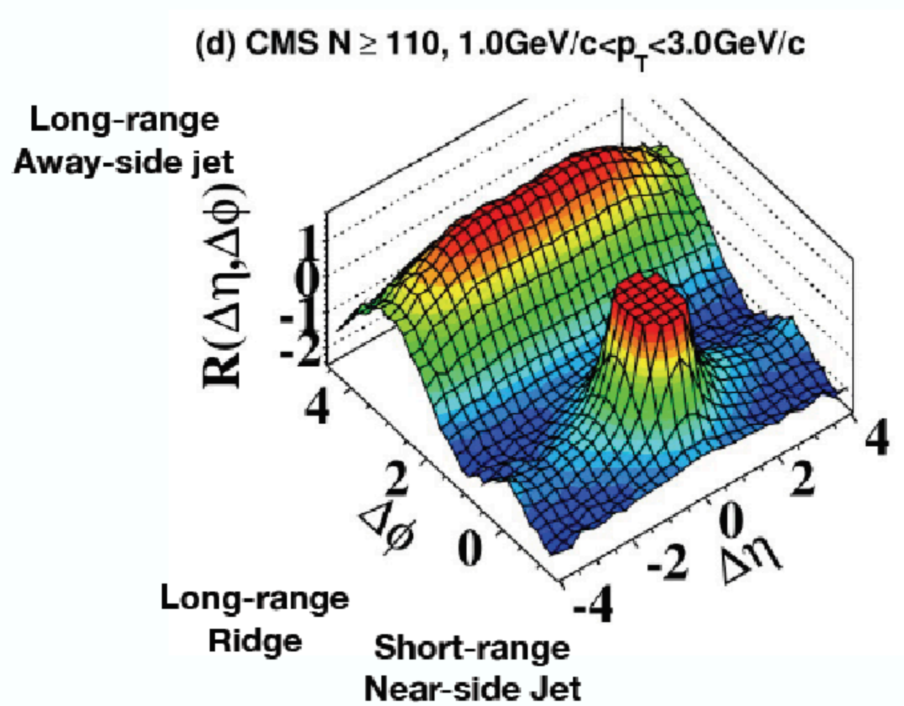


Collectivity in small systems

~ year 2005: sQGP signature
~ year 2010: sQGP in pp as well?

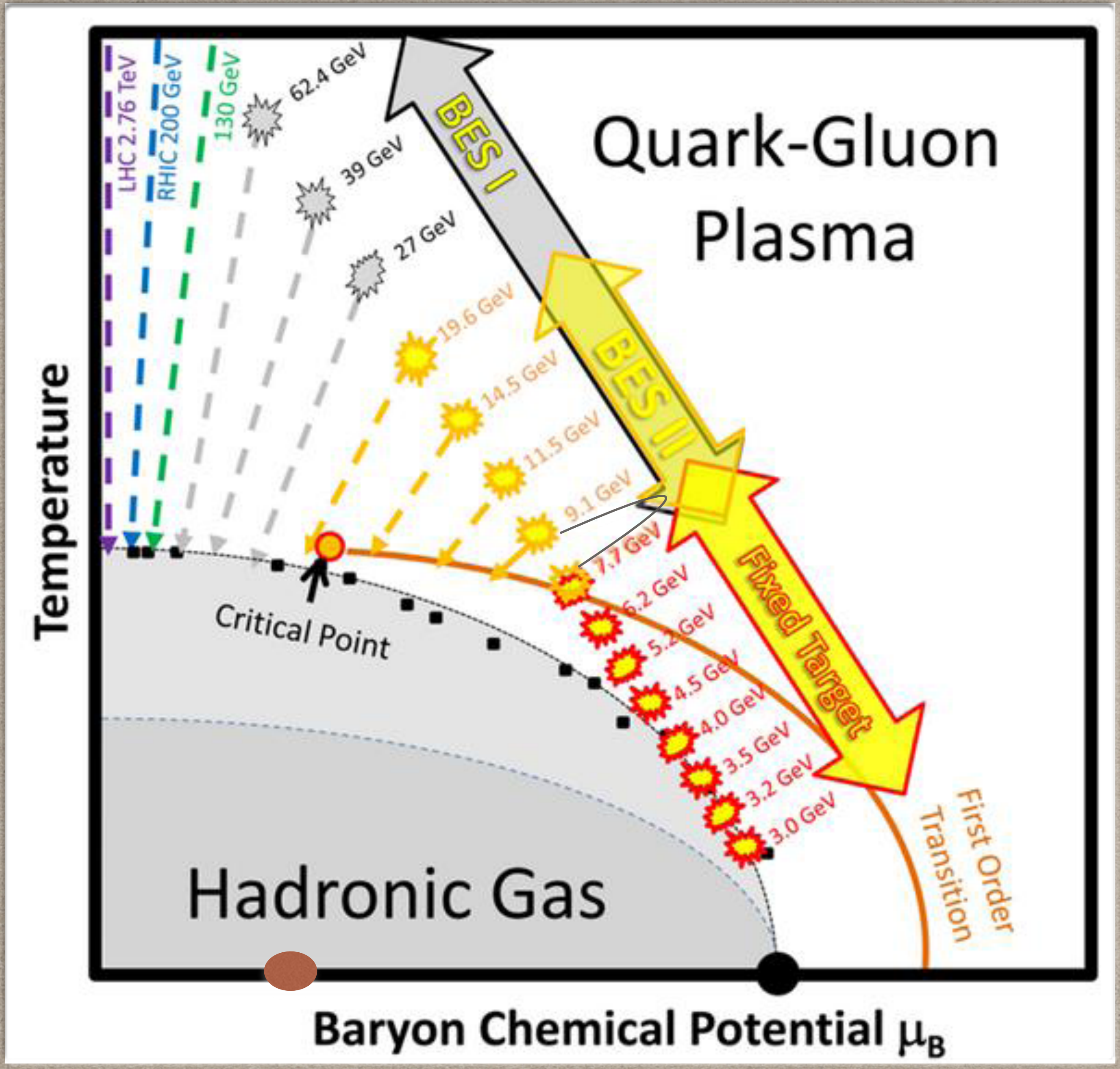
ridge includes v_2 + higher orders

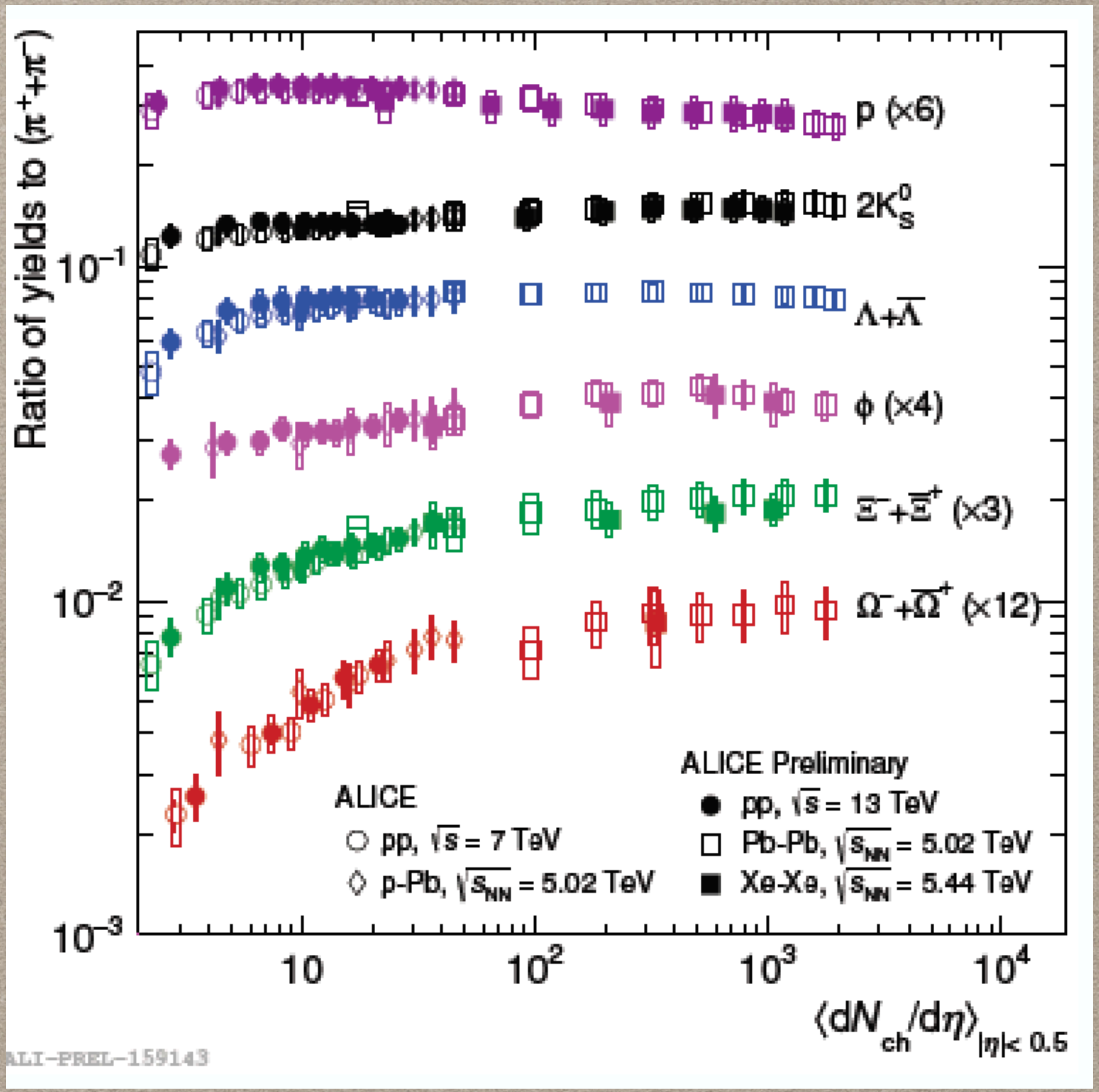
Li Yi (Shandong University) 6

QGP droplet in high-multiplicity pp events?

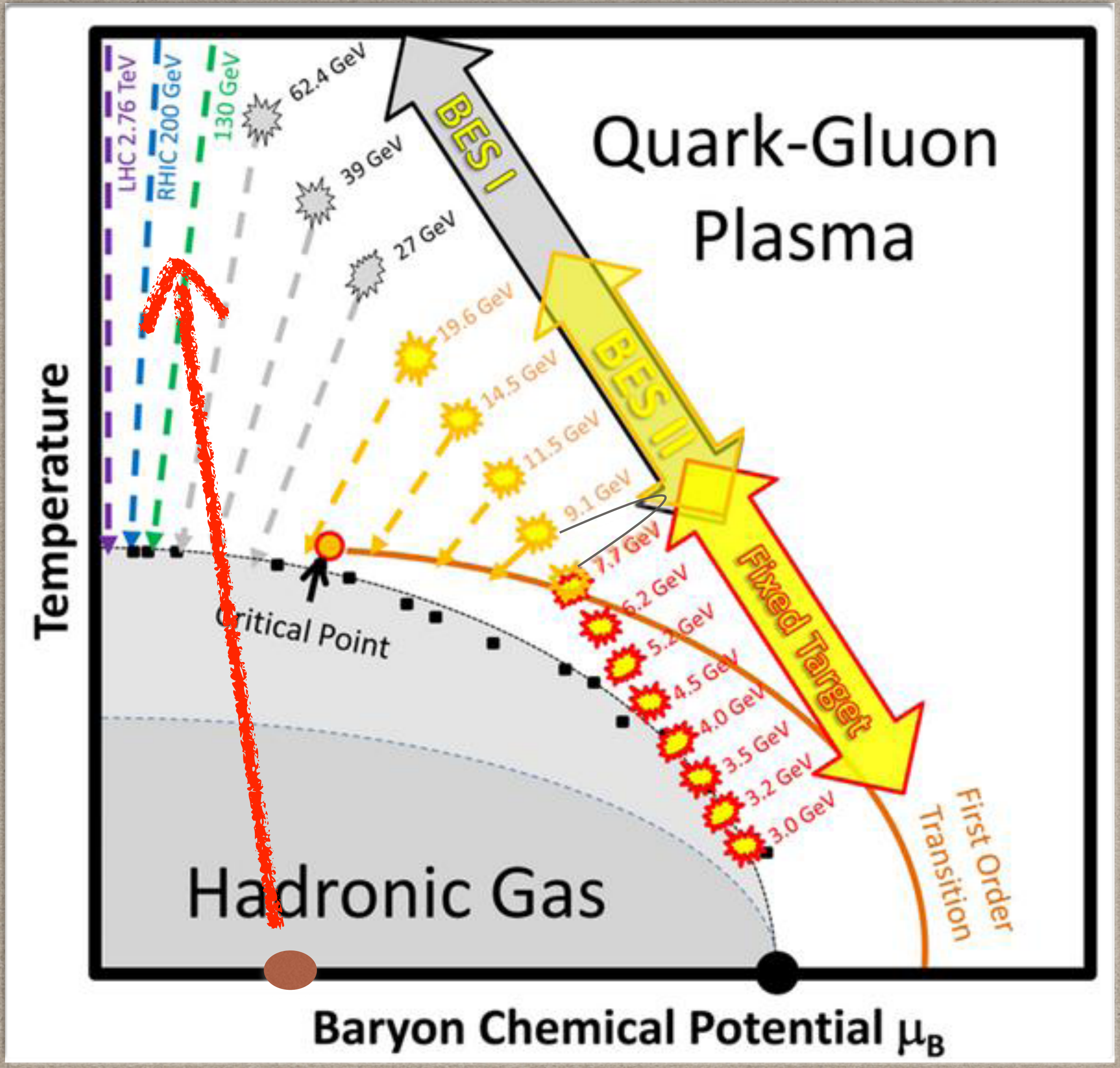
2020s

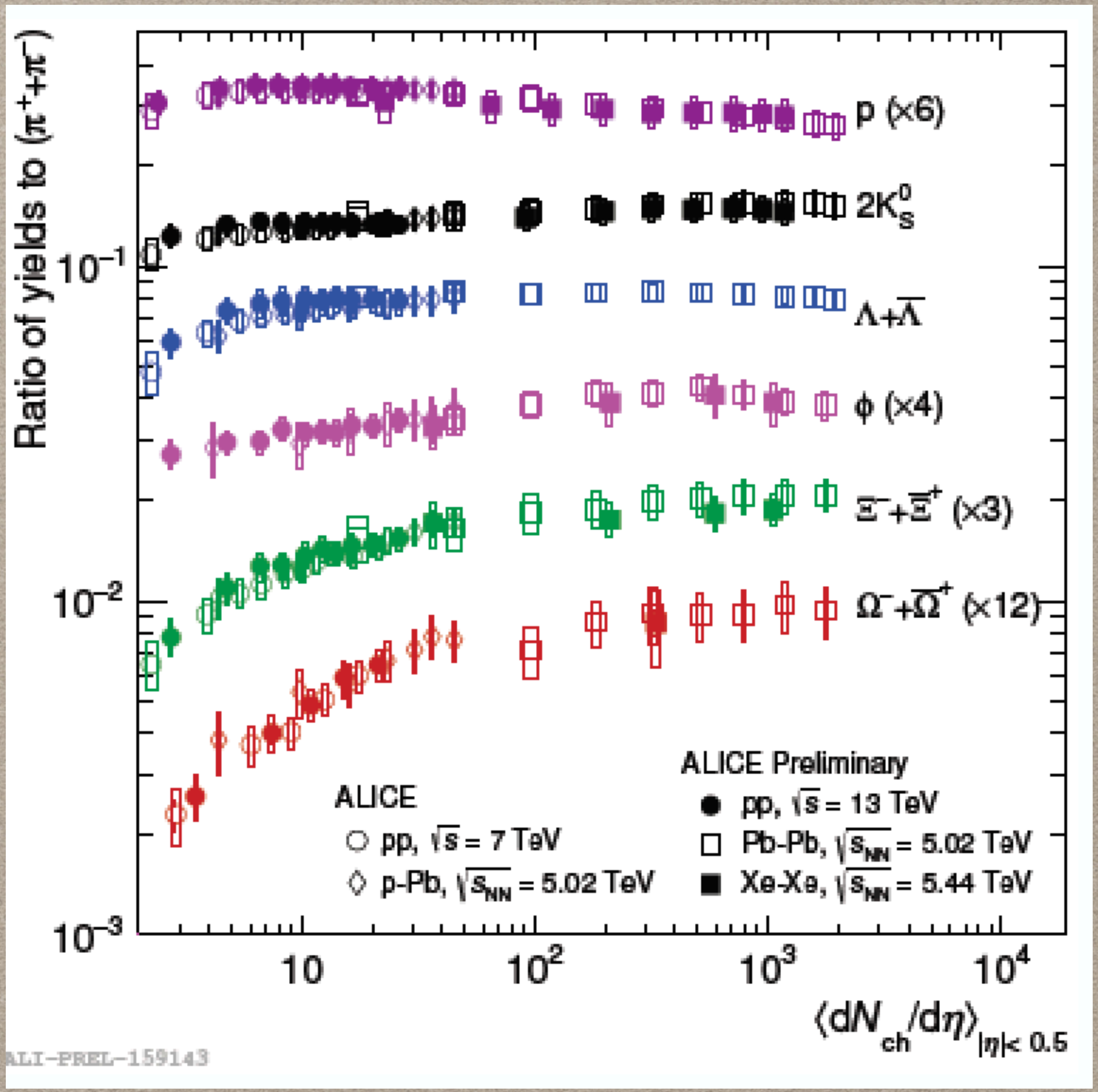
EXPLORING QCD PHASE III (RUN3)





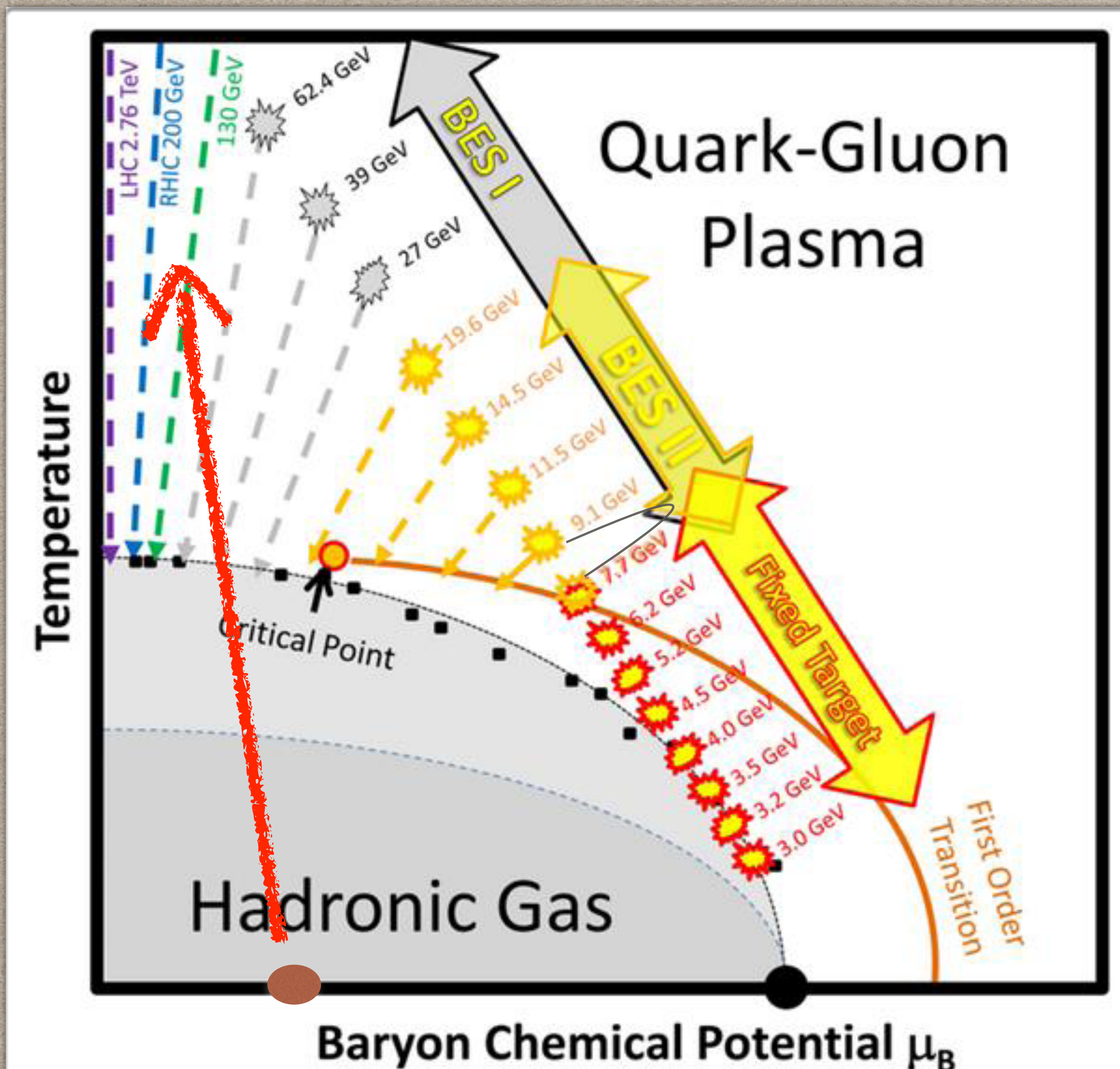
EXPLORING QCD PHASE III (RUN3)



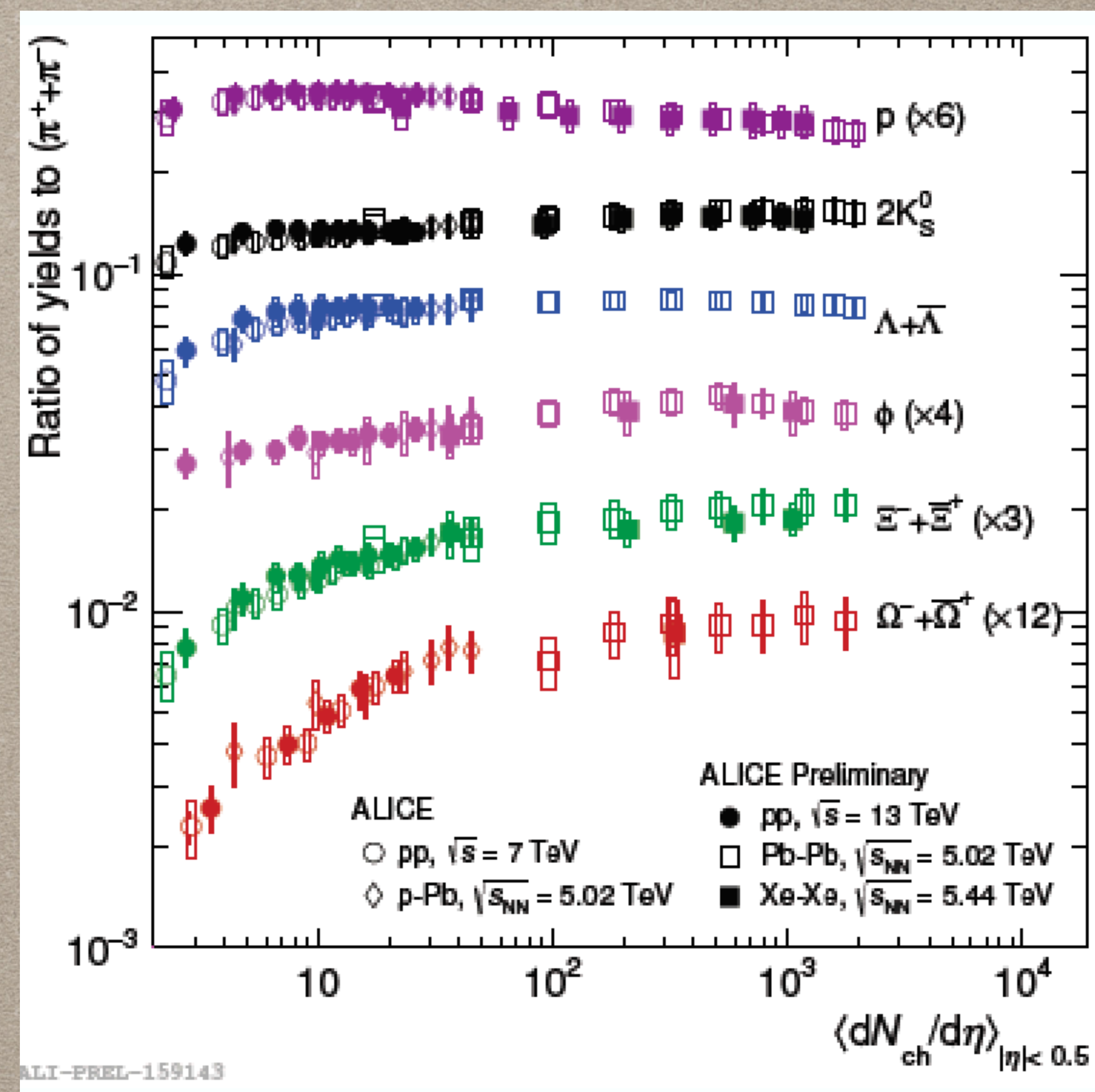


2020s

EXPLORING QCD PHASE III (RUN3)

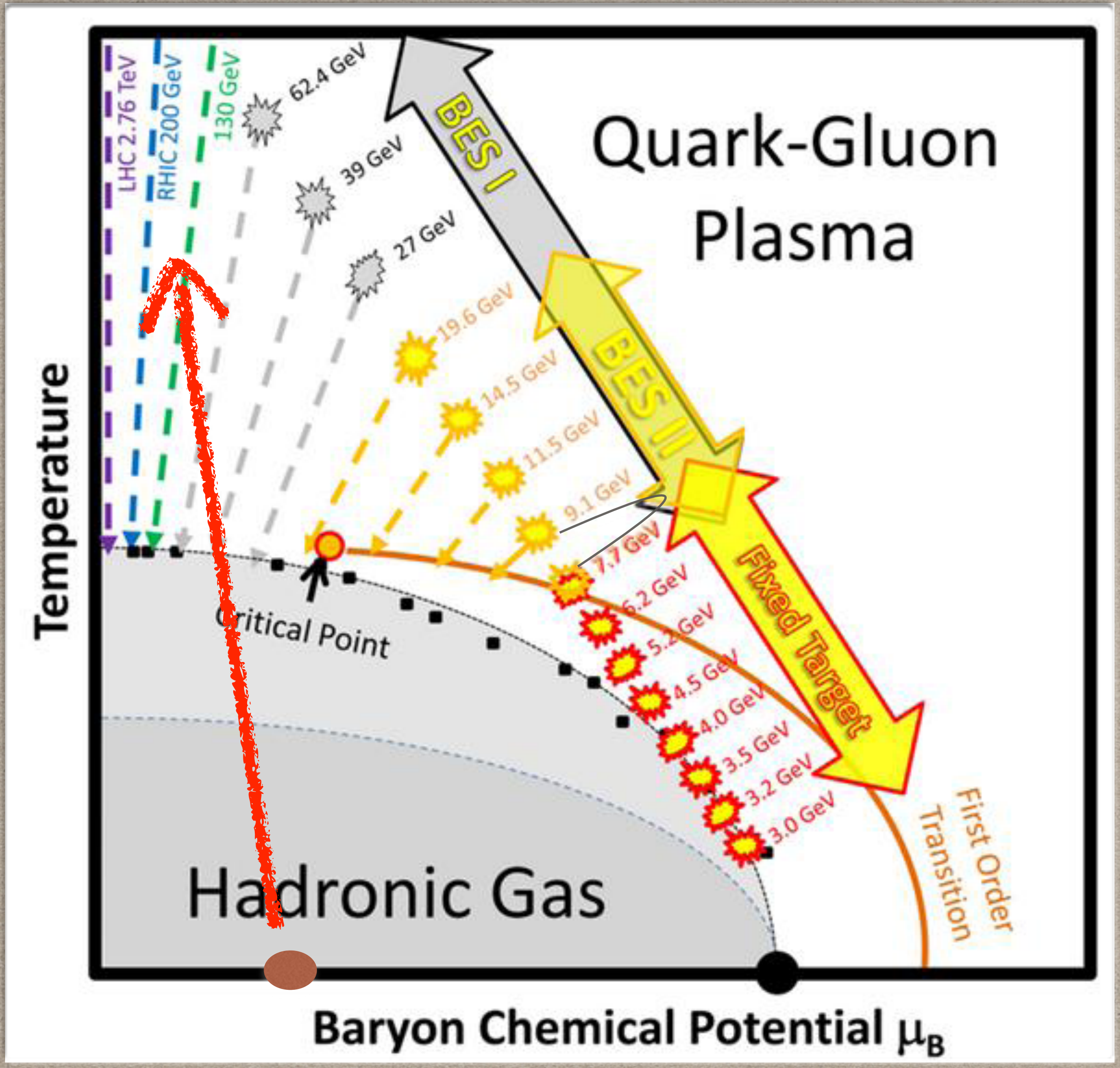


Hot matter study

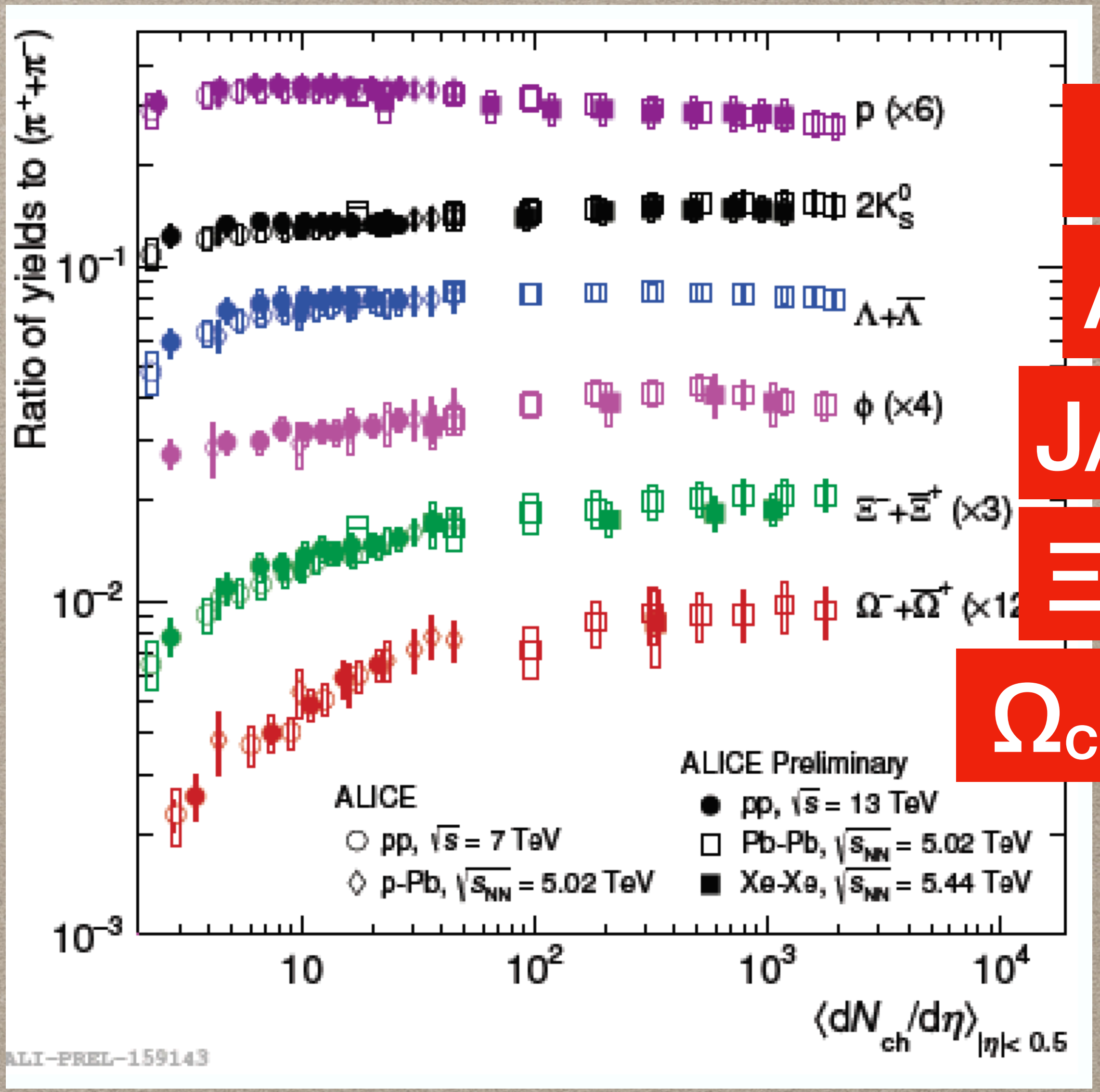


EXPLORING QCD PHASE III (RUN3)

2020s



Hot matter study



D

Λ_c

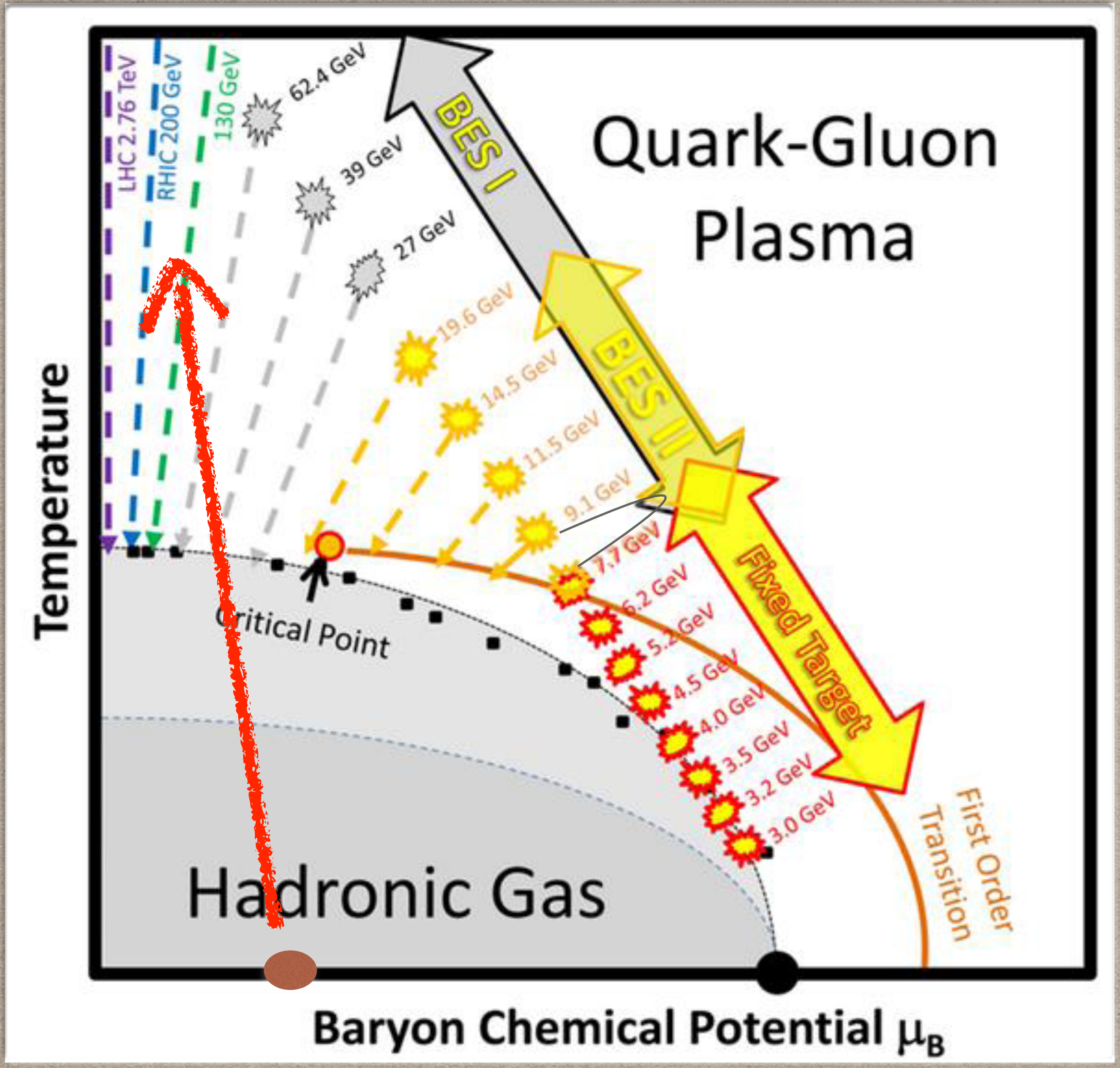
J/ψ

Ξ_{cc}

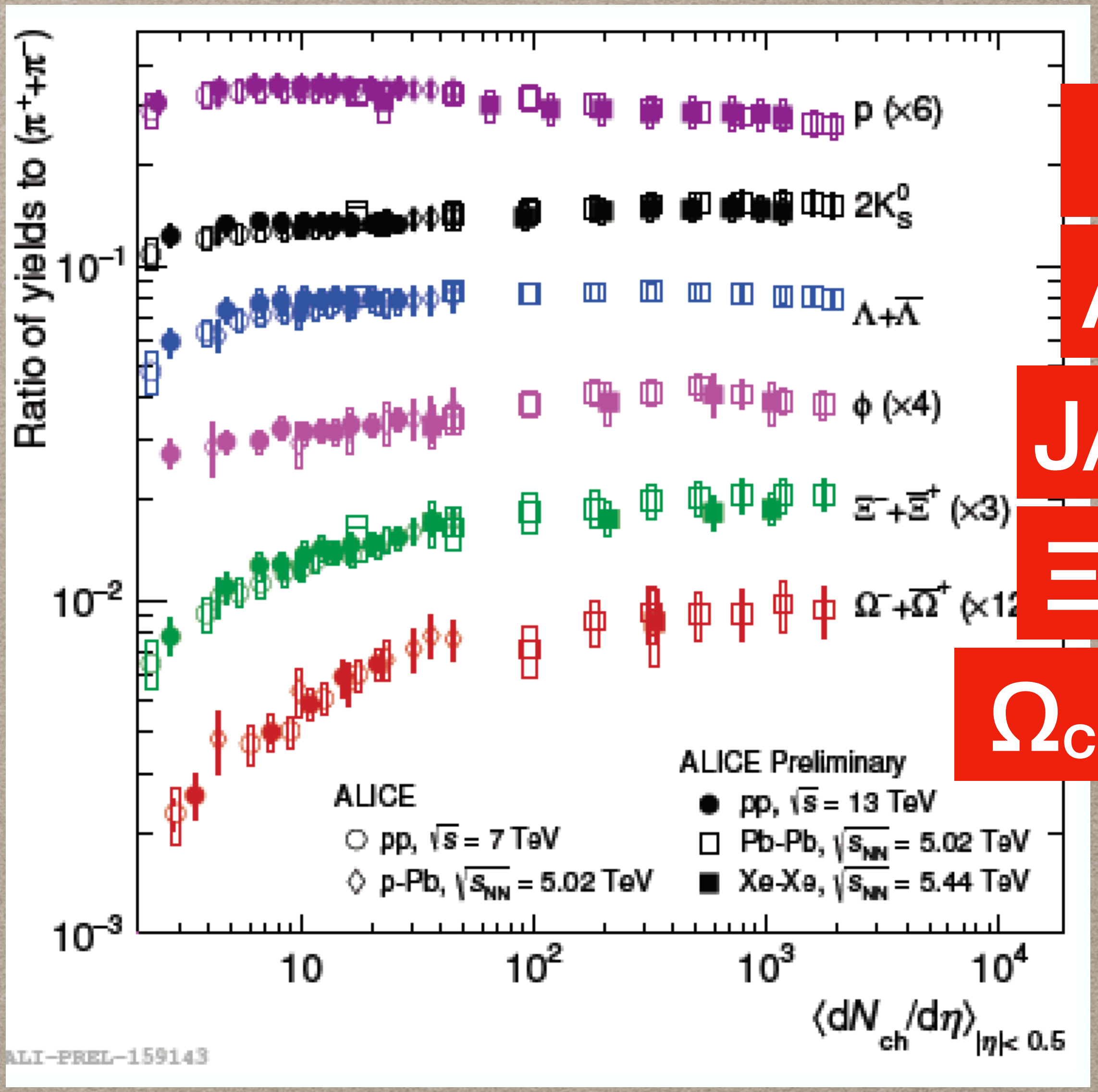
Ω_{ccc}

EXPLORING QCD PHASE III (RUN3)

2020s



Hot matter study



D

Λ_c

J/ψ

Ξ_{cc}

Ω_{ccc}

LHC RUN3: 2.4 x 10^{27}/cm^{2}s ~ 10 nb^{-1} (PbPb)

ALICE Upgrade is NOW ongoing (LS2)

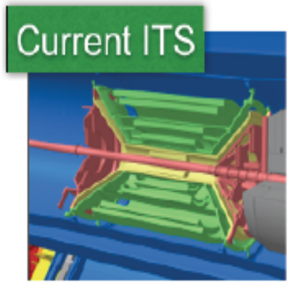
Scientific Advance is more often driven by the development of a NEW tool than a new concept

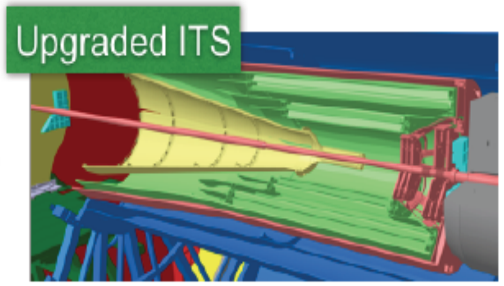
- Freeman Dyson

ITS Upgrade in LS2 (ITS2)

2020s

L. Musa@SQM2019





6 layers (39mm < r < 440mm)
$-1 \le \eta \le 1$

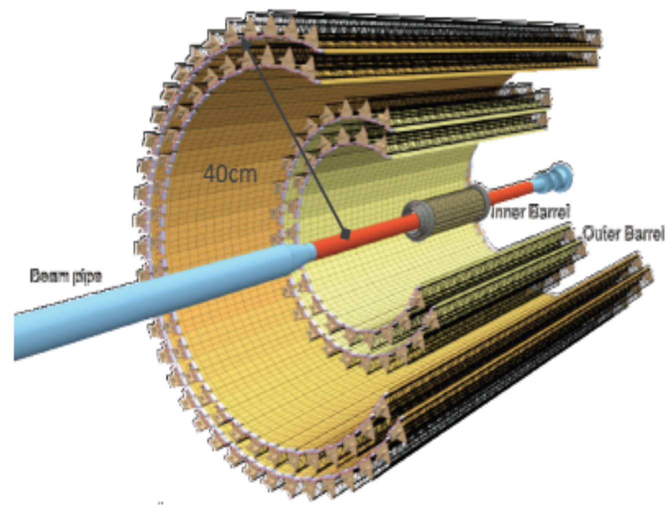
7 layers (22mm < r < 400mm)
$-1.3 \le \eta \le 1.3$

Motivations and goals

- Improved vertex and tracking precision
  - ⇨ closer to IP, smaller pixels, less material
- Faster readout

Based on novel MAPS (ALPIDE)

- 10 m^2 active silicon area (12.5 G-pixels)
- Spatial resolution ~5µm
- Power density < 40mW / cm^2
- Max particle rate ~ 100MHz /cm^2 (w/o pile-up)
- Fake hit rate: < 1Hz/cm^2
- X/X_0 (first three layers): 0.35%



⇨ further improvements exploiting technological innovations

2020s

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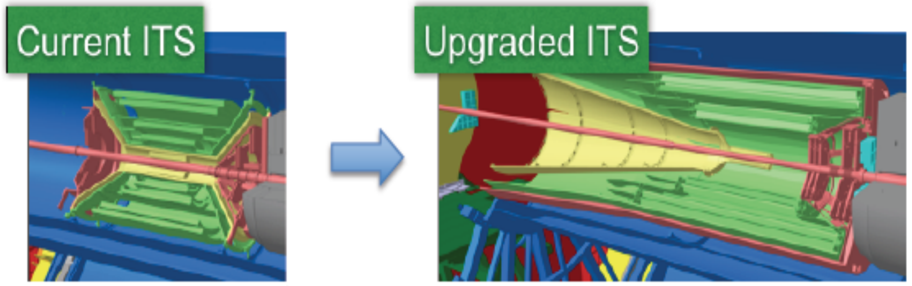
ITS Upgrade in LS2 (ITS2)



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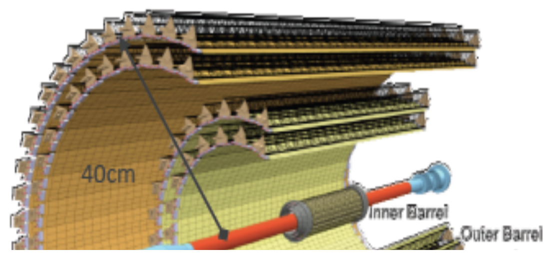
➪ furthe



TPC Continuous Readout with GEMs (Gas Electron Multiplier)

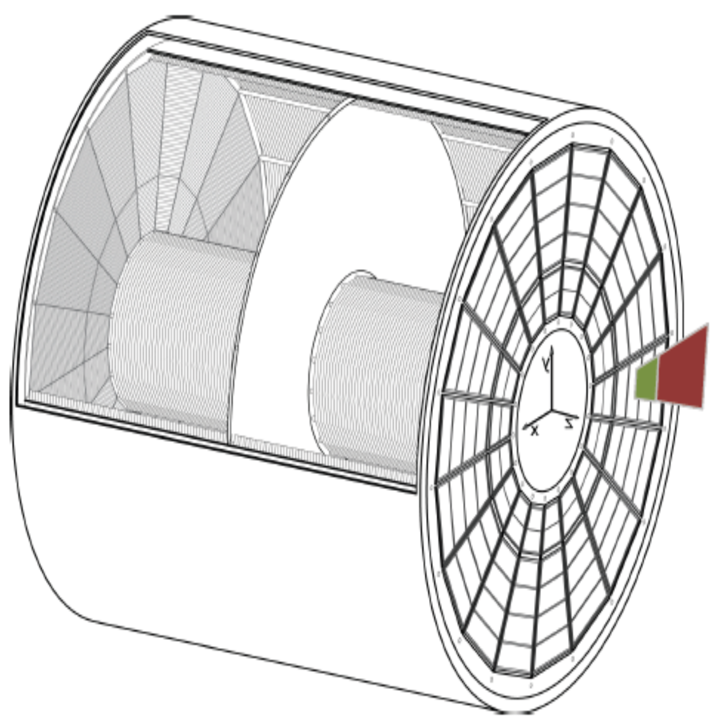
Gate-less TPC for continuous readout

Current MWPC: readout rate limited by ion backflow

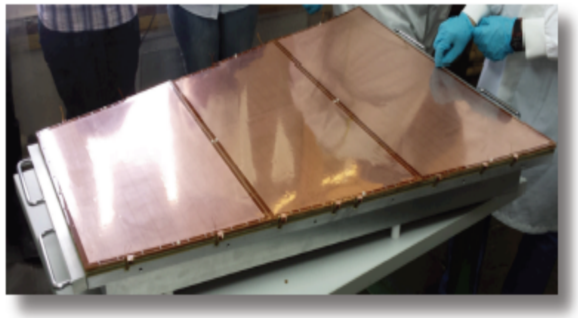
Operate TPC at 50 kHz ➪ no gating grid

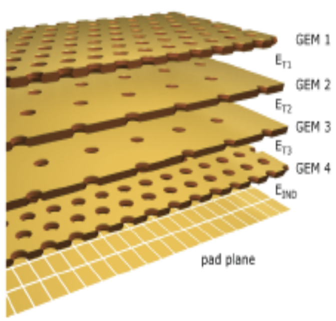
Need to minimize IBF ➪ Replace MWPC with 4-GEMs

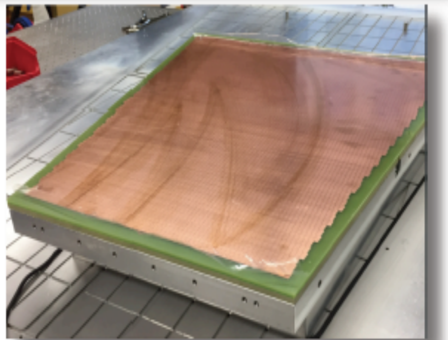
100 m^2 single-mask foils GEM production

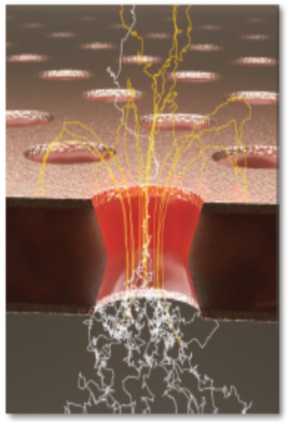


Read Out Chamber









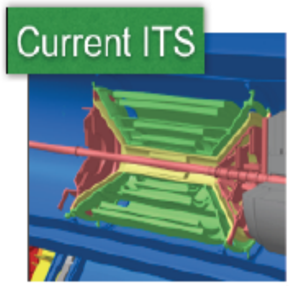
➪ GEM provides ion backflow suppression to < 1%

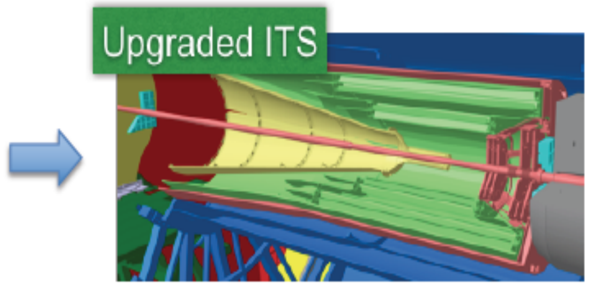
➪ 524 000 pads readout continuosly (10bit x 5MSPS) via 6552 links ➪ 3.4 TByte/sec

ITS Upgrade in LS2 (ITS2)

2020s

L. Musa@SQM2019





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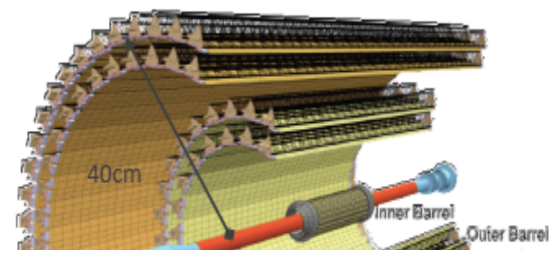

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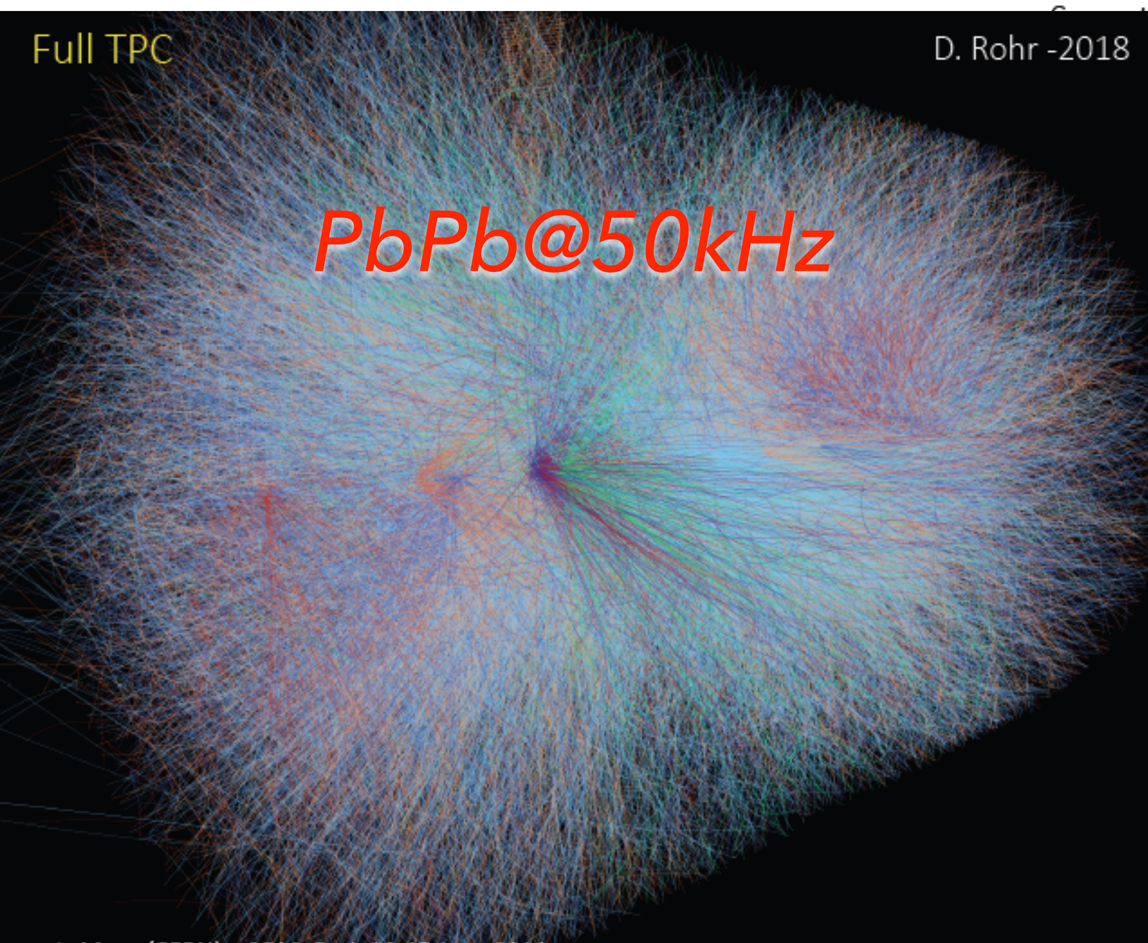

Gate-less TPC for continuous readout

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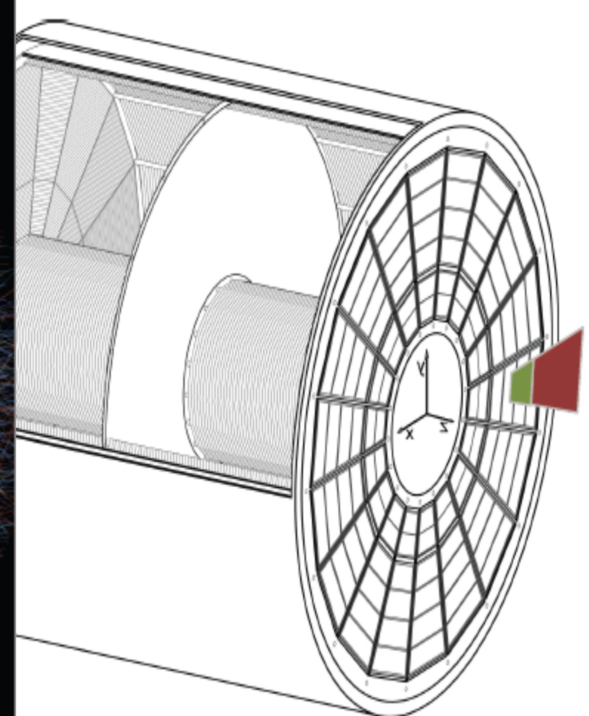

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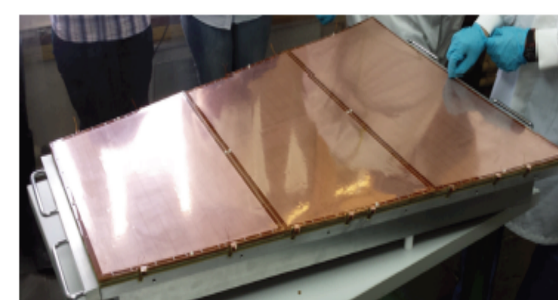
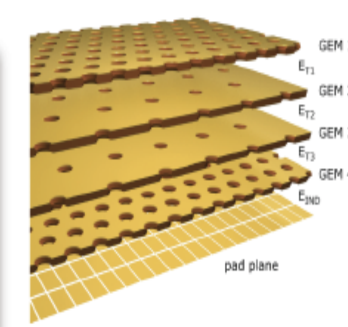
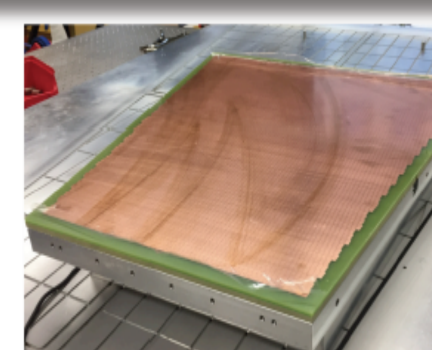
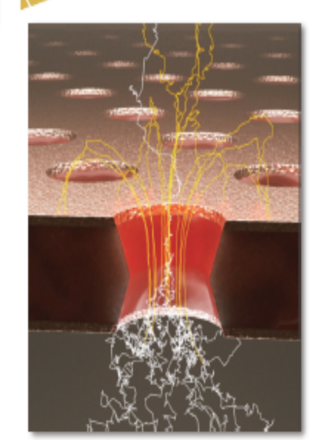








M provides ion backflow suppression to **< 1%**

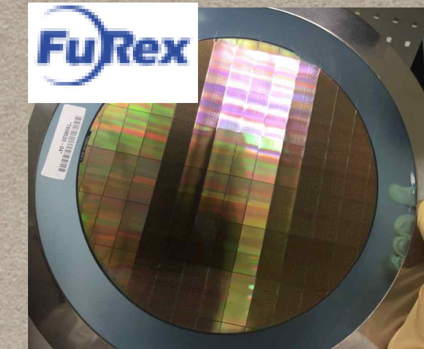
4 000 pads readout continuosly (10bit x 5MSPS) via 6552 links ➩ **3.4 TByte/sec**

KOREAN CONTRIBUTIONS (ALICE ITS2) (2012 ~ ...)

Mass Chip Test

Facilitie

Pusan & Yonsei, Korea



65k (all) chip tests completed

- 10 000 class of Cleanliness
- Temperature, Humidity under control.
  - with realtime monitoring
- Mass Chip Test, HIC Assembl

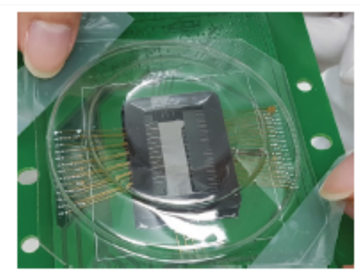
- ALICIA made by IBS, Netherlands
- Customized machine for this project
- Measuring position, placing chip with

Mass Chip Test

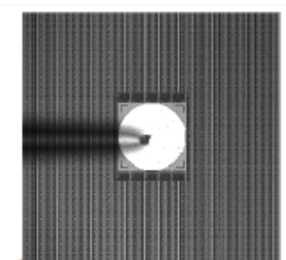
- Dimension Inspection
- Electrical Test
- Total Test time: ~5min/chip

- PNU/Inha participated mainly at MAR2017 — May 2018

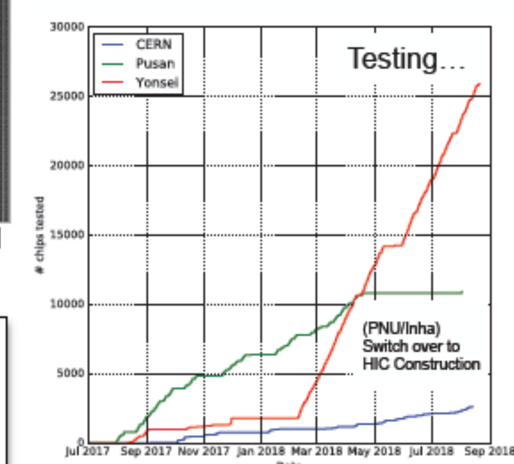
Probecard



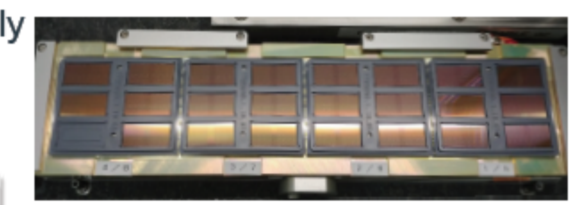
Needles of Probecard
67 needles to contact



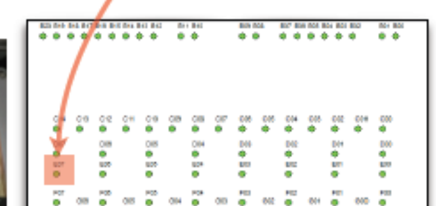
Needle on pad



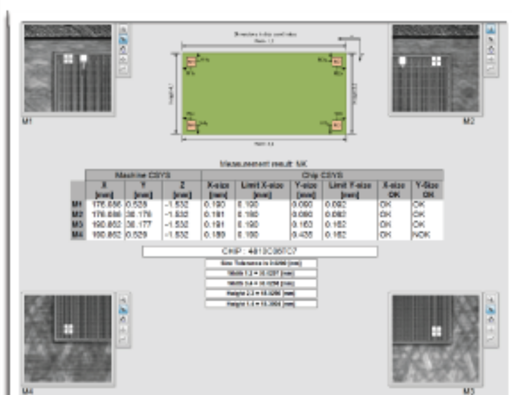
Accumulated number of tested chips
M.Mager (CERN) / 27AUG2018 / ITS Plenary



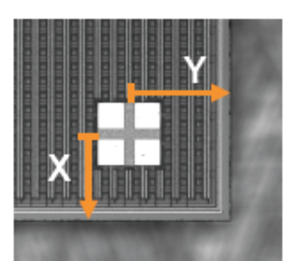
23 of ALPIDE Chips in Tray



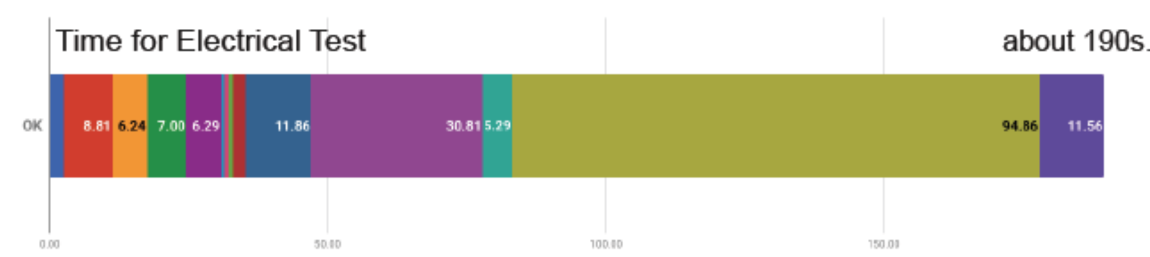
Pads on ALPIDE



Dimension Inspection



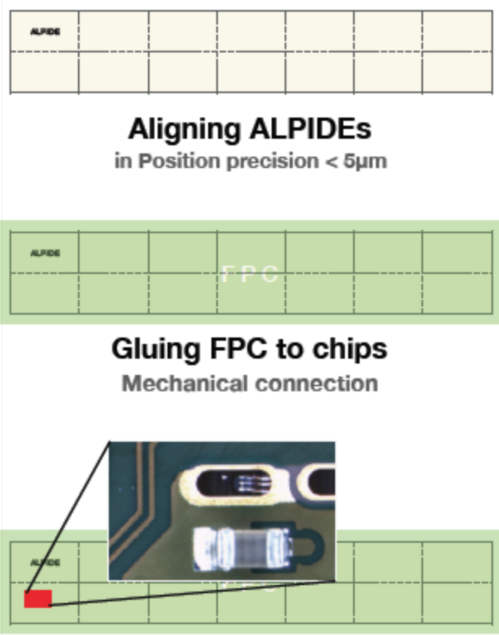
Measuring Dimensions



B.Lim (PNU) / 26JUN2017 / 9th ALICE ITS upgrade, MFT and O2 Asian Workshop

KOREAN CONTRIBUTIONS (ALICE ITS2) (2012 ~ ...)

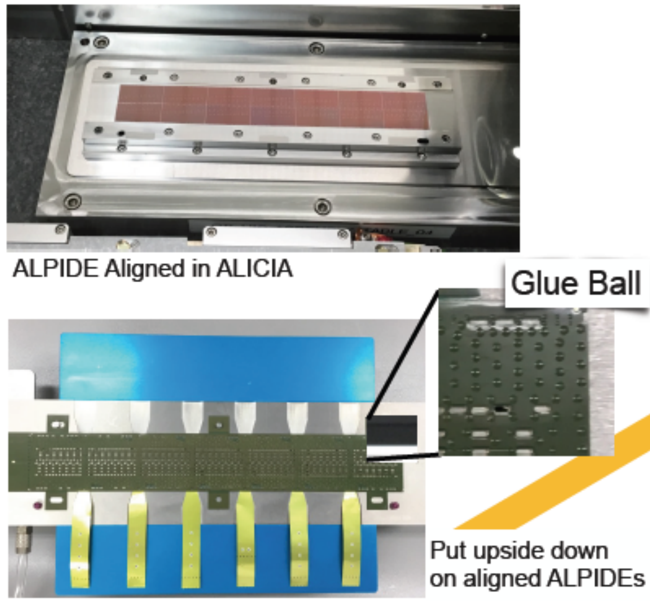
HIC Production
Construction of the elements

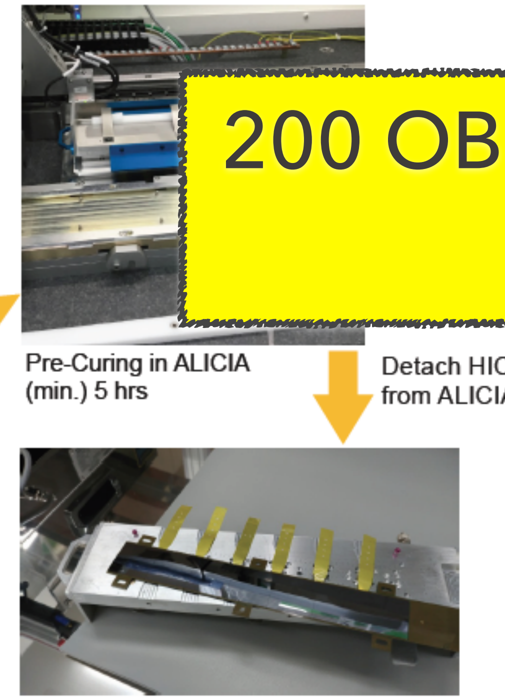


Aligning ALPIDEs
in Position precision < 5μm

Gluing FPC to chips
Mechanical connection

Wire-bonding
Electrical connection

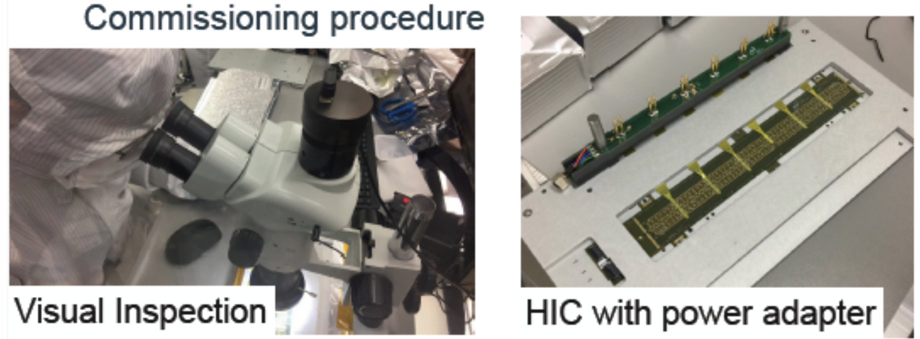




In Pusan/Inha Team, wire-bonding is being done by out-sourcing company MEMSPACK

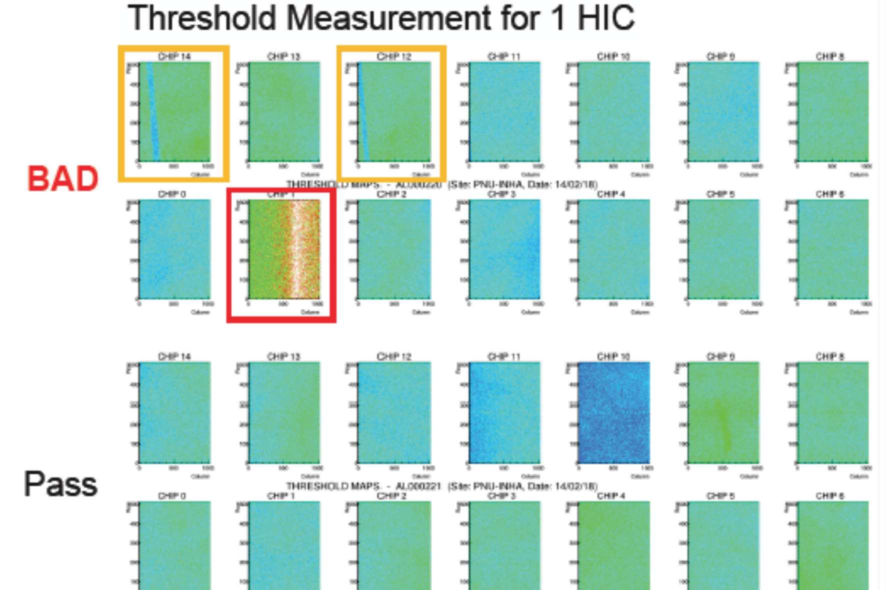
200 OB HIC production + tests completed

HIC Production
Commissioning procedure



- Visual Inspection
  - Confirm bonding quality with microscope
- Impedance Test
  - IV Scan
- Qualification Test
  - Classifying the HIC (Powering, FIFO, Digital Scan, Threshold Scan)
- Endurance Test
  - Long time running test (~ 3.5days)

Threshold Measurement for 1 HIC



KOREAN CONTRIBUTIONS (ALICE ITS2) (2012 ~ …)

200 OB HIC production + tests completed

Final assembly & Commissioning is NOW ongoing at CERN

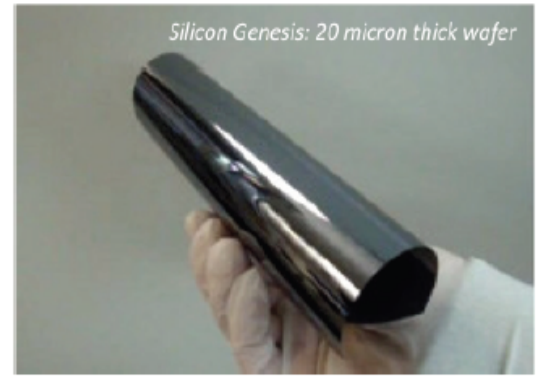
Vertex Detector (innermost 3 layers)

2030s

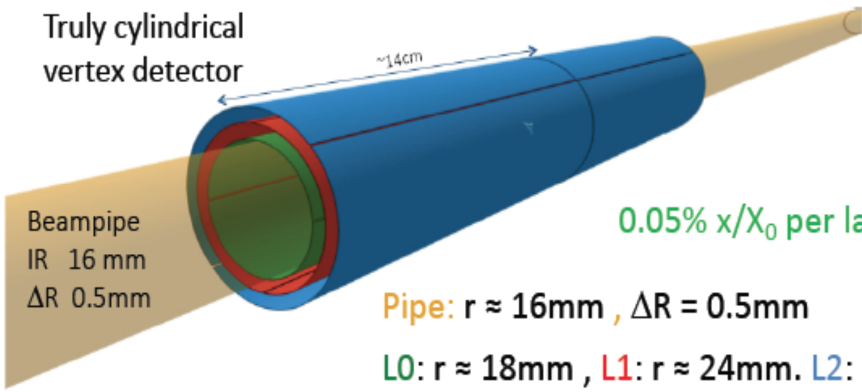
EoI for new ultra-light Inner Barrel in LS3 (CDS, ALICE-PUBLIC-2018-013)

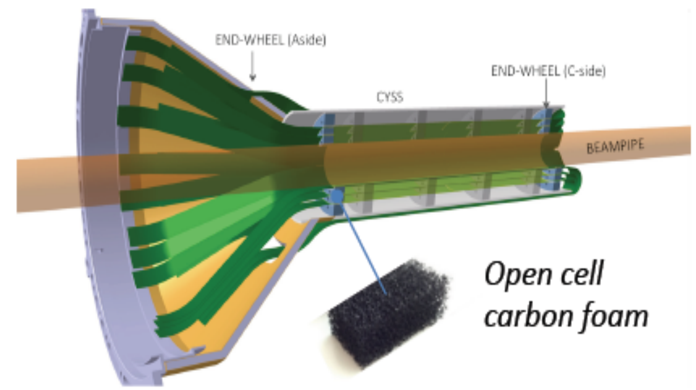
Recent silicon technologies (ultra-thin wafer-scale sensors) allow

- Eliminate active cooling ⇨ possible for power < $20 mW/cm^2$
- Eliminate electrical substrate ⇨ Possible if sensor covers the full stave length
- Sensors arranged with a perfectly cylindrical shape ⇨ sensors thinned to ~30μm can be curved to a radius of 10-20mm



ideal ITS (LS3)





A new experiment based on a "all-silicon" detector

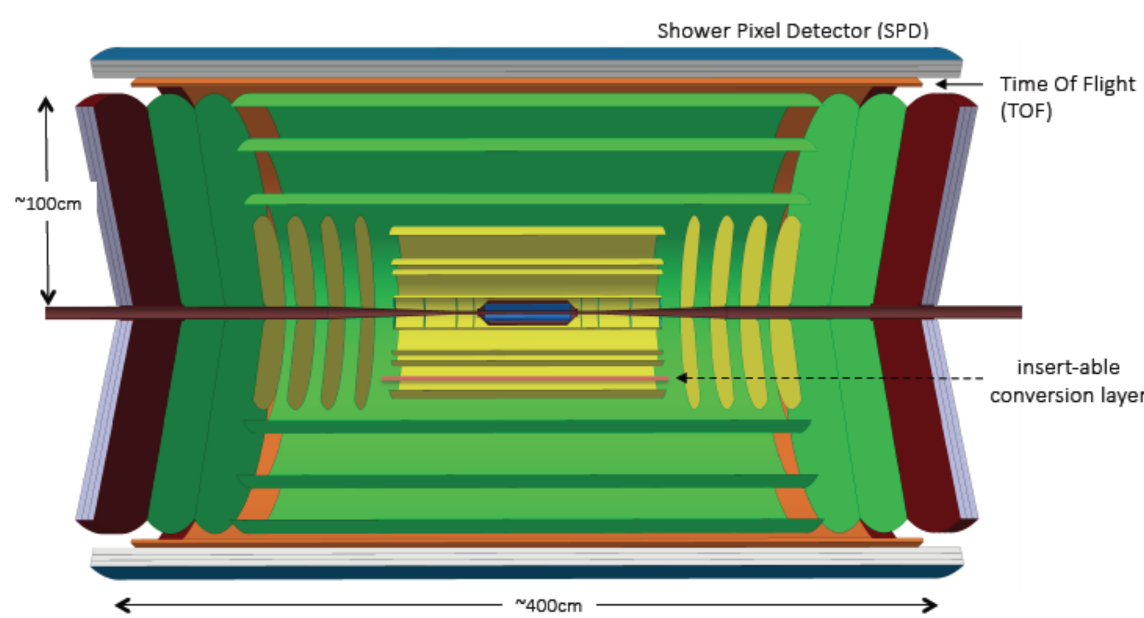
All-Silicon ALICE (LS4)

Tracker: ~10 tracking barrel layers (blue, yellow and green) based on CMOS sensors

Particle ID:

- TOF with outer silicon layers (orange)
- Shower Pixel Detector (outermost blue layer)

Extended rapidity coverage: up to 8 rapidity units



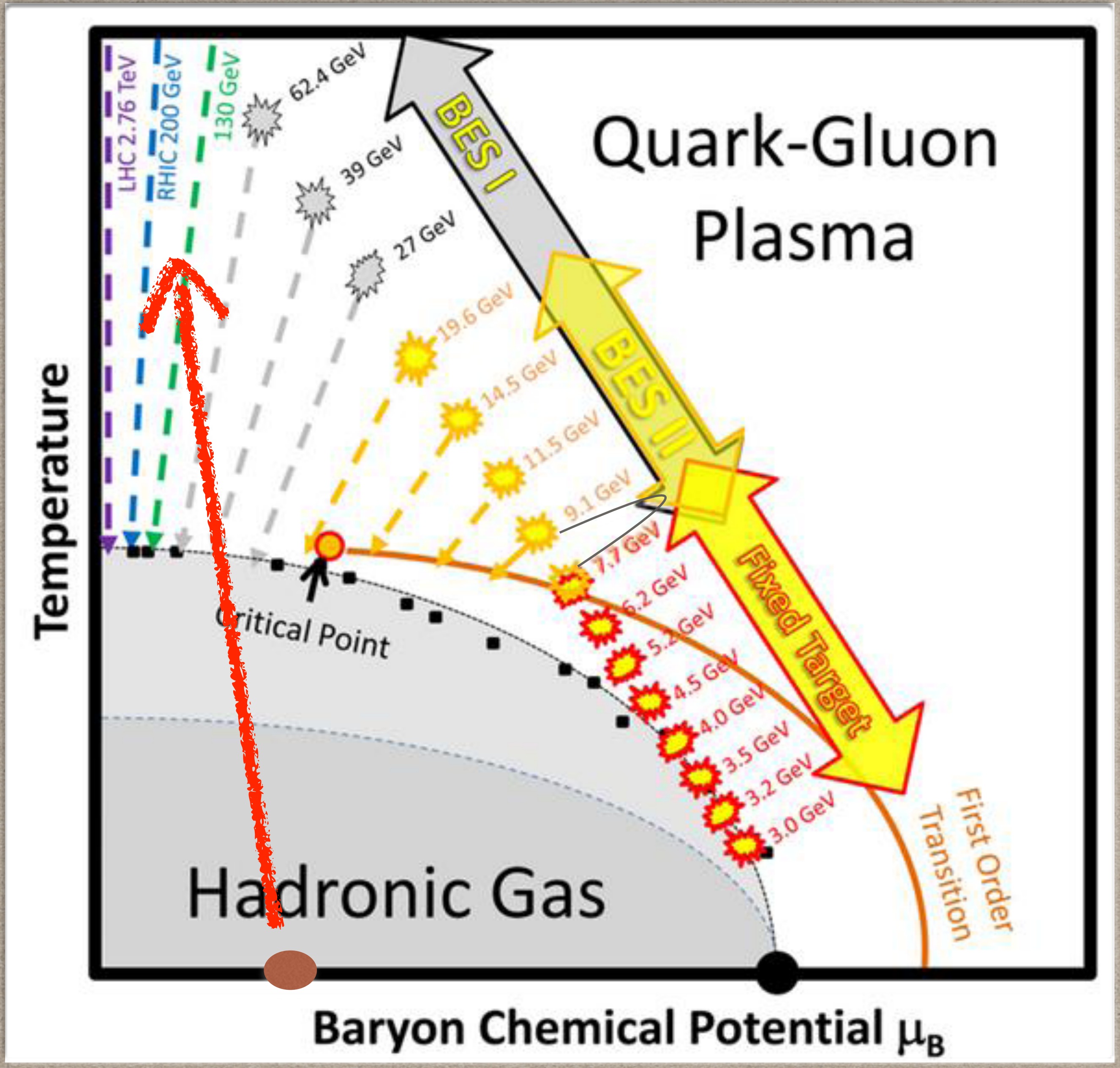
Magnetic Field
- B = 0.5 or 1 T

Spatial resolution
- Innermost 3 layers: $\sigma < 3\mu m$
- Outer layers: $\sigma \sim 5\mu m$

Vertex material thickness
- X/X0 ~ 0.05% / layer

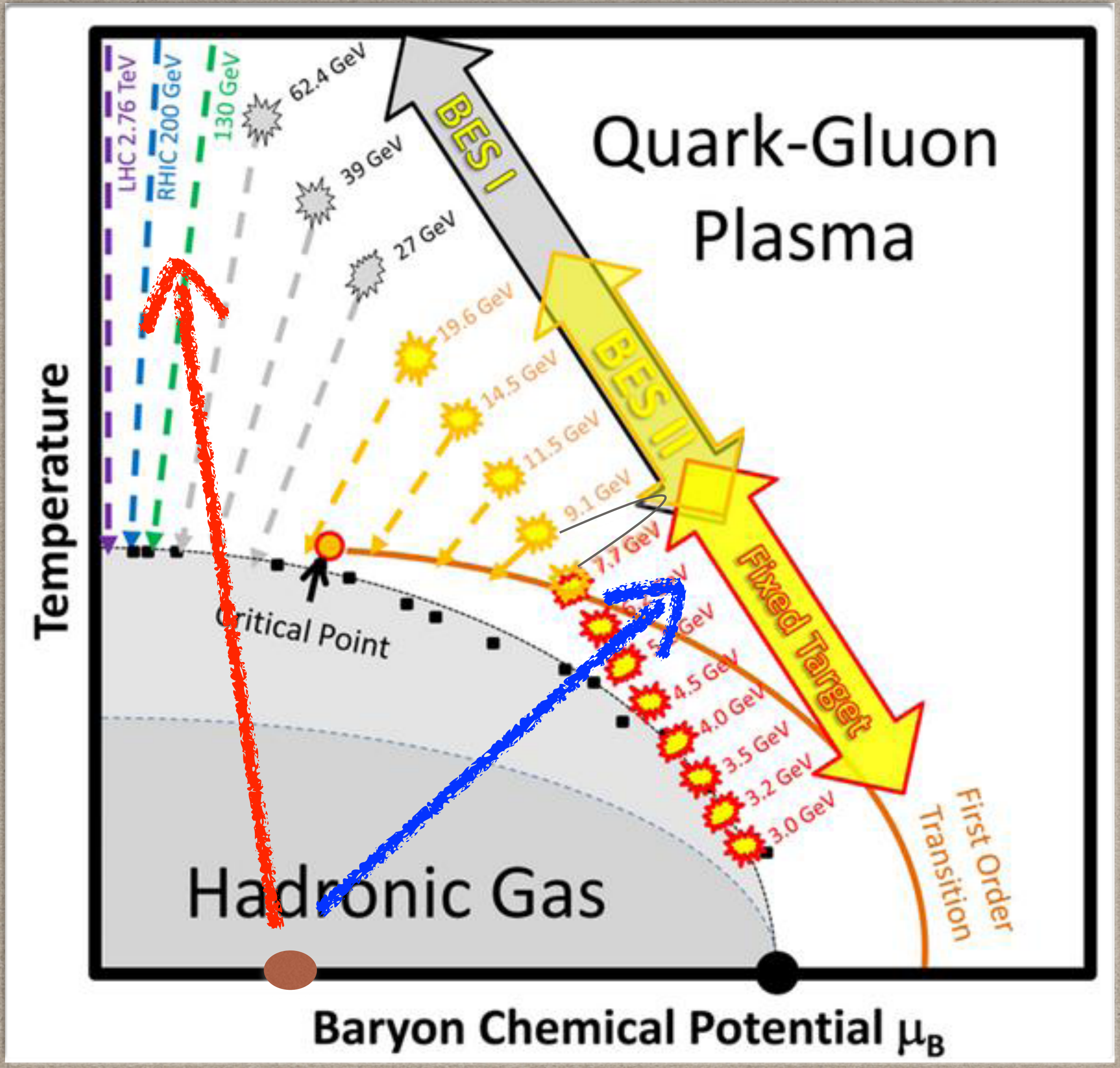
Time Measurement
Outermost layer integrates high precision time measurement ($\sigma_t \sim 20ps$)

EXPLORING QCD PHASE IV (BES)



EXPLORING QCD PHASE IV (BES)

2010s



2010s

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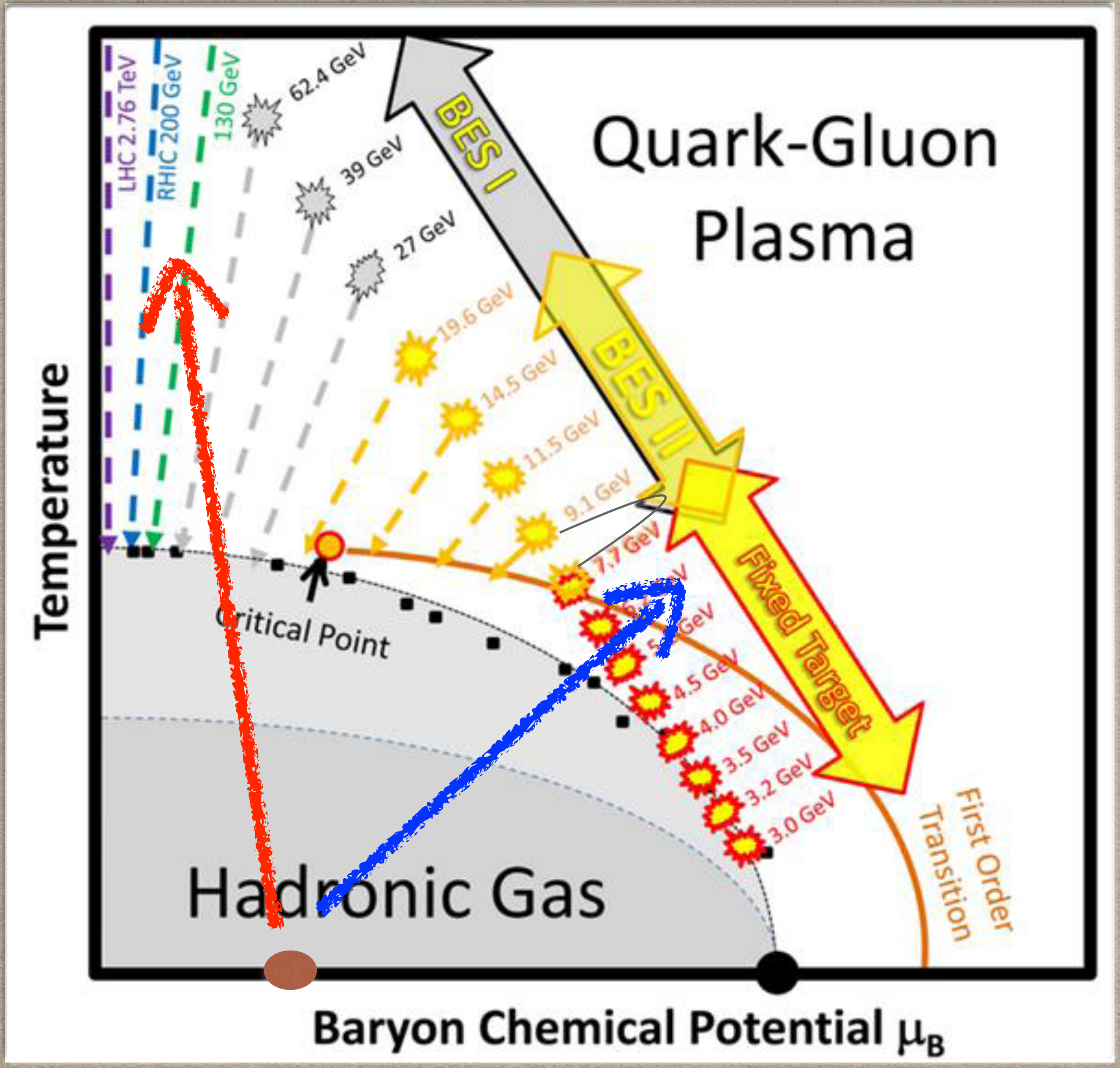

Critical Point Search
(1st order phase transition)

2010s

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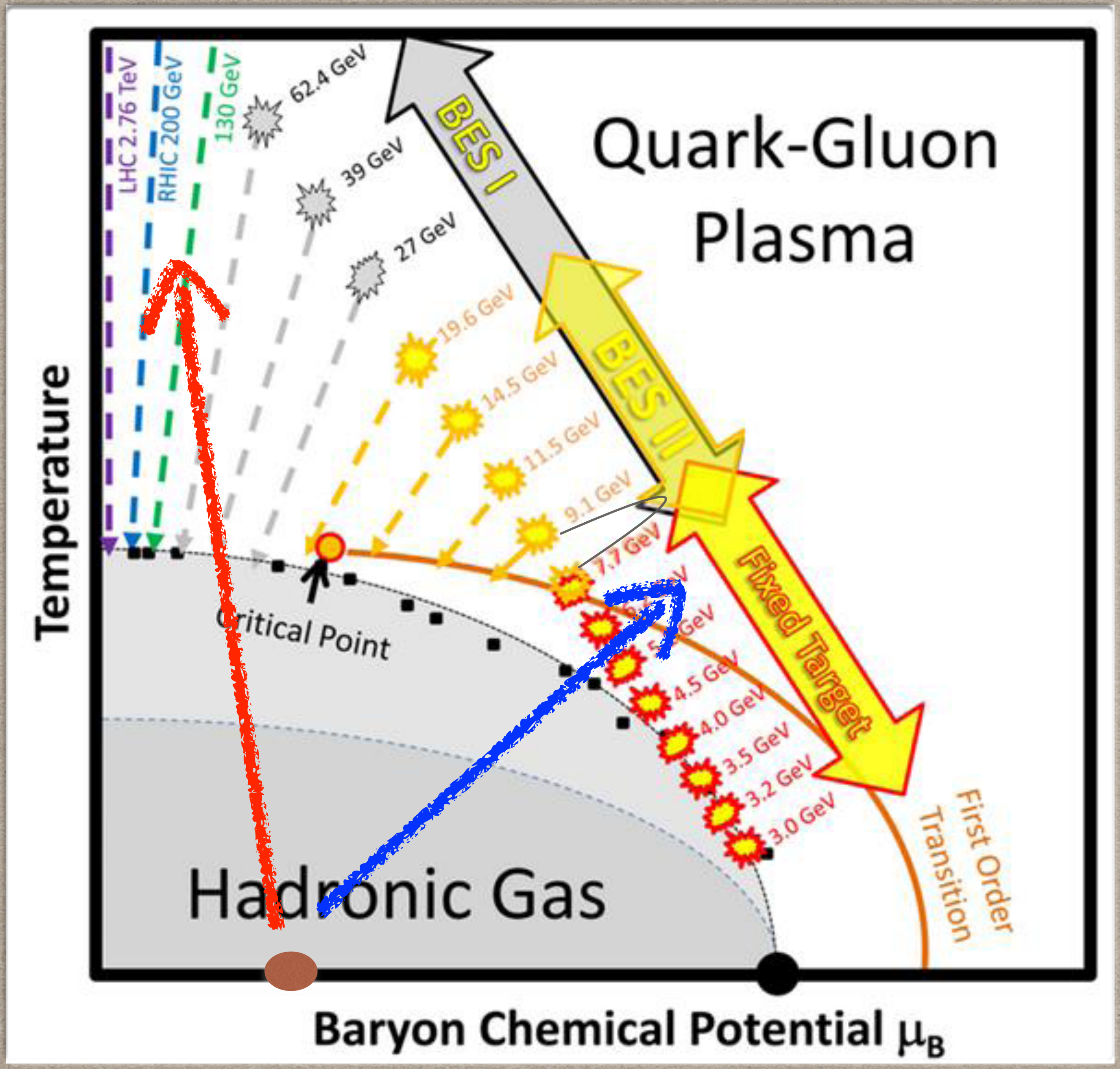

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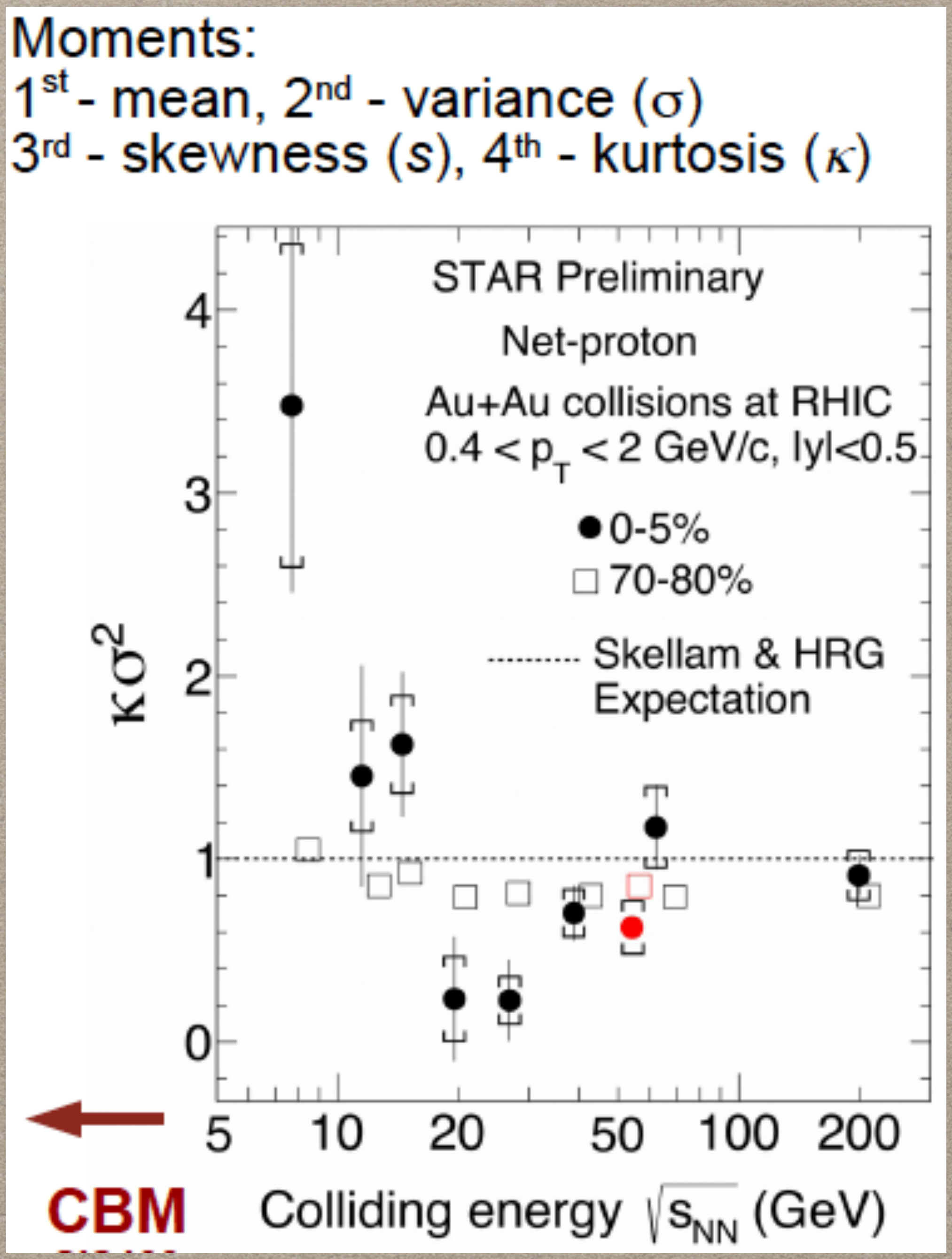

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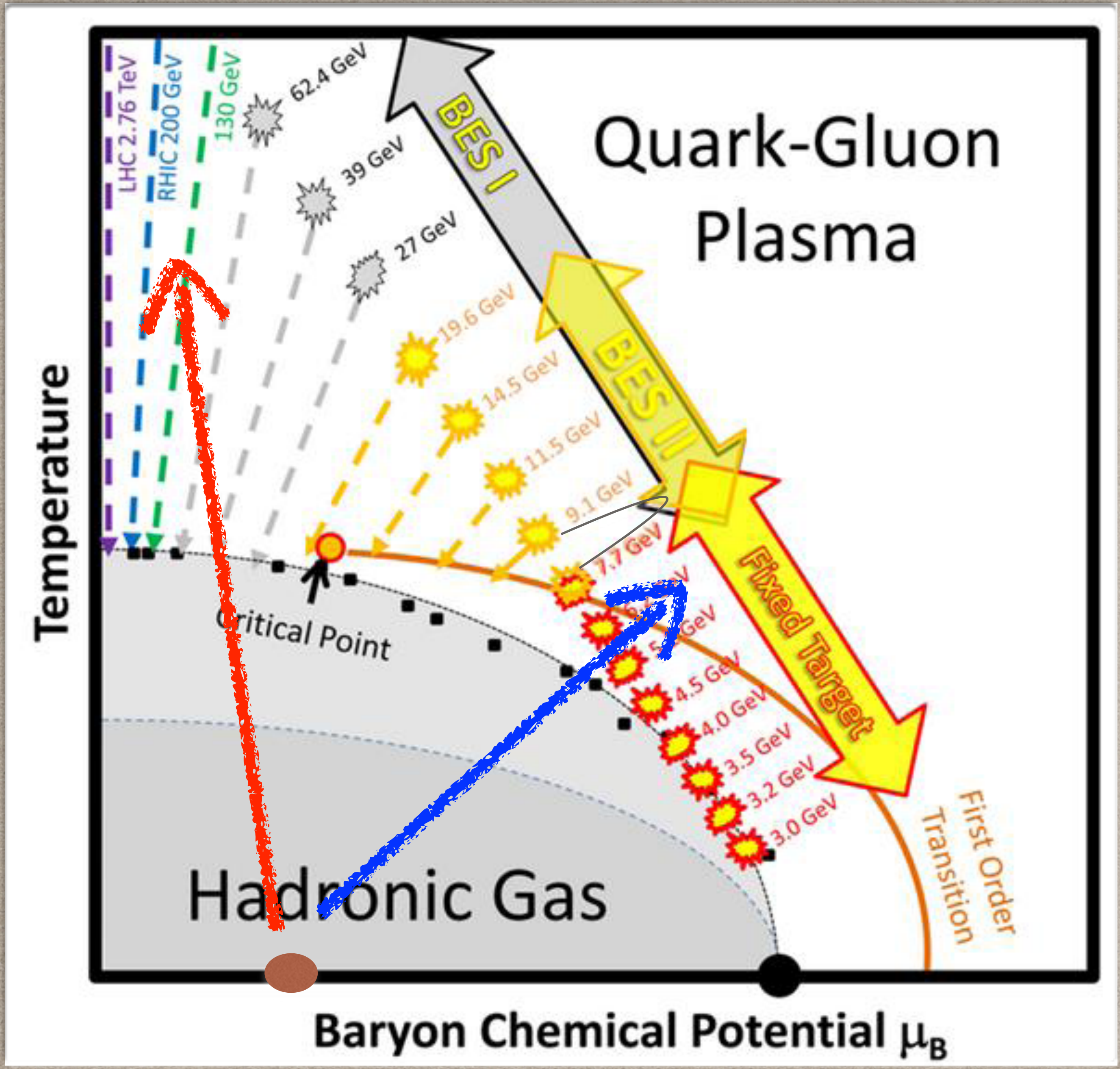

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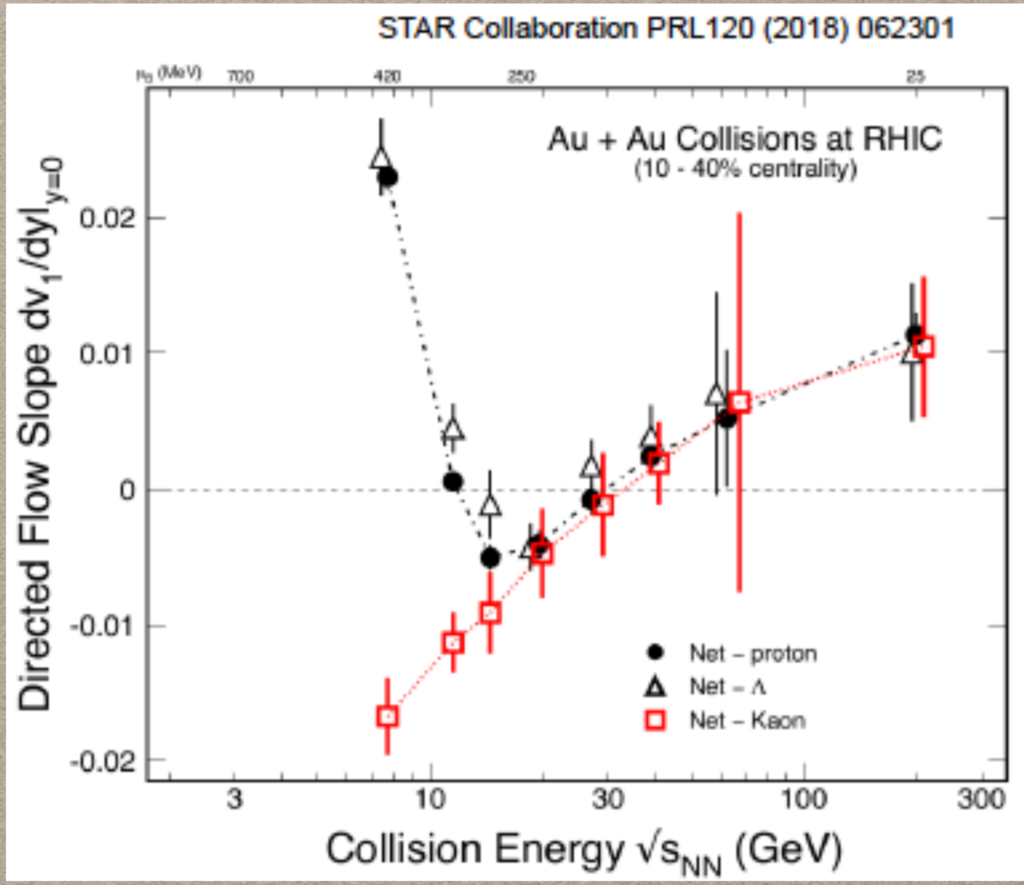

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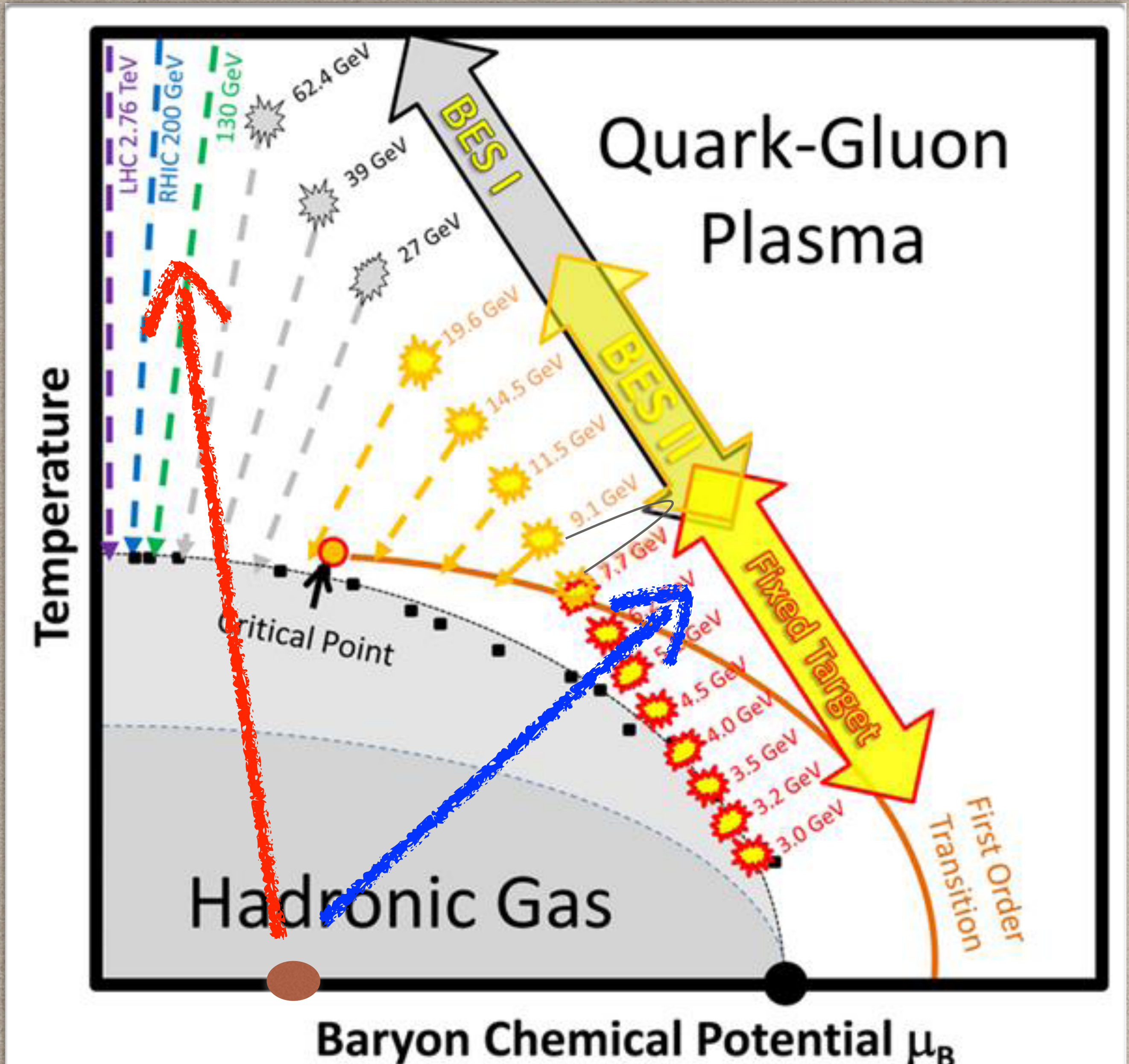

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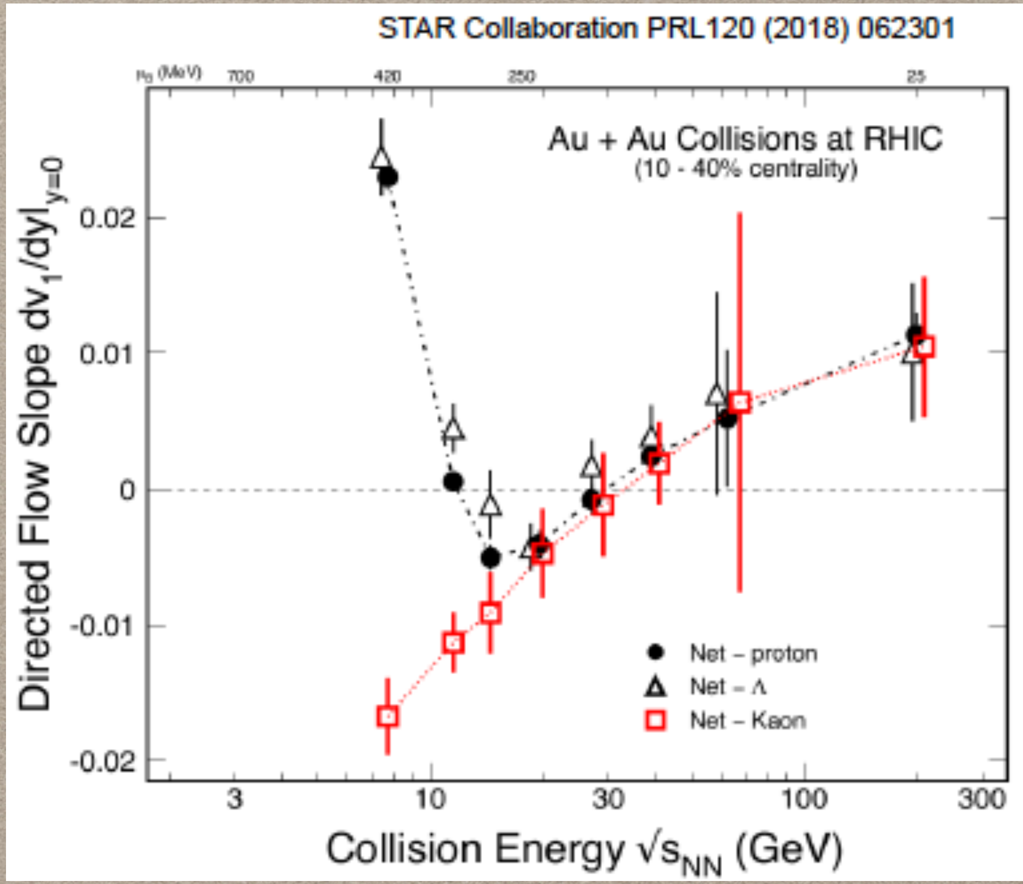
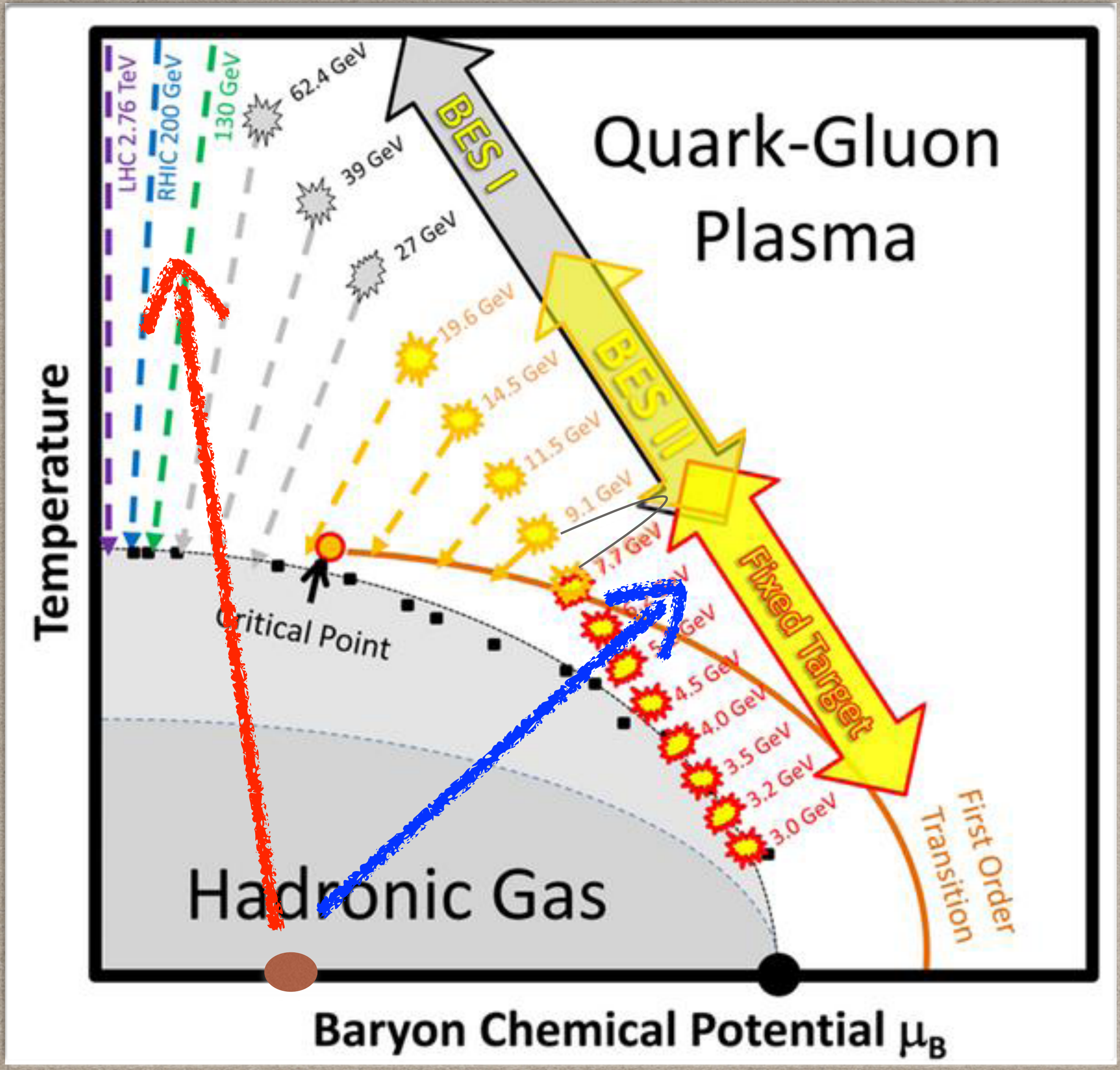


critical region of $\sqrt{s_{NN}}$ ~ 5 - 30 GeV

2030s

EXPLORING QCD PHASE V (FUTURE)



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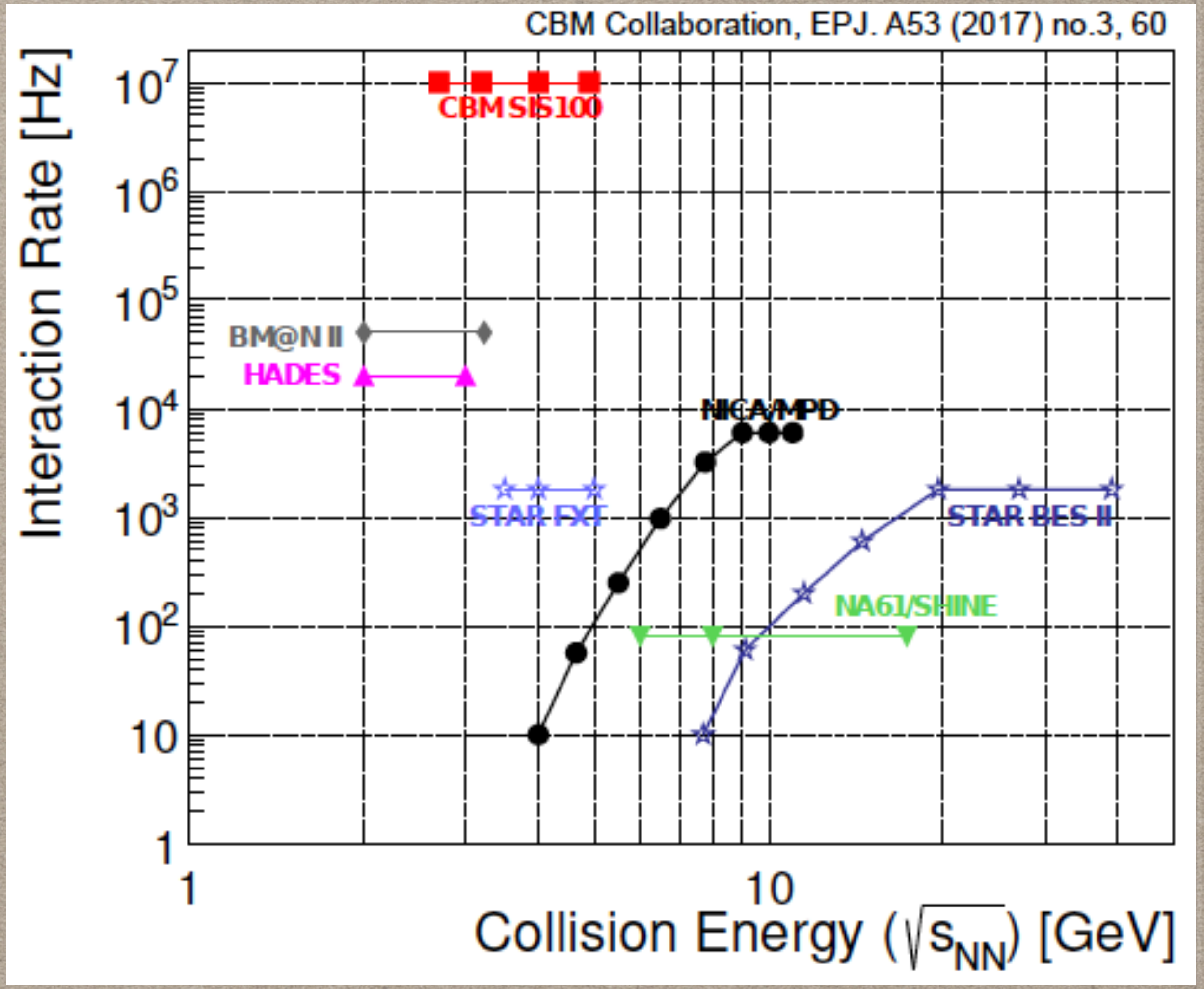

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2030s

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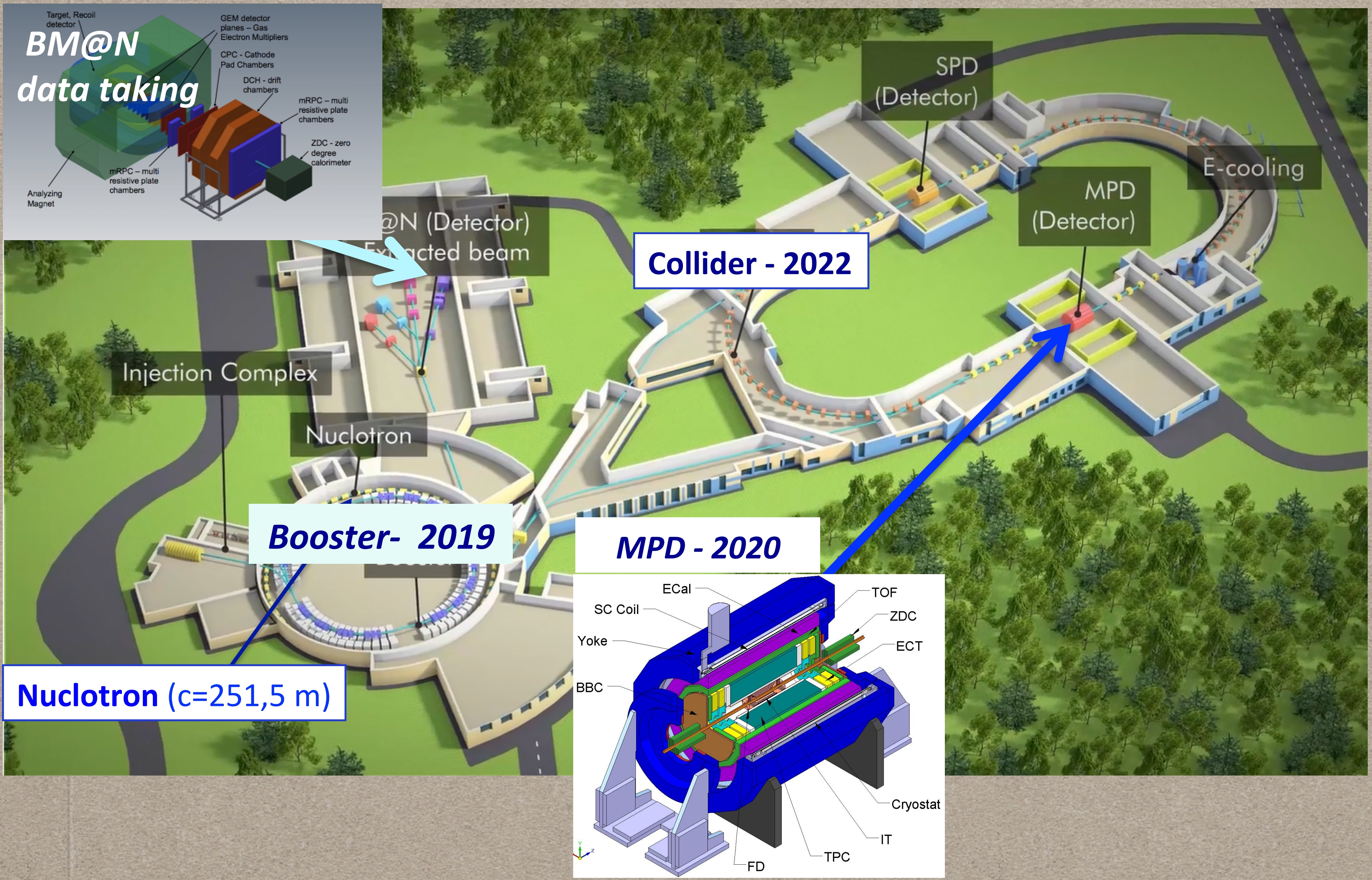

Critical Point Search
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2030s

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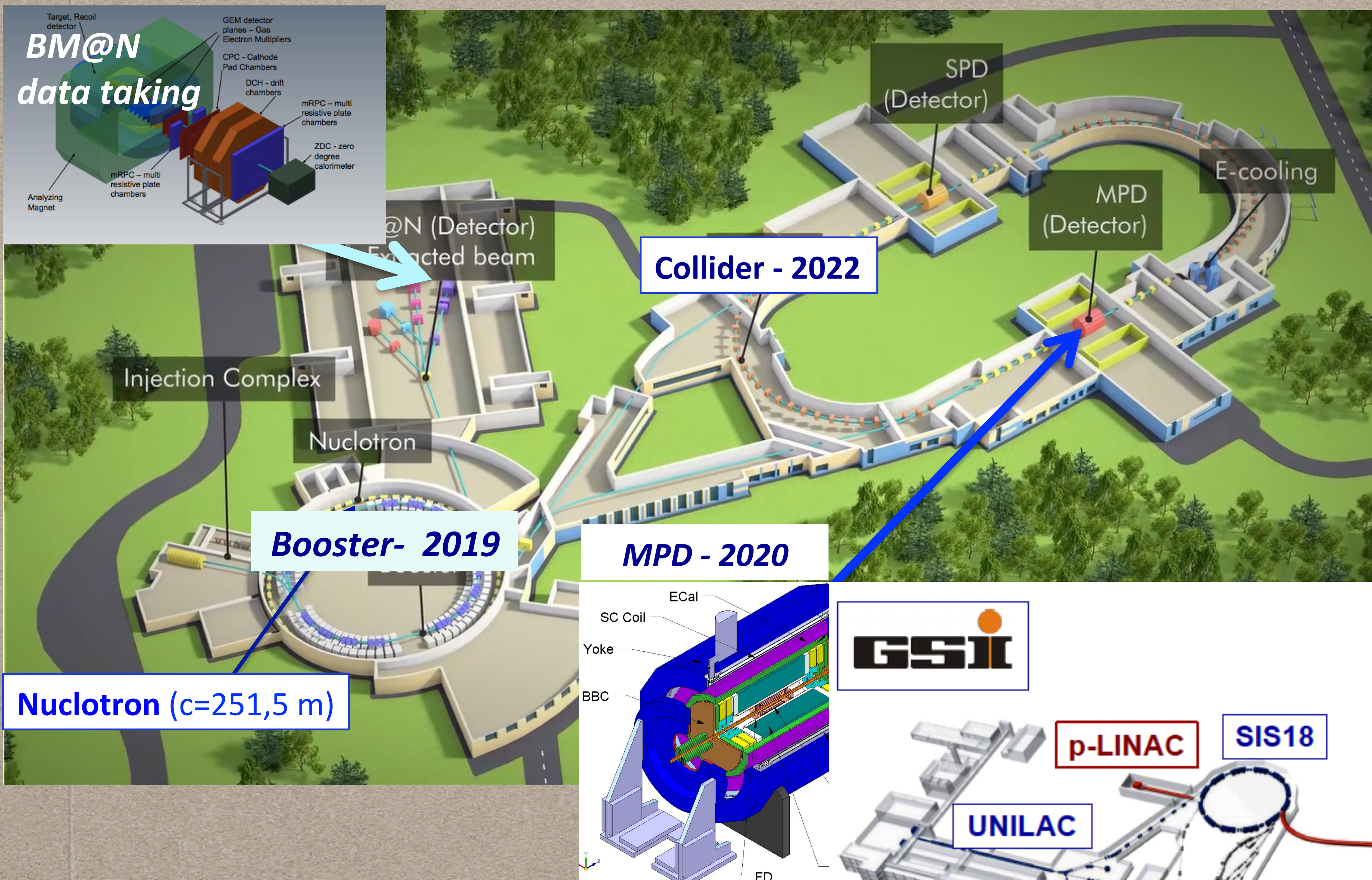

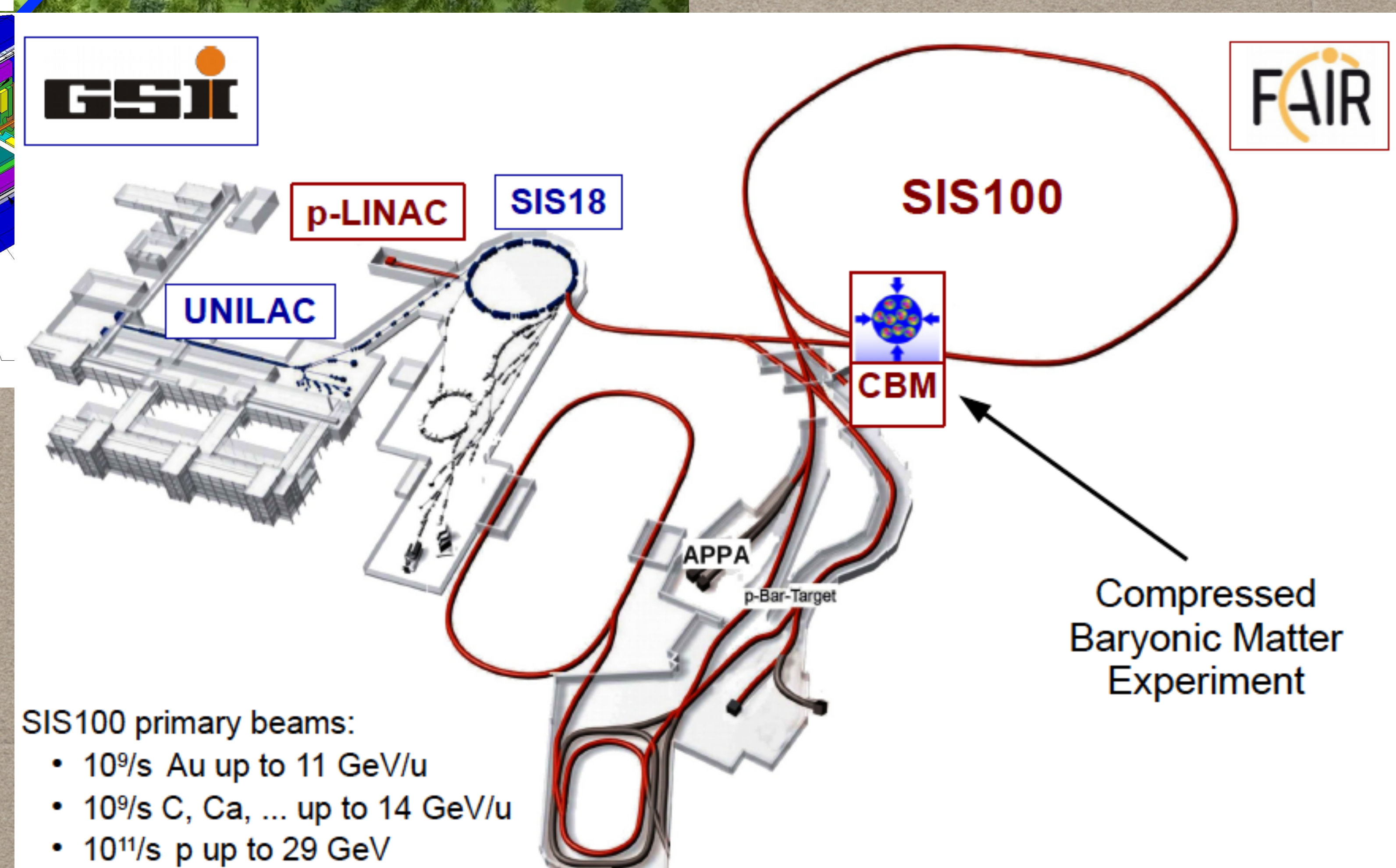

Critical Point Search
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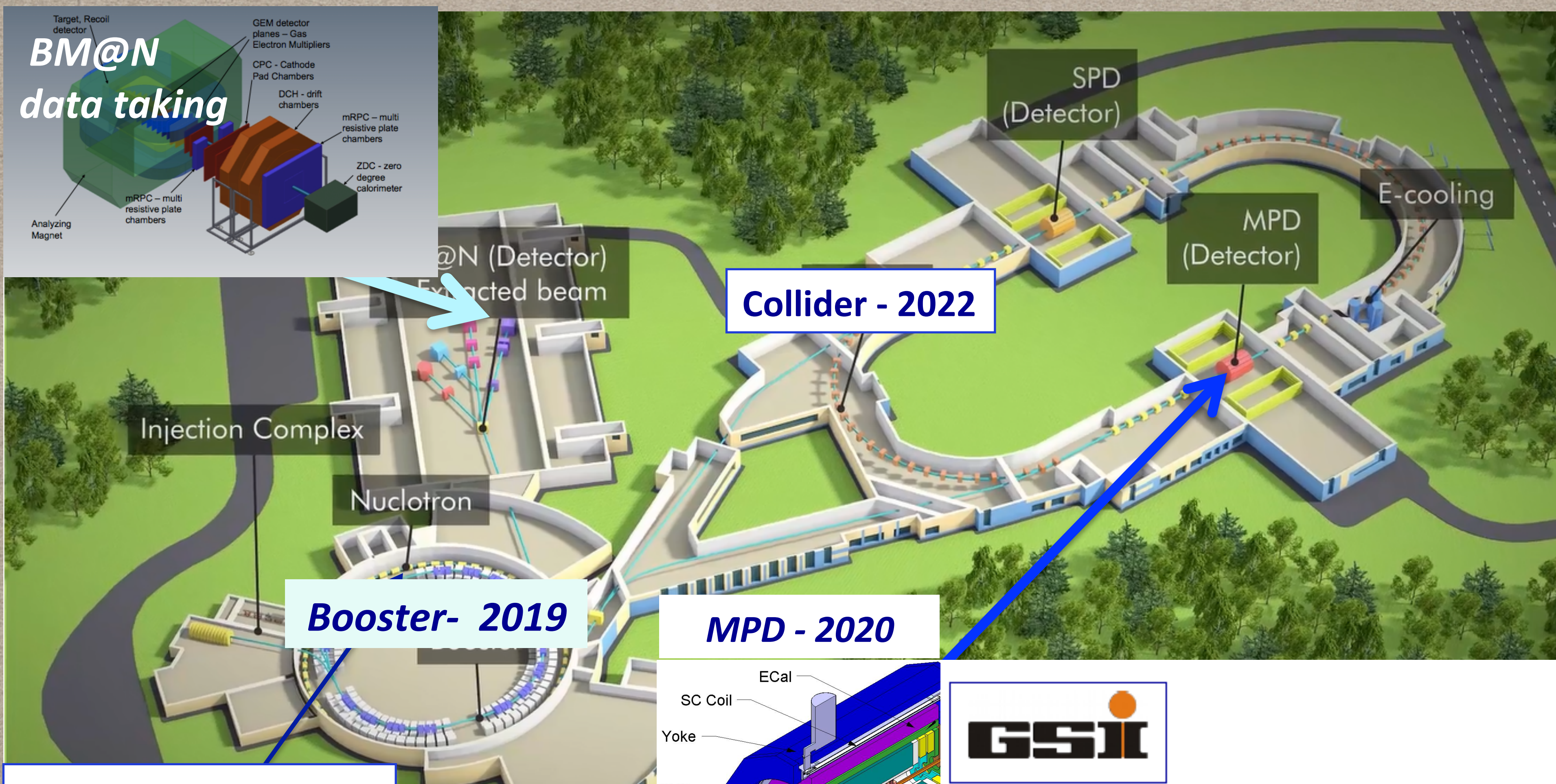
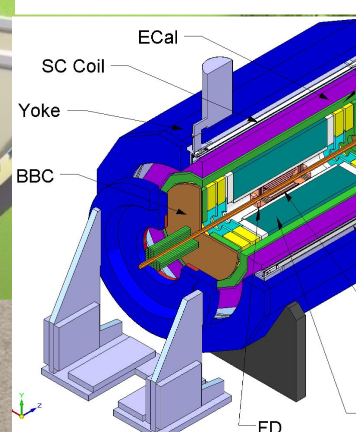
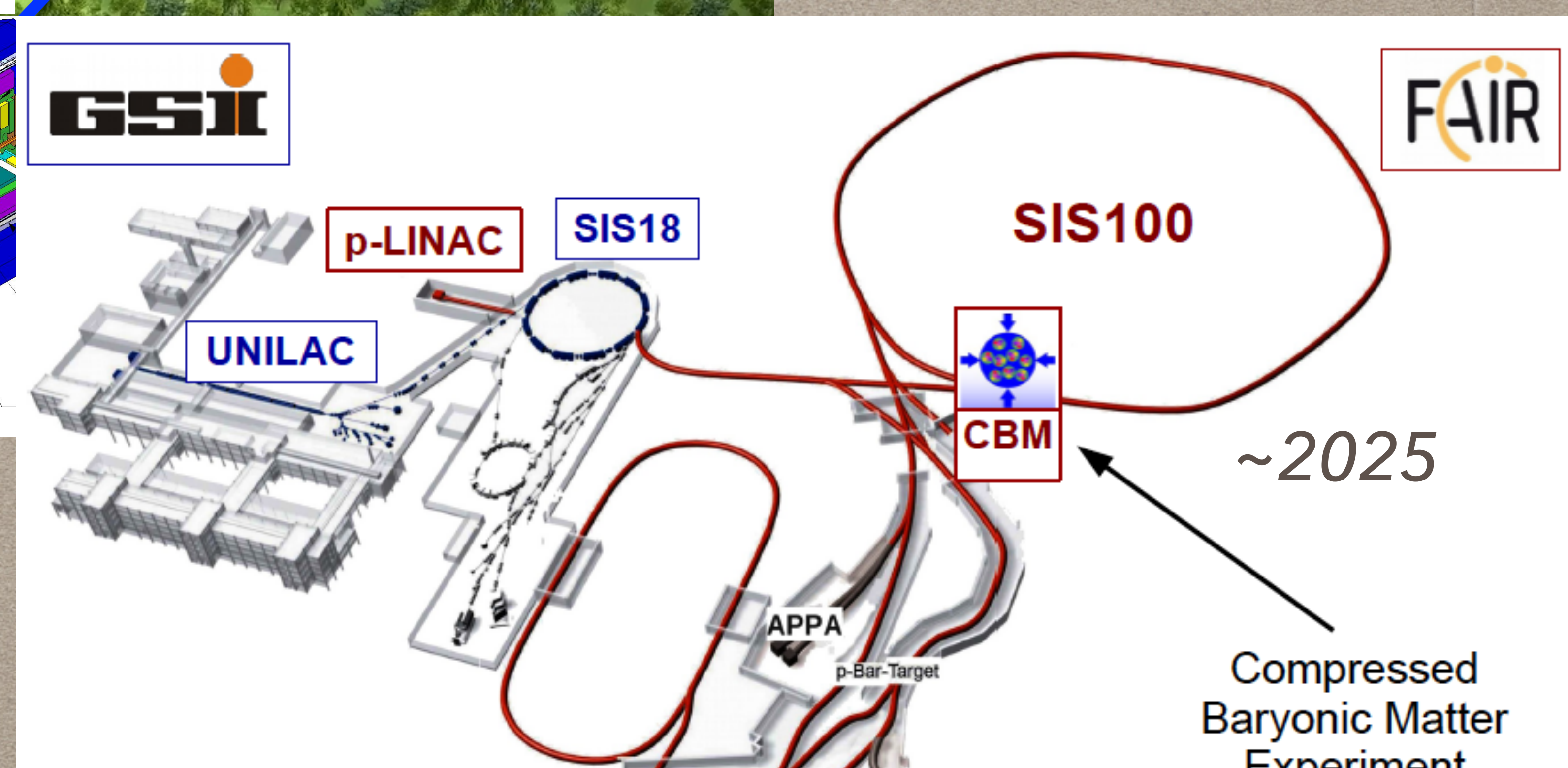


MPD - 2020





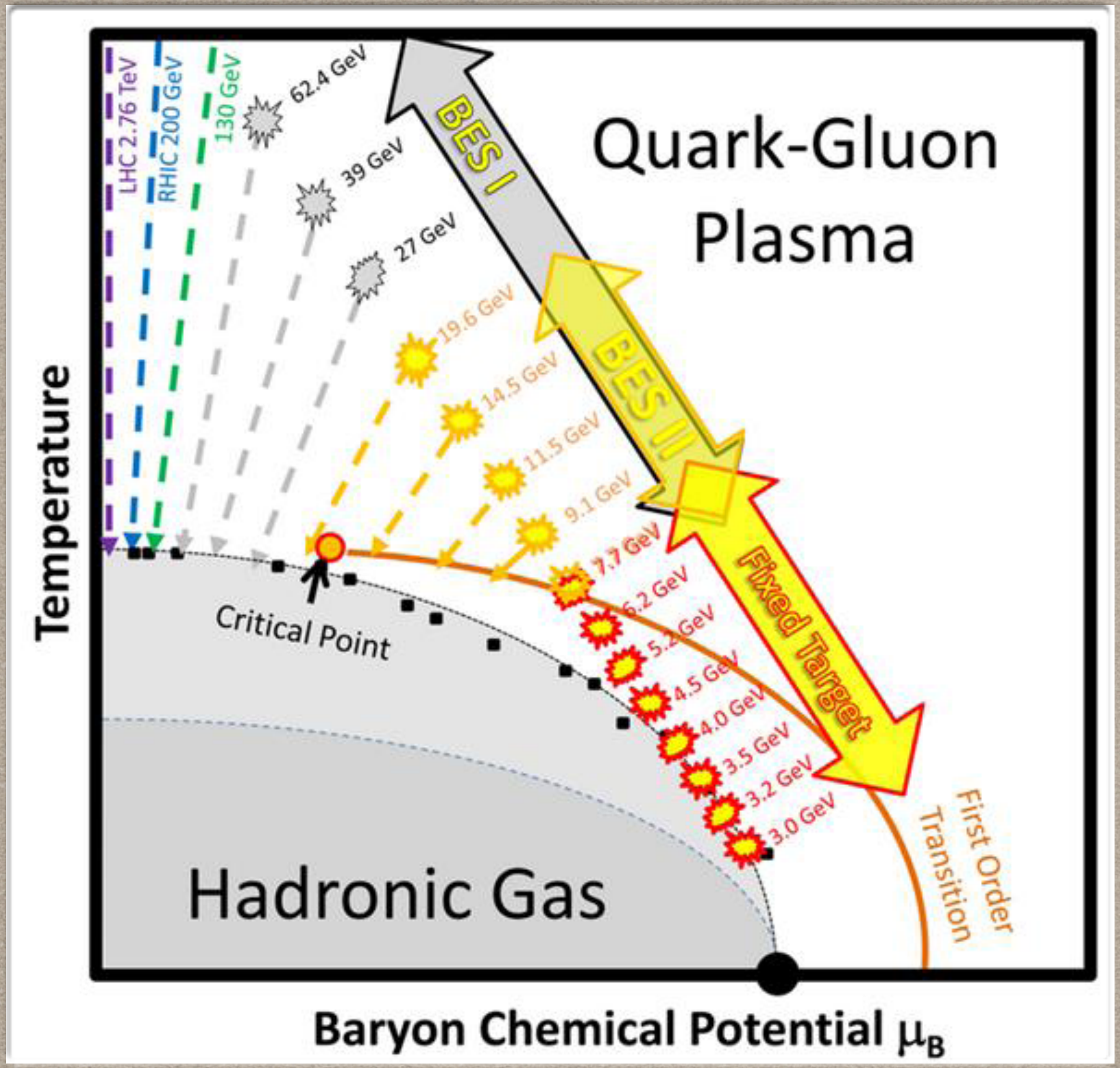
SIS100 primary beams:

- 10^9/s Au up to 11 GeV/u
- 10^9/s C, Ca, ... up to 14 GeV/u
- 10^{11}/s p up to 29 GeV

Critical Point Search
(1st order phase transition)

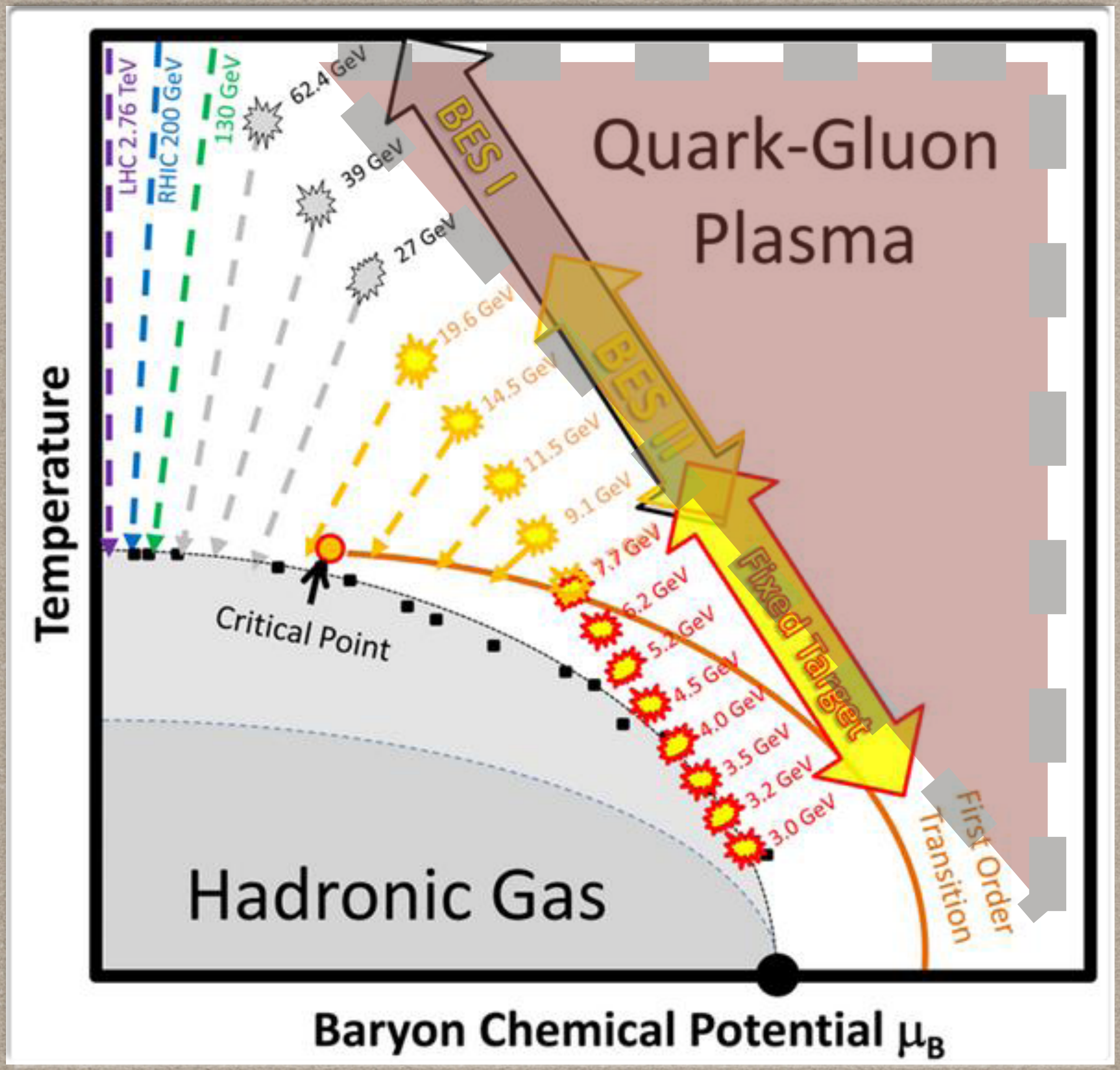
2030s

EXPLORING QCD PHASE-PROJECT X



2030s

EXPLORING QCD PHASE-PROJECT X



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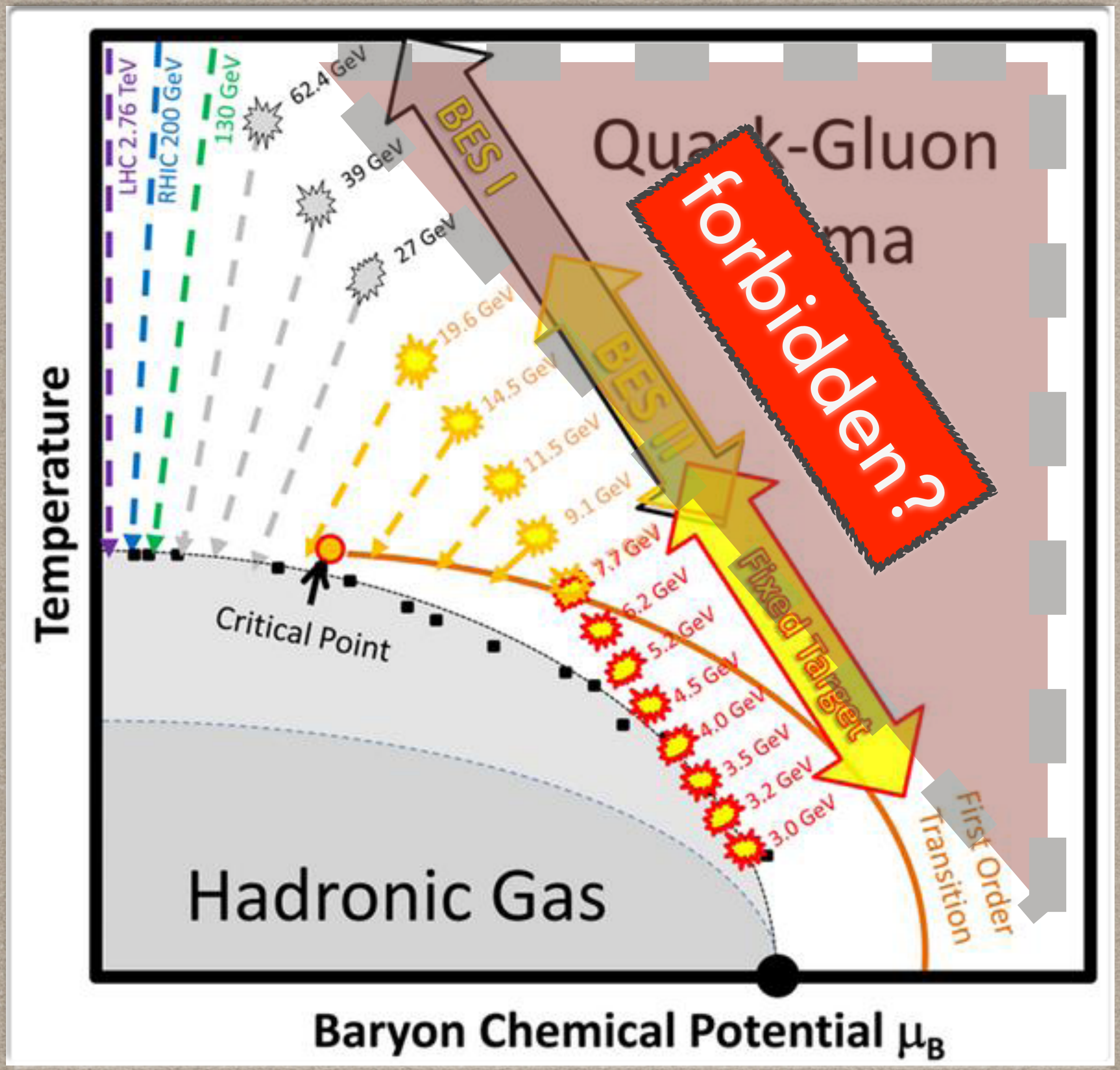
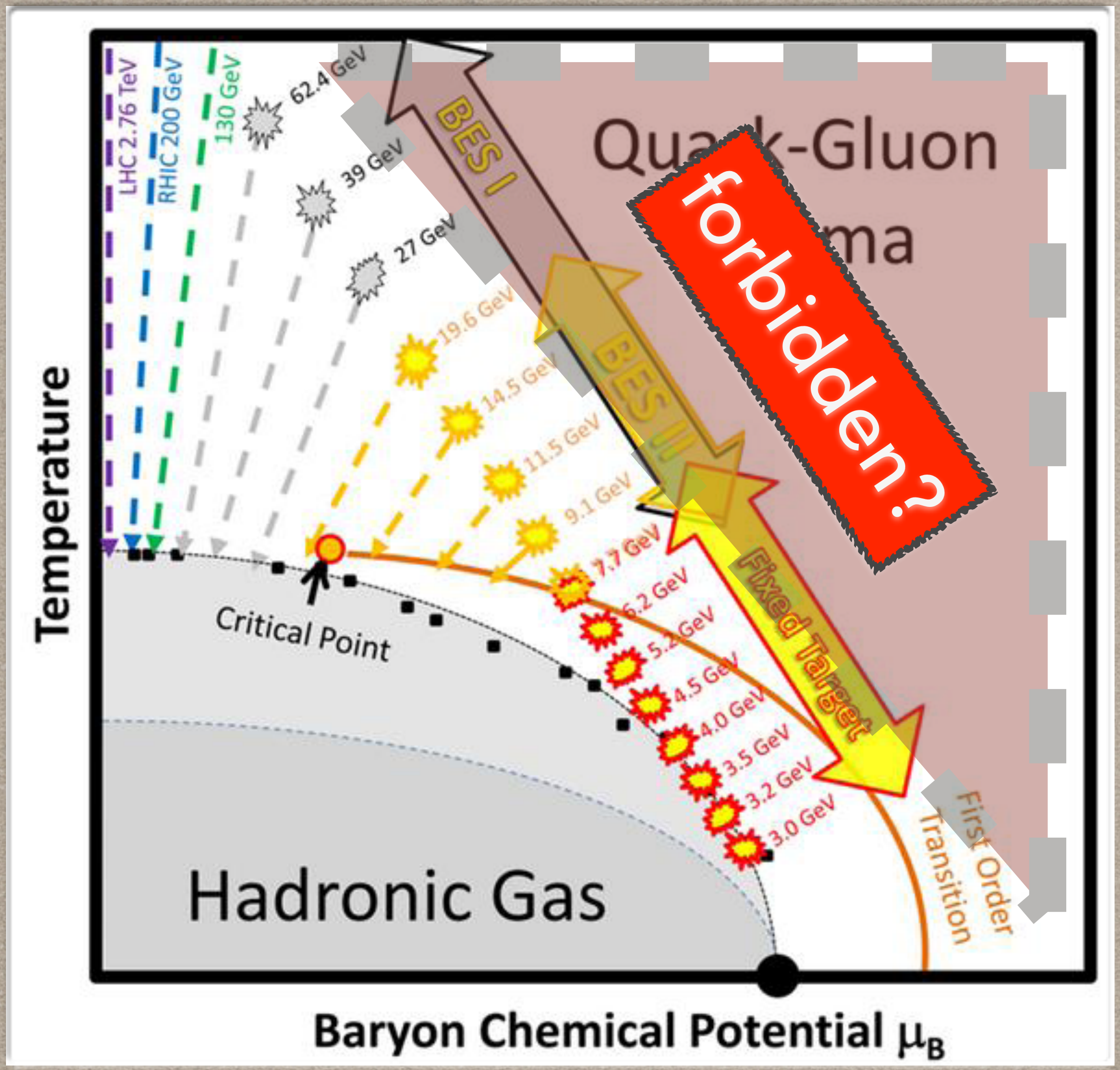


2030s

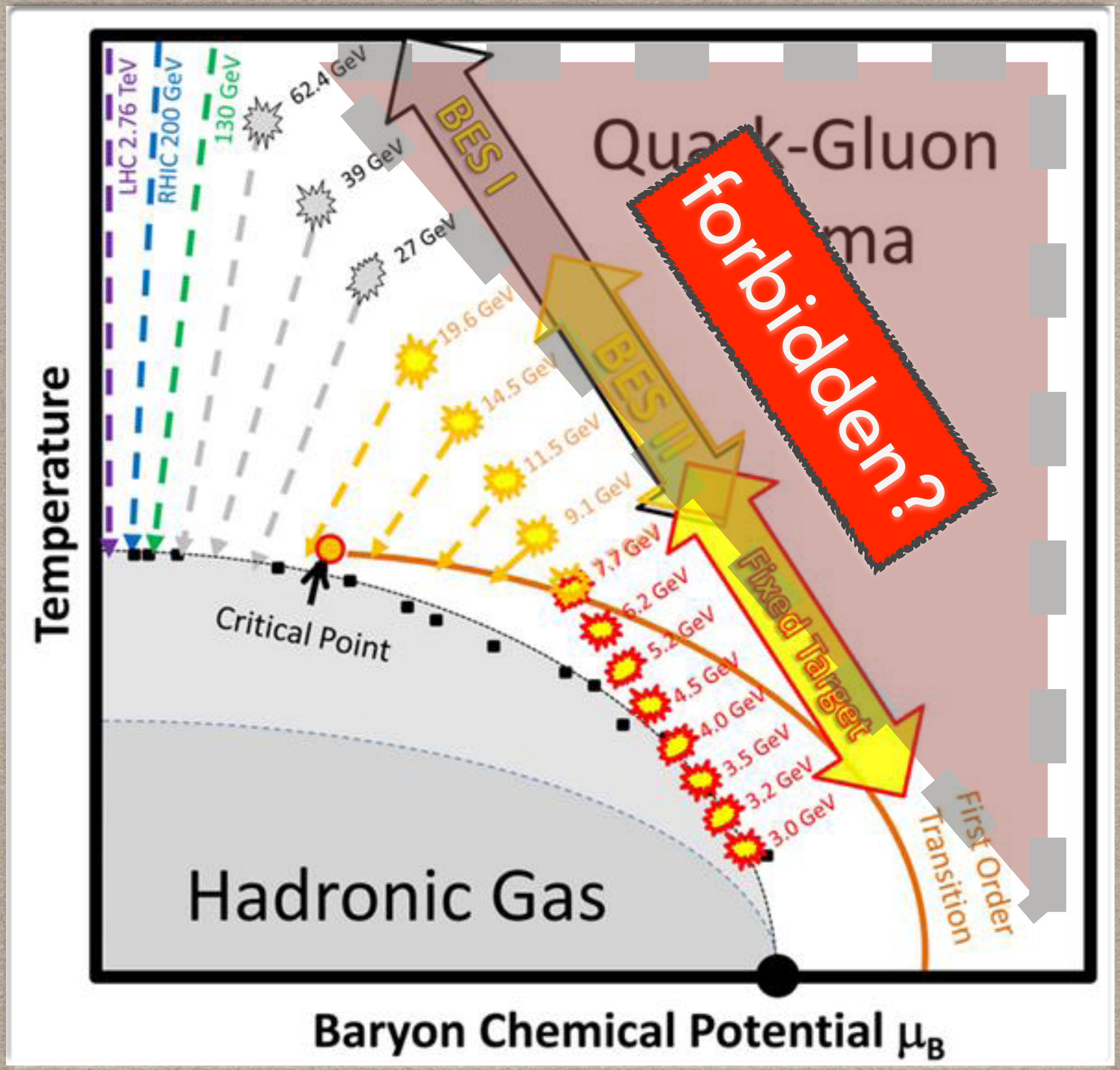
EXPLORING QCD PHASE-PROJECT X



- Experimental Dilemma

2030s

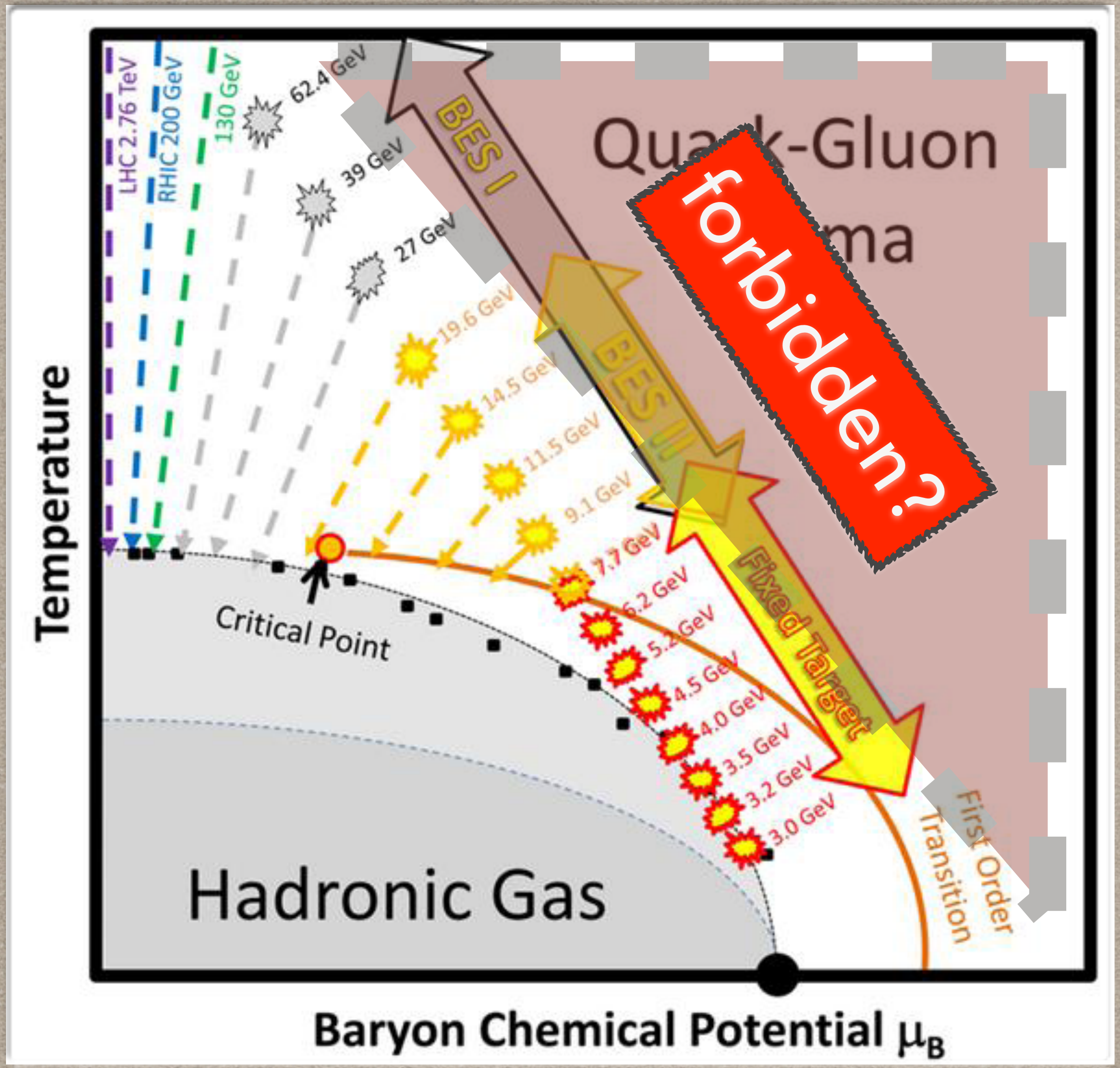
EXPLORING QCD PHASE-PROJECT X



- Experimental Dilemma
- How to touch 'high T && μ' region?

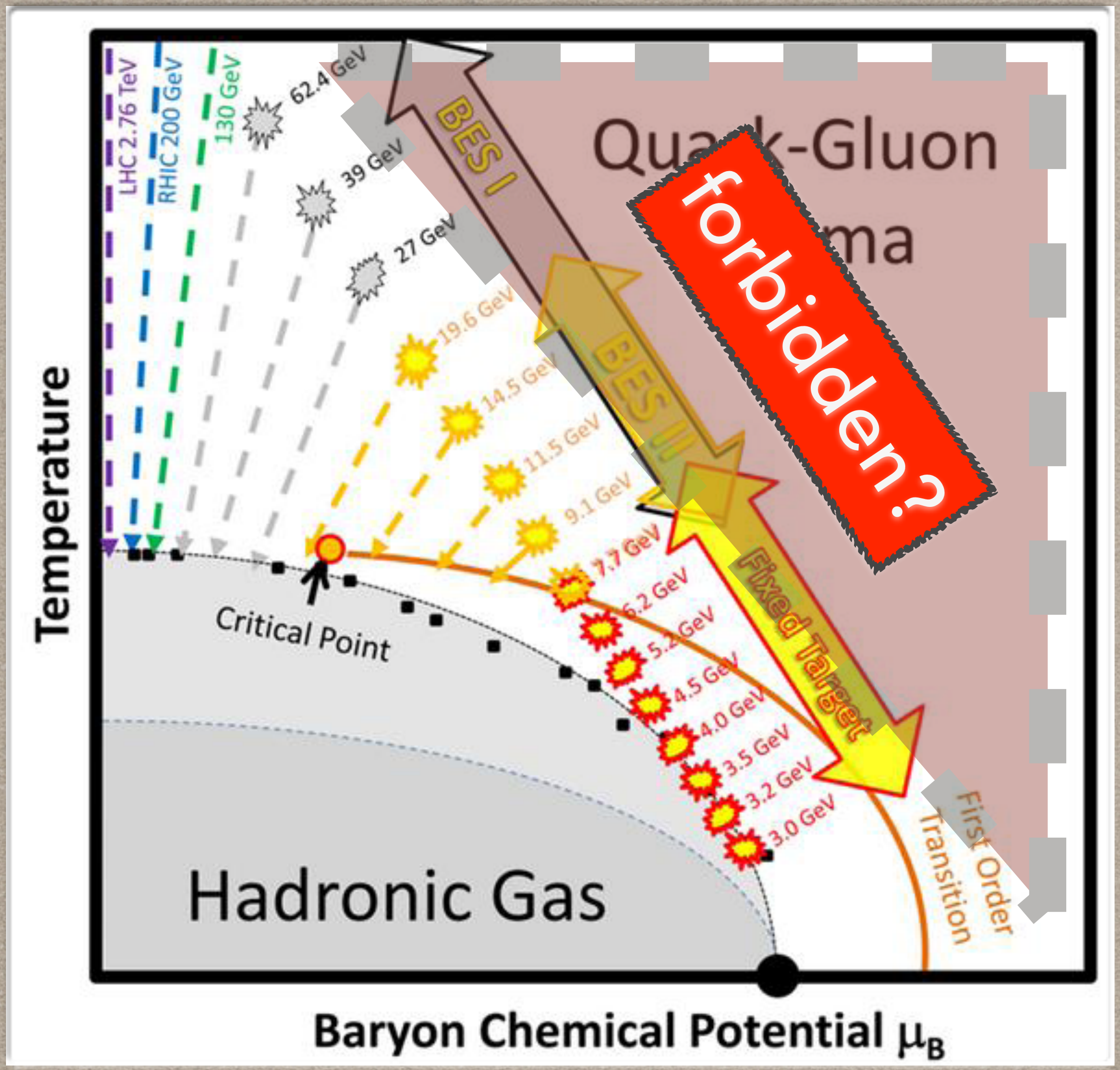
2030s

EXPLORING QCD PHASE-PROJECT X



- Experimental Dilemma
- How to touch 'high T && μ' region?
- Collider + Target?

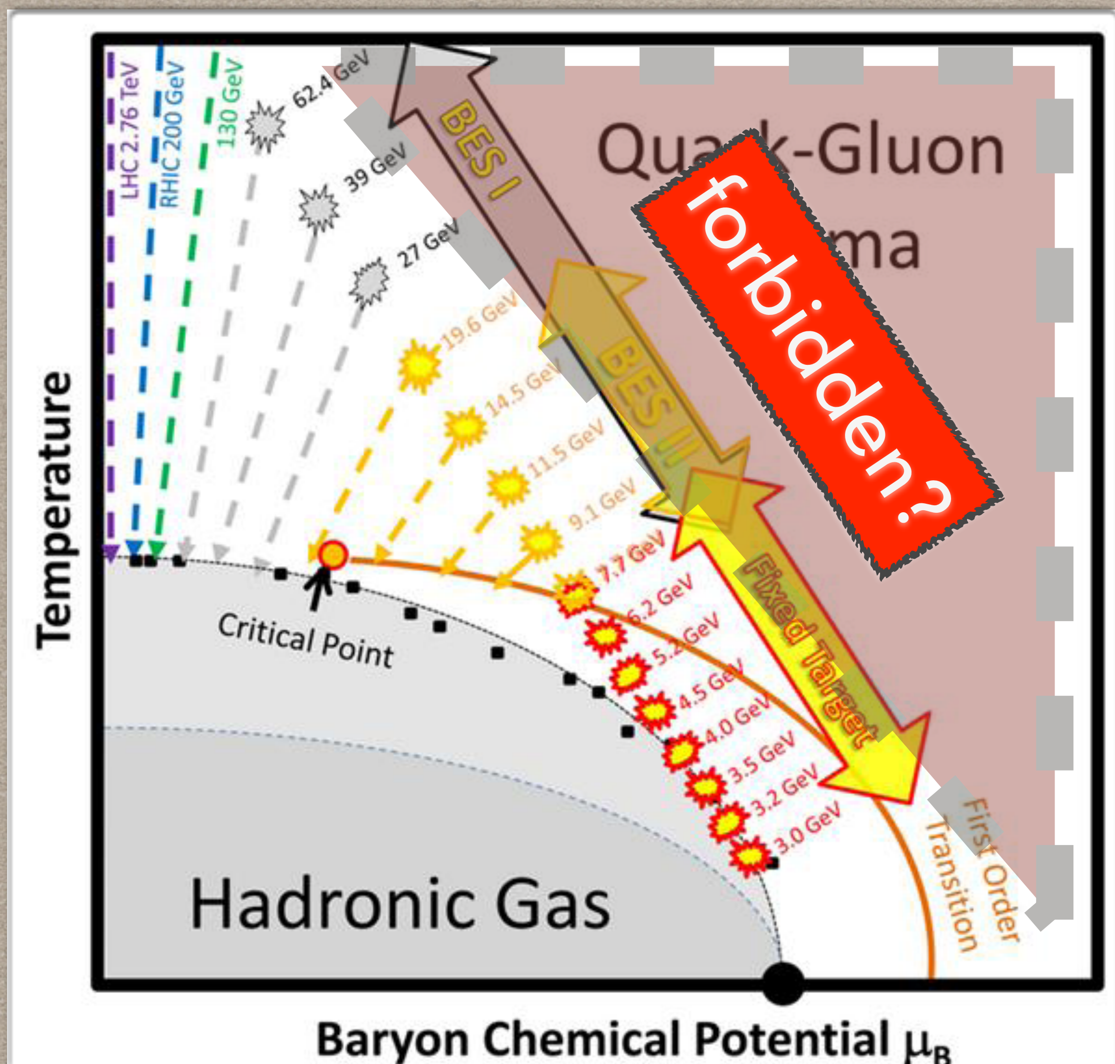
EXPLORING QCD PHASE-PROJECT X



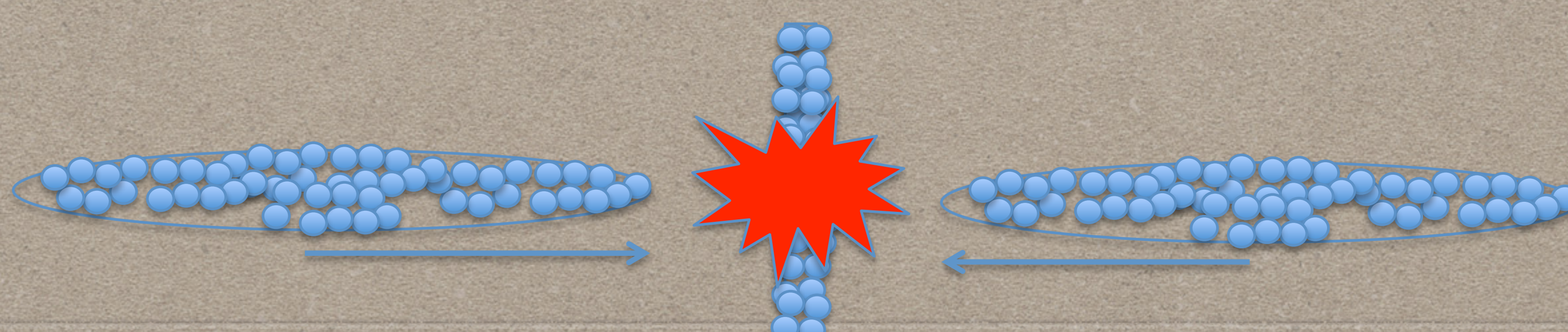
- Experimental Dilemma
- How to touch 'high T && μ' region?
- Collider + Target?
- Co-llision > Tri-llision

2030s

EXPLORING QCD PHASE-PROJECT X

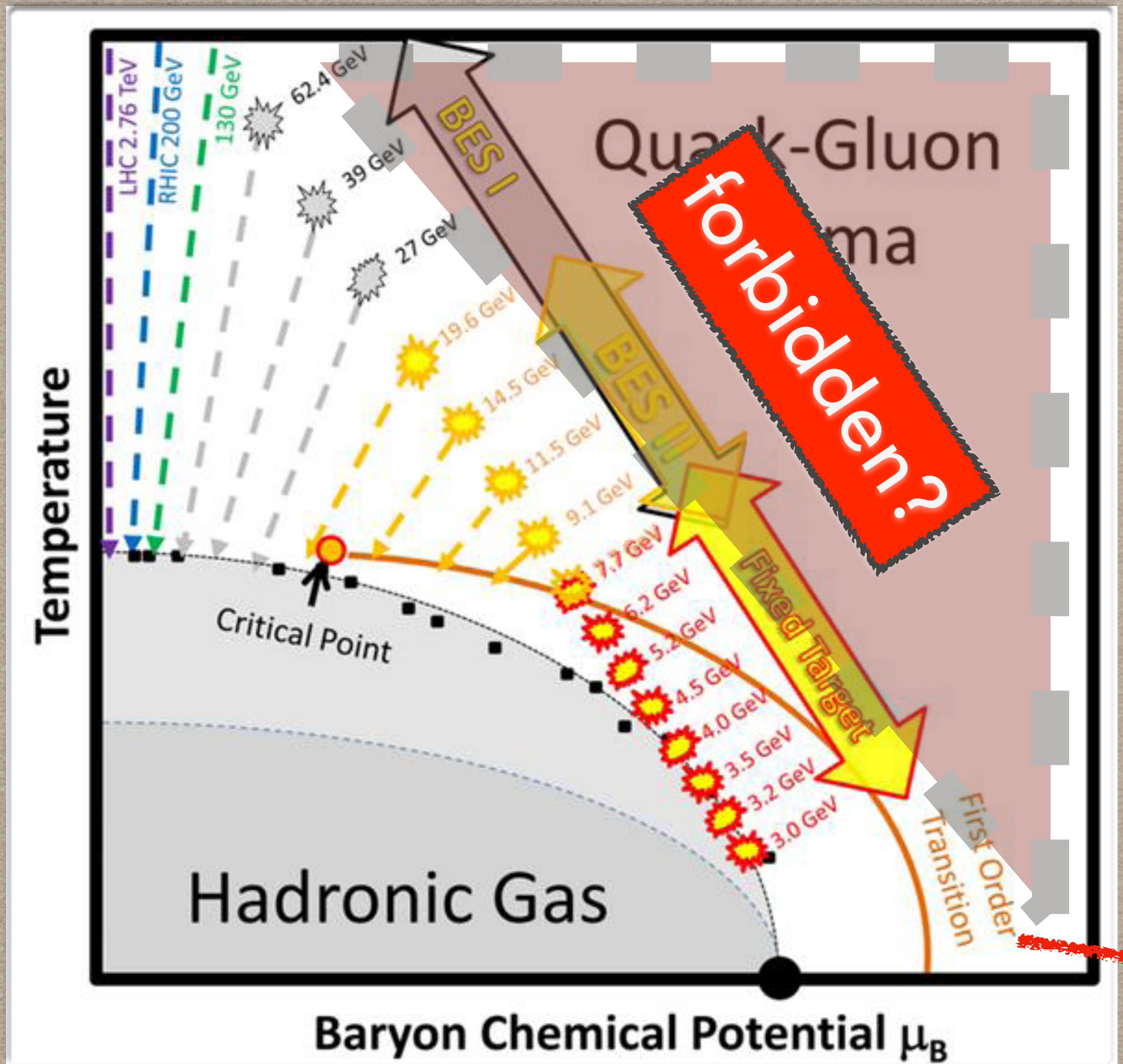


- Experimental Dilemma
- How to touch 'high T && μ' region?
- Collider + Target?
- Co-llision > Tri-llision



At rest

EXPLORING QCD PHASE-PROJECT X



- Experimental Dilemma
- How to touch 'high T && μ' region?
- Collider + Target?
- Co-llision > Tri-llision