

STAR's contributions to understanding the phase diagram

Mathias Labonté

University of California, Davis

25 Years of STAR Celebration

Brookhaven National Lab

17 December 2025

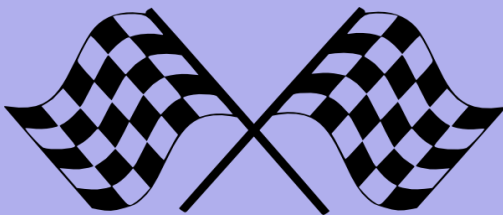


The white paper era

The beam energy scan era

First collisions

2010: BES-I



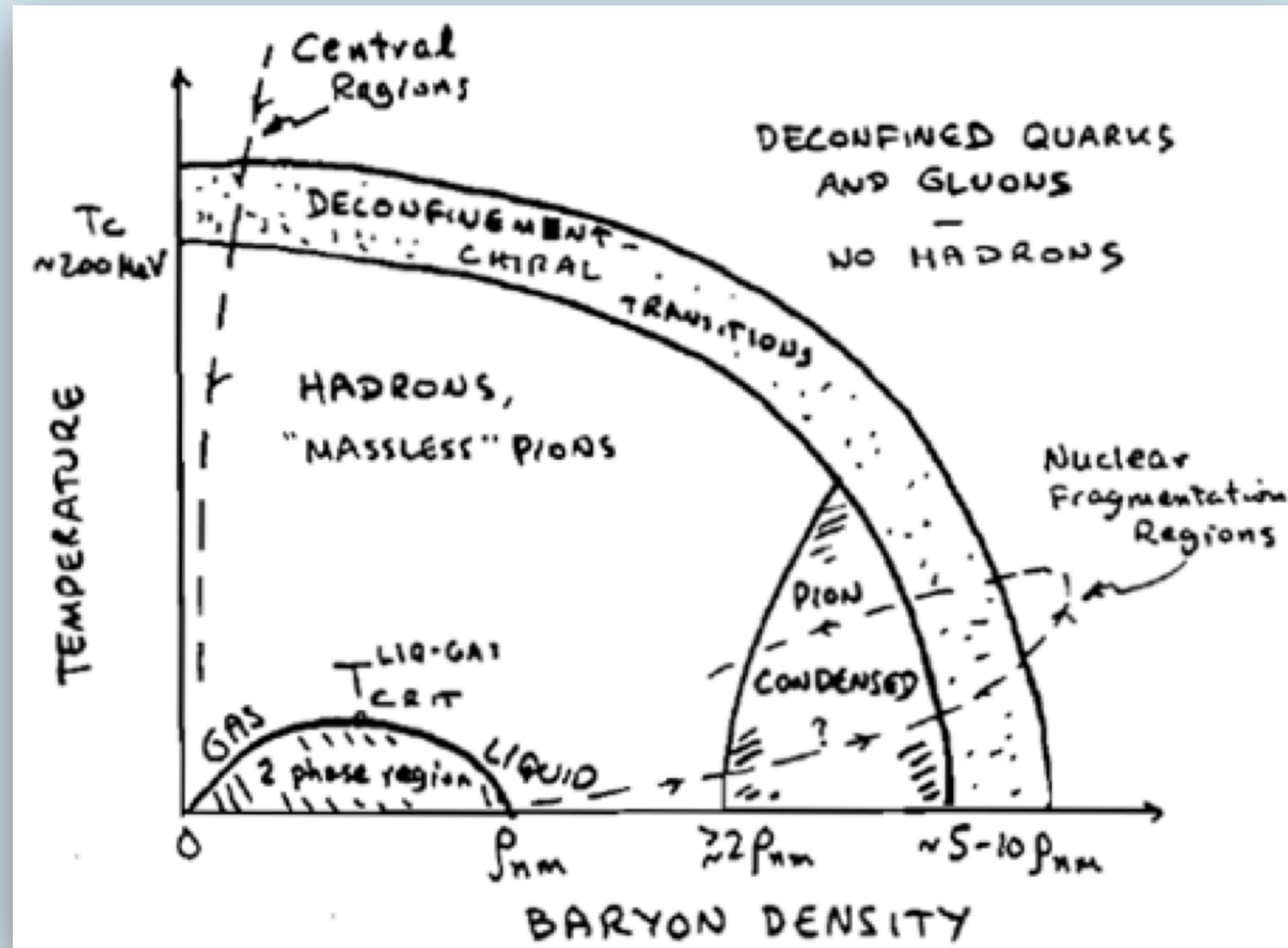
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June 12, 2000

Approx. 9:00 pm EDT

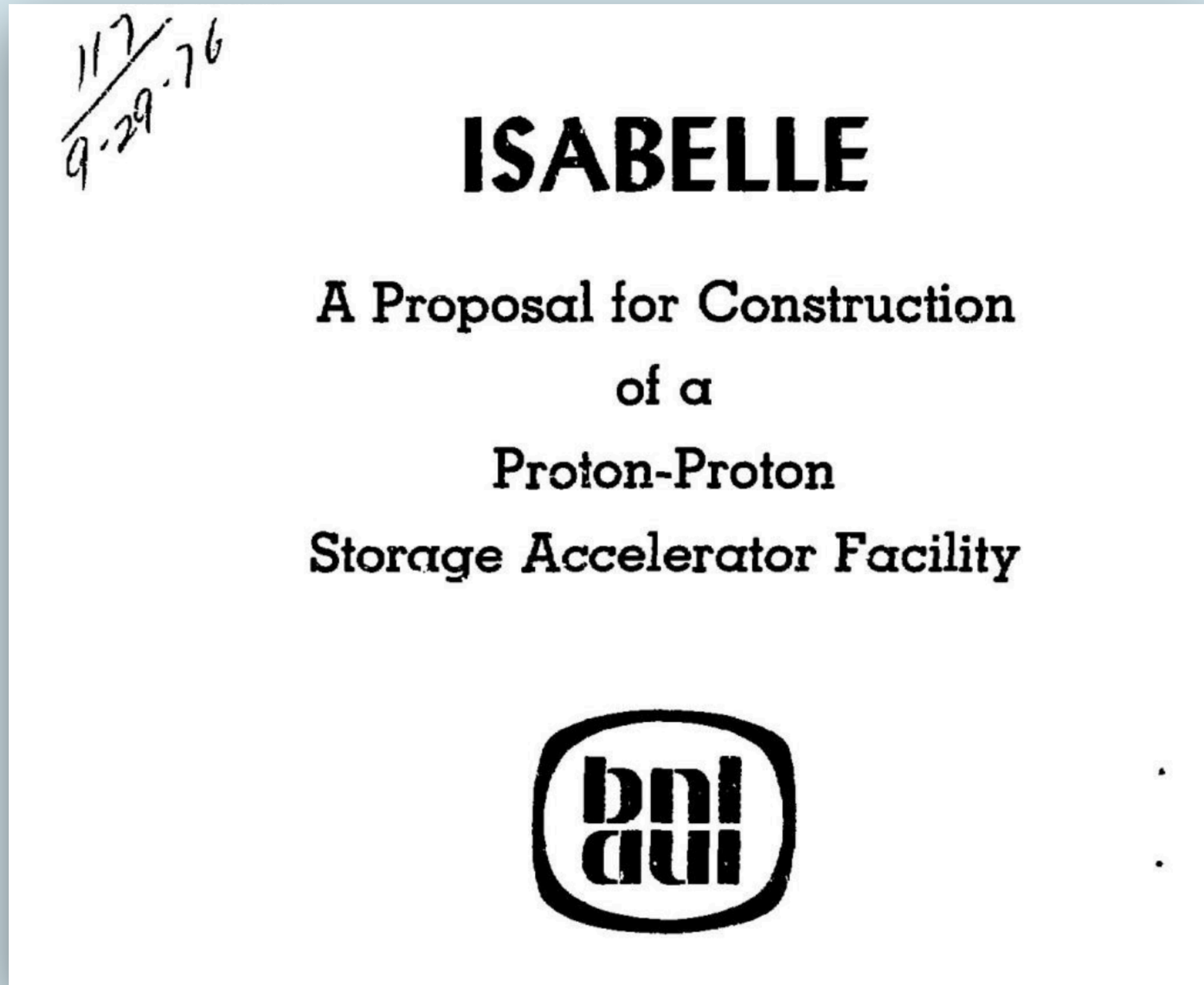
Pre-history

Baym, 1983



Pre-history

Baym, 1983



Pre-history

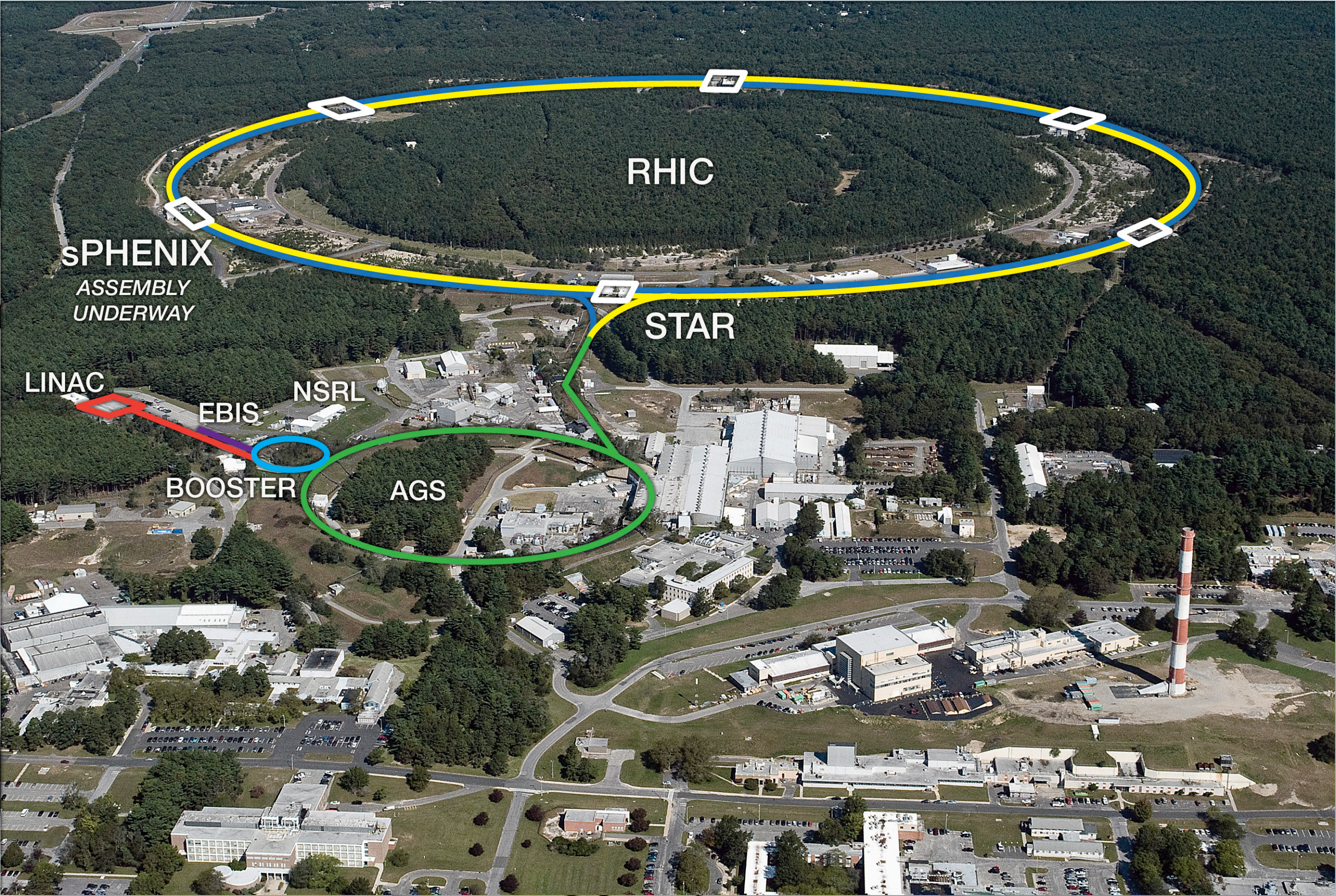
Approved in '91

117
9-29-76

ISABELLE

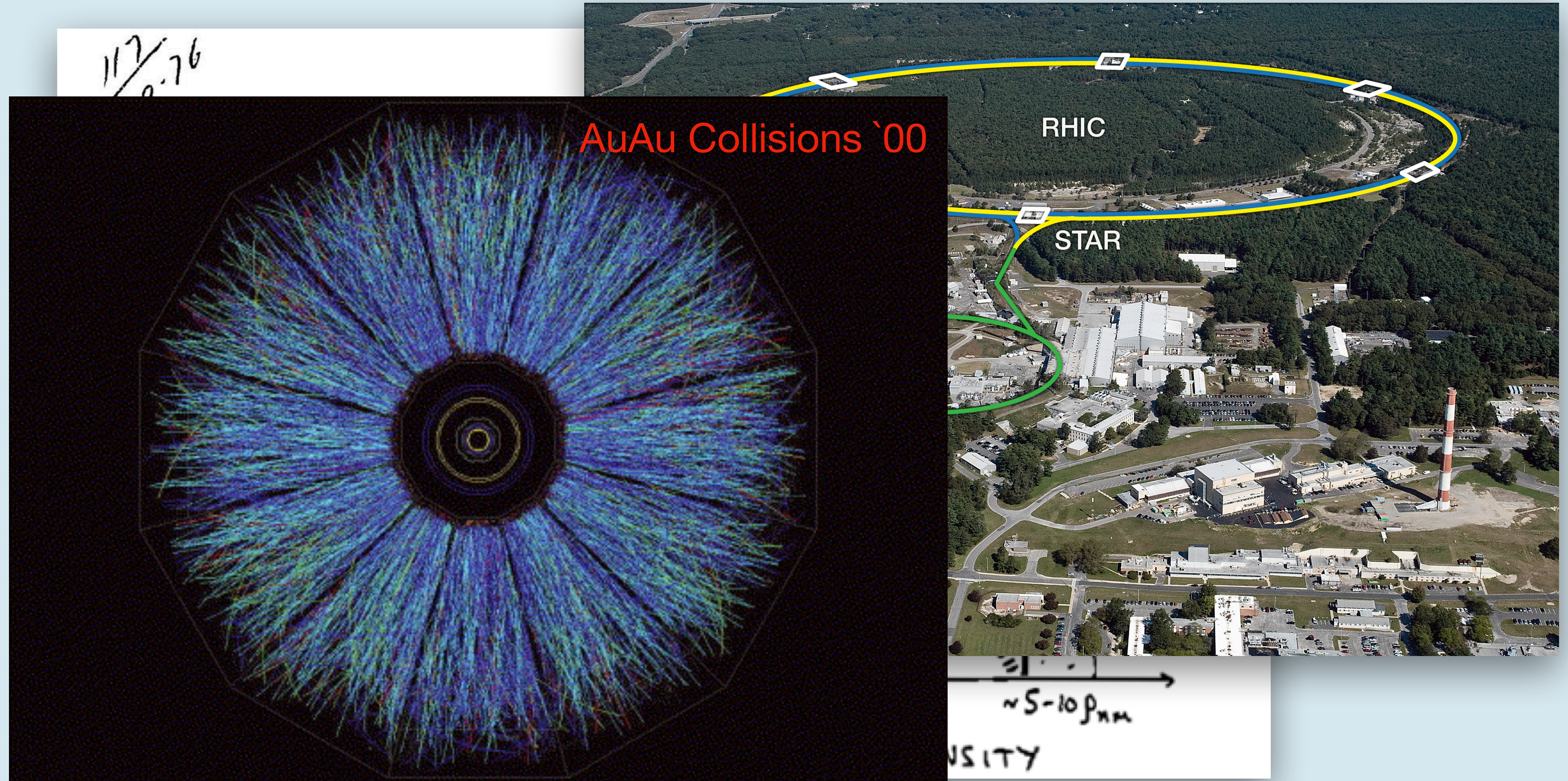
A Proposal for Construction
of a
Proton-Proton
Storage Accelerator





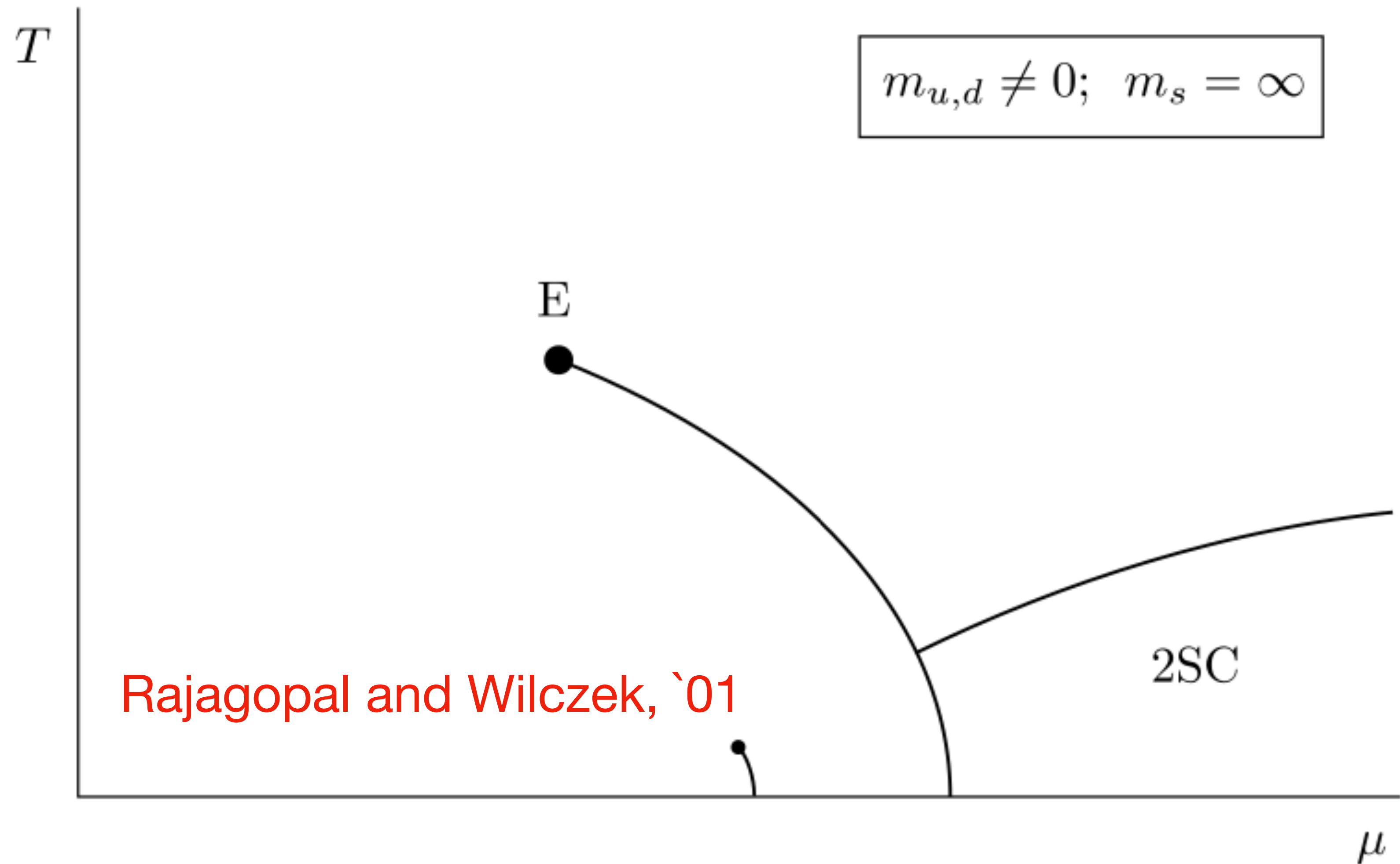
$\rho_{nm} \approx 2 \rho_{nm} \approx 5-10 \rho_{nm}$
BARYON DENSITY

Pre-history



Pre-history

Rajagopal, K., & Wilczek, F. (2001). The condensed matter physics of QCD. In *At The Frontier of Particle Physics: Handbook of QCD (In 3 Volumes)* (pp. 2061-2151).

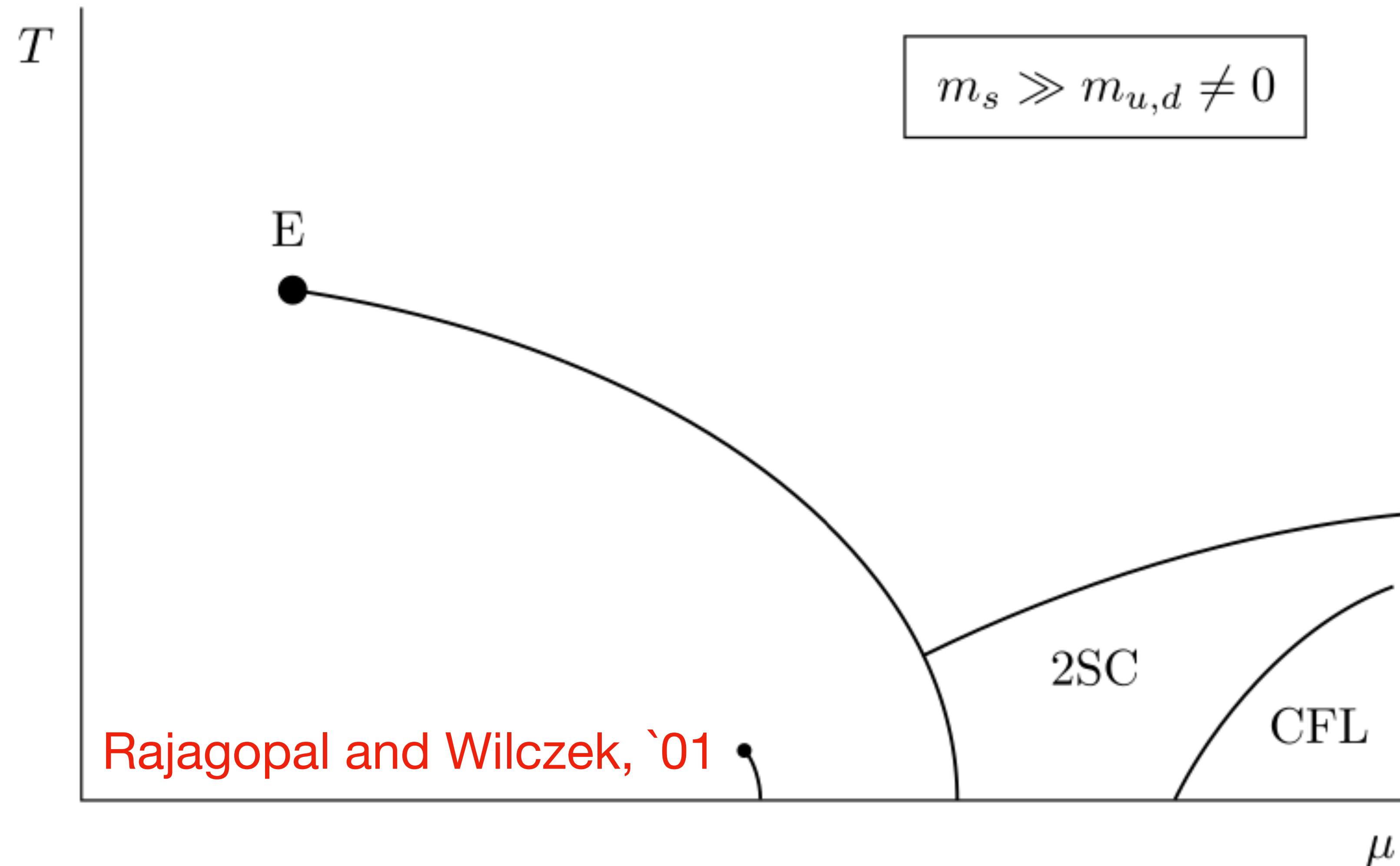


Rajagopal and Wilczek, '01

$\sim 5-10 \rho_{NM}$
DENSITY

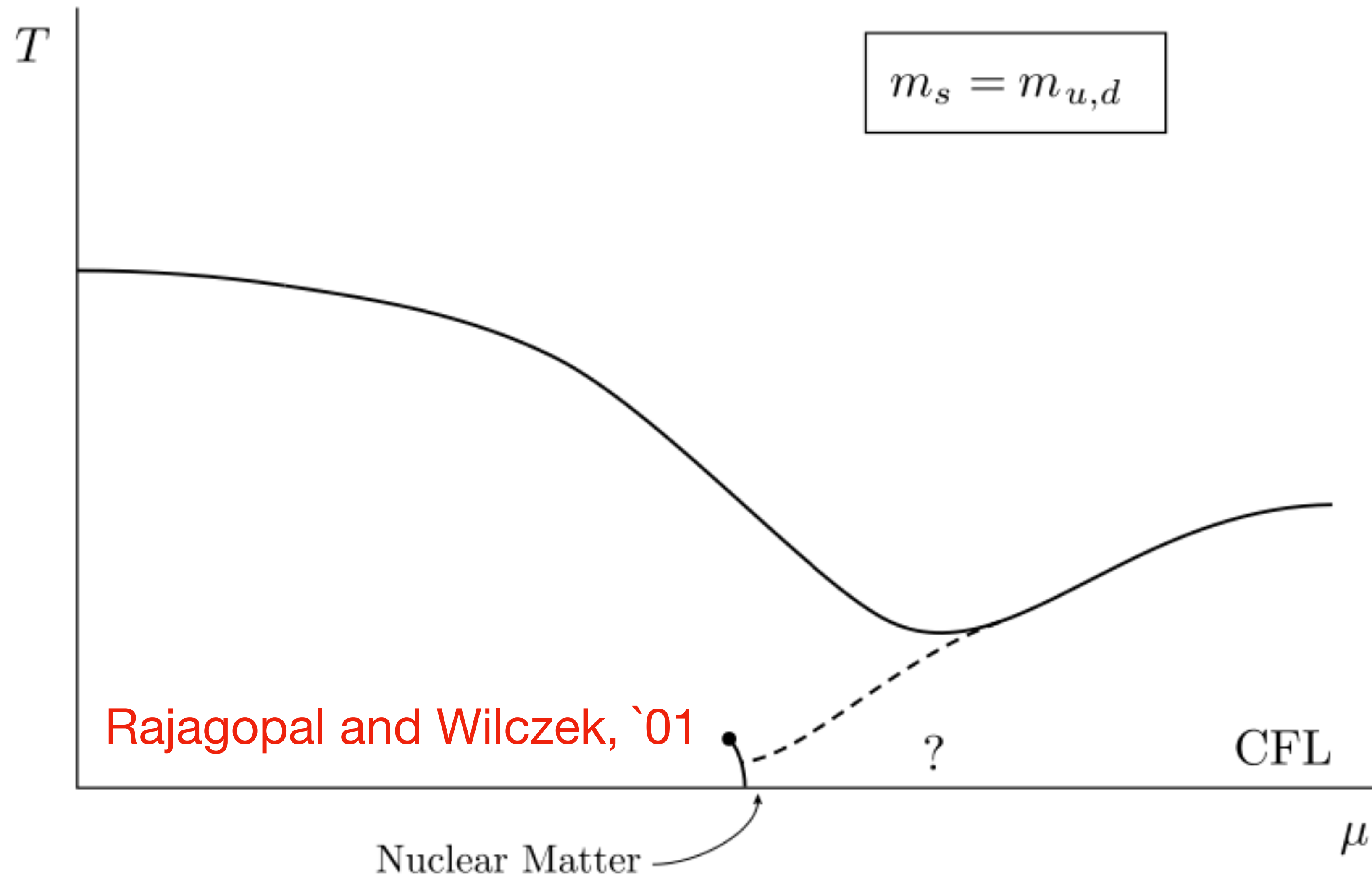
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Rajagopal and Wilczek, '01

ENSITY

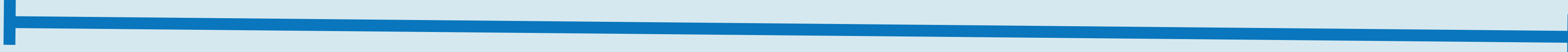
First observables and the white paper

First collisions

June 12, 2000

Approx. 9:00 pm EDT

2010: BES-I



$t = 0$

'01: First paper

'02: R_{AA}

2010: BES-I

VOLUME 89, NUMBER 20

PHYSICAL REVIEW LETTERS

11 NOVEMBER 2002

**Centrality Dependence of High- p_T Hadron Suppression
in Au + Au Collisions at $\sqrt{s_{NN}} = 130$ GeV**

C. Adler,¹¹ Z. Ahammed,²³ C. Allgower,¹² J. Amonett,¹⁴ B. D. Anderson,¹⁴ M. Anderson,⁵ G. S. Averichev,⁹
J. Balewski,¹² O. Barannikova,^{9,23} L. S. Barnby,¹⁴ J. Baudot,¹³ S. Bekele,²⁰ V.V. Belaga,⁹ R. Bellwied,³¹ J. Berger,¹¹
H. Bichsel,³⁰ A. Billmeier,³¹ L. C. Bland,² C. O. Blyth,³ B. E. Bonner,²⁴ A. Boucham,²⁶ A. Brandin,¹⁸ A. Bravar,²
R. V. Cadman,¹ H. Caines,³³ M. Calderón de la Barca Sánchez,² A. Cardenas,²³ J. Carroll,¹⁵ J. Castillo,²⁶ M. Castro,³¹
D. Cebra,⁵ P. Chaloupka,²⁰ S. Chattopadhyay,³¹ Y. Chen,⁶ S. P. Chernenko,⁹ M. Cherney,⁸ A. Chikanian,³³ B. Choi,²⁸

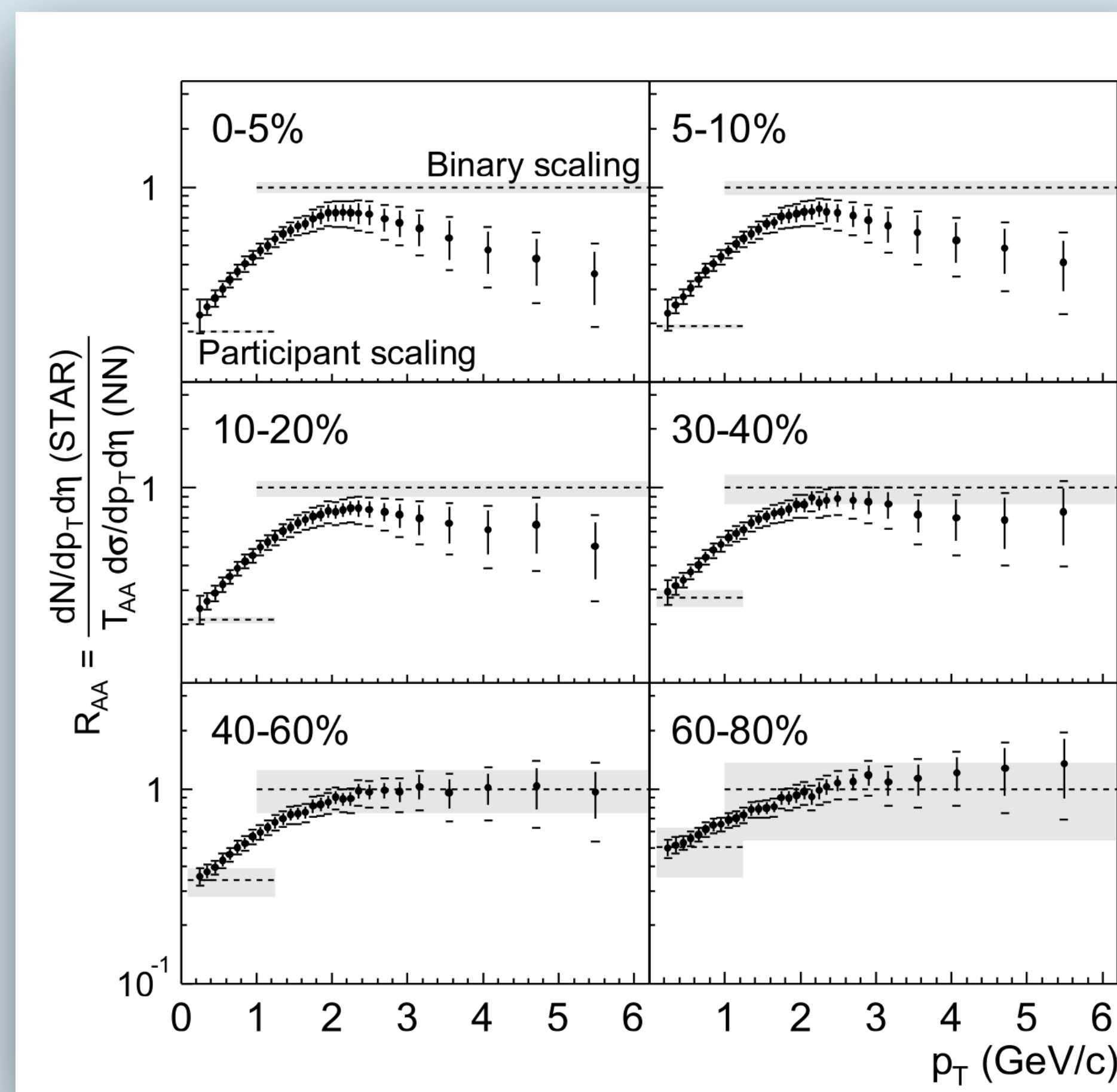
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'01: First paper

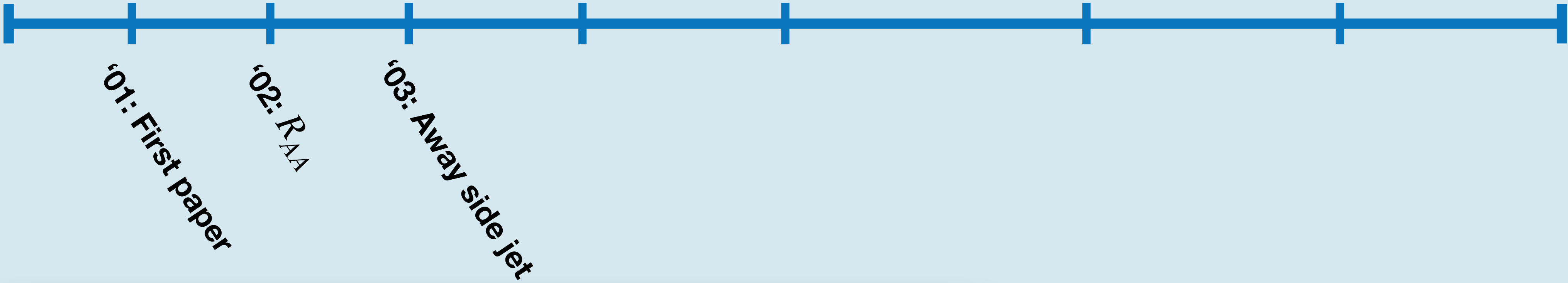
'02: R_{AA}

2010: BES-I

In summary, charged hadron production in high energy collisions of heavy nuclei has been studied over a wide range of p_T and event centrality. At high p_T , hadron yields scale with the number of binary collisions for peripheral collisions, while significant suppression of hadron production is seen for central collisions. This phenomenon indicates substantial energy loss of the final state partons or their hadronic fragments in the medium generated by high energy nuclear collisions, though quantitative measurement of this effect requires additional reference data.



t = 0



2010: BES-I

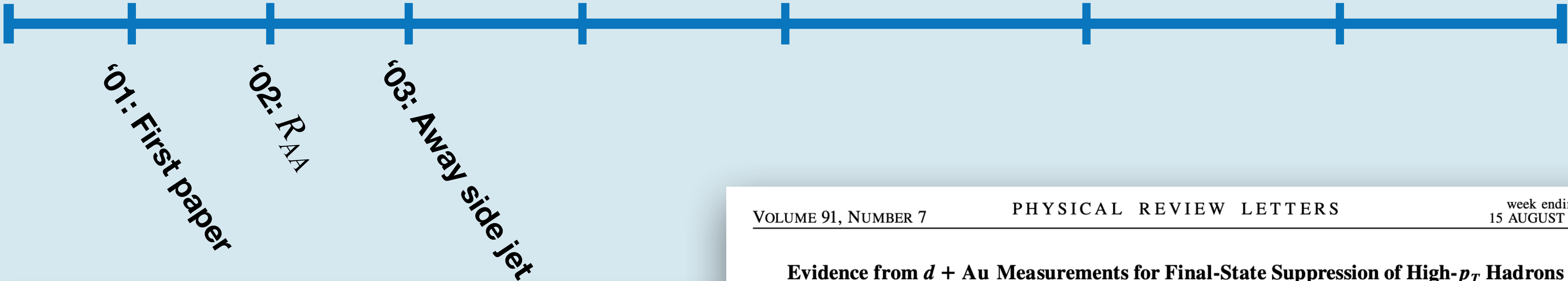
VOLUME 90, NUMBER 8

PHYSICAL REVIEW LETTERS

week ending
28 FEBRUARY 2003

**Disappearance of Back-To-Back High- p_T Hadron Correlations
in Central Au + Au Collisions at $\sqrt{s_{NN}} = 200$ GeV**

C. Adler,¹¹ Z. Ahammed,²³ C. Allgower,¹² J. Amonett,¹⁴ B. D. Anderson,¹⁴ M. Anderson,⁵ G. S. Averichev,⁹
J. Balewski,¹² O. Barannikova,^{9,23} L. S. Barnby,¹⁴ J. Baudot,¹³ S. Bekele,²⁰ V.V. Belaga,⁹ R. Bellwied,³¹ J. Berger,¹¹
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W. Christie,² J. P. Coffin,¹³ T. M. Cormier,³¹ M. M. Corral,¹⁶ J. G. Cramer,³⁰ H. J. Crawford,⁴ A. A. Derevschikov,²²
L. Didenko,² T. Dietel,¹¹ J. E. Draper,⁵ V. B. Dunin,⁹ J. C. Dunlop,³³ V. Eckardt,¹⁶ L. G. Efimov,⁹ V. Emelianov,¹⁸
J. Engelage,⁴ G. Eppley,²⁴ B. Erazmus,²⁶ P. Fachini,² V. Faine,² J. Faivre,¹³ R. Fatemi,¹² K. Filimonov,¹⁵ E. Finch,³³
Y. Fisyak,² D. Flierl,¹¹ K. J. Foley,² J. Fu,^{15,32} C. A. Gagliardi,²⁷ N. Gagunashvili,⁹ J. Gans,³³ L. Gaudichet,²⁶
M. Germain,¹³ F. Geurts,²⁴ V. Ghazikhanian,⁶ O. Grachov,³¹ V. Grigoriev,¹⁸ M. Guedon,¹³ E. Gushin,¹⁸ T. J. Hallman,²
D. Hardtke,¹⁵ J. W. Harris,³³ T. W. Henry,²⁷ S. Heppelmann,²¹ T. Herston,²³ B. Hippolyte,¹³ A. Hirsch,²³ E. Hjort,¹⁵
G. W. Hoffmann,²⁸ M. Horsley,³³ H. Z. Huang,⁶ T. J. Humanic,²⁰ G. Igo,⁶ A. Ishihara,²⁸ Yu. I. Ivanshin,¹⁰ P. Jacobs,¹⁵
W. W. Jacobs,¹² M. Janik,²⁹ I. Johnson,¹⁵ P. G. Jones,³ E. G. Judd,⁴ M. Kaneta,¹⁵ M. Kaplan,⁷ D. Keane,¹⁴ J. Kiryluk,⁶
A. Kisiel,²⁹ J. Klay,¹⁵ S. R. Klein,¹⁵ A. Klyachko,¹² T. Kollegger,¹¹ A. S. Konstantinov,²² M. Kopytine,¹⁴ L. Kotchenda,¹⁸
A. D. Kovalenko,⁹ M. Kramer,¹⁹ P. Kravtsov,¹⁸ K. Krueger,¹ C. Kuhn,¹³ A. I. Kulikov,⁹ G. J. Kunde,³³ C. L. Kunz,⁷
R. Kh. Kutuev,¹⁰ A. A. Kuznetsov,⁹ L. Lakehal-Ayat,²⁶ M. A. C. Lamont,³ J. M. Landgraf,² S. Lange,¹¹ C. P. Lansdell,²⁸
B. Lasiuk,³³ F. Laue,² J. Lauret,² A. Lebedev,² R. Lednický,⁹ V. M. Leontiev,²² M. J. LeVine,² Q. Li,³¹
S. J. Lindenbaum,¹⁹ M. A. Lisa,²⁰ F. Liu,³² L. Liu,³² Z. Liu,³² Q. J. Liu,³⁰ T. Ljubicic,² W. J. Llope,²⁴ G. LoCurto,¹⁶



VOLUME 90, NUMBER 8 PHYSICAL REVIEW LETTERS

Disappearance of Back-To-Back High- p_T Hadron Correlation in Central Au + Au Collisions at $\sqrt{s_{NN}} = 200$ GeV

C. Adler,¹¹ Z. Ahammed,²³ C. Allgower,¹² J. Amonett,¹⁴ B. D. Anderson,¹⁴ M. Anderson,⁵ J. Balewski,¹² O. Barannikova,^{9,23} L. S. Barnby,¹⁴ J. Baudot,¹³ S. Bekele,²⁰ V.V. Belag, H. Bichsel,³⁰ A. Billmeier,³¹ L. C. Bland,² C. O. Blyth,³ B. E. Bonner,²⁴ A. Boucham, R. V. Cadman,¹ H. Caines,³³ M. Calderón de la Barca Sánchez,² A. Cardenas,²³ J. Carroll, D. Cebra,⁵ P. Chaloupka,²⁰ S. Chattopadhyay,³¹ Y. Chen,⁶ S. P. Chernenko,⁹ M. Cherney, W. Christie,² J. P. Coffin,¹³ T. M. Cormier,³¹ M. M. Corral,¹⁶ J. G. Cramer,³⁰ H. J. Crawford, L. Didenko,² T. Dietel,¹¹ J. E. Draper,⁵ V. B. Dunin,⁹ J. C. Dunlop,³³ V. Eckardt,¹⁶ L. Engelage,⁴ G. Eppley,²⁴ B. Erasmus,²⁶ P. Fachini,² V. Faine,² J. Faivre,¹³ R. Fatemi, Y. Fisyak,² D. Flierl,¹¹ K. J. Foley,² J. Fu,^{15,32} C. A. Gagliardi,²⁷ N. Gagunashvili,⁹ M. Germain,¹³ F. Geurts,²⁴ V. Ghazikhanian,⁶ O. Grachov,³¹ V. Grigoriev,¹⁸ M. Guedon, D. Hardtke,¹⁵ J. W. Harris,³³ T. W. Henry,²⁷ S. Heppelmann,²¹ T. Herston,²³ B. Hippolyte, G. W. Hoffmann,²⁸ M. Horsley,³³ H. Z. Huang,⁶ T. J. Humanic,²⁰ G. Igo,⁶ A. Ishihara,²⁸ W. W. Jacobs,¹² M. Janik,²⁹ I. Johnson,¹⁵ P. G. Jones,³ E. G. Judd,⁴ M. Kaneta,¹⁵ M. Kap A. Kisiel,²⁹ J. Klay,¹⁵ S. R. Klein,¹⁵ A. Klyachko,¹² T. Kollegger,¹¹ A. S. Konstantinov,²² M. Kopylov, A. D. Kovalenko,⁹ M. Kramer,¹⁹ P. Kravtsov,¹⁸ K. Krueger,¹ C. Kuhn,¹³ A. I. Kulikov,⁹ G. J. Kunde,³³ C. L. Kunz,⁷ R. Kh. Kutuev,¹⁰ A. A. Kuznetsov,⁹ L. Lakehal-Ayat,²⁶ M. A. C. Lamont,³ J. M. Landgraf,² S. Lange,¹¹ C. P. Lansdell,²⁸ B. Lasiuk,³³ F. Laue,² J. Lauret,² A. Lebedev,² R. Lednický,⁹ V. M. Leontiev,²² M. J. LeVine,² Q. Li,³¹ S. J. Lindenbaum,¹⁹ M. A. Lisa,²⁰ F. Liu,³² L. Liu,³² Z. Liu,³² Q. J. Liu,³⁰ T. Ljubicic,² W. J. Llope,²⁴ G. LoCurto,¹⁶

VOLUME 91, NUMBER 7 PHYSICAL REVIEW LETTERS week ending 15 AUGUST 2003

Evidence from $d + \text{Au}$ Measurements for Final-State Suppression of High- p_T Hadrons in Au + Au Collisions at RHIC

J. Adams,³ C. Adler,¹² M. M. Aggarwal,²⁵ Z. Ahammed,²⁸ J. Amonett,¹⁷ B. D. Anderson,¹⁷ M. Anderson,⁵ D. Arkhipkin,¹¹ G. S. Averichev,¹⁰ S. K. Badyal,¹⁶ J. Balewski,¹³ O. Barannikova,^{28,10} L. S. Barnby,¹⁷ J. Baudot,¹⁵ S. Bekele,²⁴ V.V. Belaga,¹⁰ R. Bellwied,⁴¹ J. Berger,¹² B. I. Bezverkhny,⁴³ S. Bhardwaj,²⁹ P. Bhaskar,³⁸ A. K. Bhati,²⁵ H. Bichsel,⁴⁰ A. Billmeier,⁴¹ L. C. Bland,² C. O. Blyth,³ B. E. Bonner,³⁰ M. Botje,²³ A. Boucham,³⁴ A. Brandin,²¹ A. Bravar,² R. V. Cadman,¹ X. Z. Cai,³³ H. Caines,⁴³ M. Calderón de la Barca Sánchez,² J. Carroll,¹⁸ J. Castillo,¹⁸ M. Castro,⁴¹ D. Cebra,⁵ P. Chaloupka,⁹ S. Chattopadhyay,³⁸ H. F. Chen,³² Y. Chen,⁶ S. P. Chernenko,¹⁰ M. Cherney,⁸ A. Chikanian,⁴³ B. Choi,³⁶ W. Christie,² J. P. Coffin,¹⁵ T. M. Cormier,⁴¹ J. G. Cramer,⁴⁰ H. J. Crawford,⁴ D. Das,³⁸ S. Das,³⁸ A. A. Derevschikov,²⁷ L. Didenko,² T. Dietel,¹² X. Dong,^{32,18} J. E. Draper,⁵ F. Du,⁴³ A. K. Dubey,¹⁴ V. B. Dunin,¹⁰ J. C. Dunlop,² M. R. Dutta Majumdar,³⁸ V. Eckardt,¹⁹ L. G. Efimov,¹⁰ V. Emelianov,²¹ J. Engelage,⁴ G. Eppley,³⁰ B. Erasmus,³⁴ P. Fachini,² V. Faine,² J. Faivre,¹⁵ R. Fatemi,¹³ K. Filimonov,¹⁸ P. Filip,⁹ E. Finch,⁴³ Y. Fisyak,² D. Flierl,¹² K. J. Foley,² J. Fu,⁴² C. A. Gagliardi,³⁵ M. S. Ganti,³⁸ N. Gagunashvili,¹⁰ J. Gans,⁴³ L. Gaudichet,³⁴ M. Germain,¹⁵ F. Geurts,³⁰ V. Ghazikhanian,⁶ P. Ghosh,³⁸ J. E. Gonzalez,⁶ O. Grachov,⁴¹ V. Grigoriev,²¹ S. Gronstal,⁸ D. Grosnick,³⁷ M. Guedon,¹⁵ S. M. Guertin,⁶ A. Gupta,¹⁶ E. Gushin,²¹ T. D. Gutierrez,⁵ T. J. Hallman,² D. Hardtke,¹⁸ J. W. Harris,⁴³ M. Heinz,⁴³ T. W. Henry,³⁵ S. Heppelmann,²⁶ T. Herston,²⁸ B. Hippolyte,⁴³ A. Hirsch,²⁸ E. Hjort,¹⁸ G. W. Hoffmann,³⁶ M. Horsley,⁴³ H. Z. Huang,⁶ S. L. Huang,³² T. J. Humanic,²⁴ G. Igo,⁶ A. Ishihara,³⁶ P. Jacobs,¹⁸ W. W. Jacobs,¹³ M. Janik,³⁹ I. Johnson,¹⁸ P. G. Jones,³ E. G. Judd,⁴ S. Kabana,⁴³ M. Kaneta,¹⁸ M. Kaplan,⁷ D. Keane,¹⁷ J. Kiryluk,⁶ A. Kisiel,³⁹ J. Klay,¹⁸ S. R. Klein,¹⁸ A. Klyachko,¹³ D. D. Koetke,³⁷ T. Kollegger,¹² A. S. Konstantinov,²⁷ M. Kopytine,¹⁷ L. Kotchenda,²¹ A. D. Kovalenko,¹⁰ M. Kramer,²² P. Kravtsov,²¹ K. Krueger,¹ C. Kuhn,¹⁵ A. I. Kulikov,¹⁰ A. Kumar,²⁵ G. J. Kunde,⁴³ C. L. Kunz,⁷ R. Kh. Kutuev,¹¹ A. A. Kuznetsov,¹⁰ M. A. C. Lamont,³ J. M. Landgraf,² S. Lange,¹² C. P. Lansdell,³⁶ B. Lasiuk,⁴³ F. Laue,² J. Lauret,² A. Lebedev,² R. Lednický,¹⁰ V. M. Leontiev,²⁷ M. J. LeVine,² C. Li,³² Q. Li,⁴¹ S. J. Lindenbaum,²² M. A. Lisa,²⁴ F. Liu,⁴² L. Liu,⁴² Z. Liu,⁴² Q. J. Liu,⁴⁰ T. Ljubicic,² W. J. Llope,³⁰ H. Long,⁶ R. S. Longacre,² M. Lopez-Noriega,²⁴ W. A. Love,²

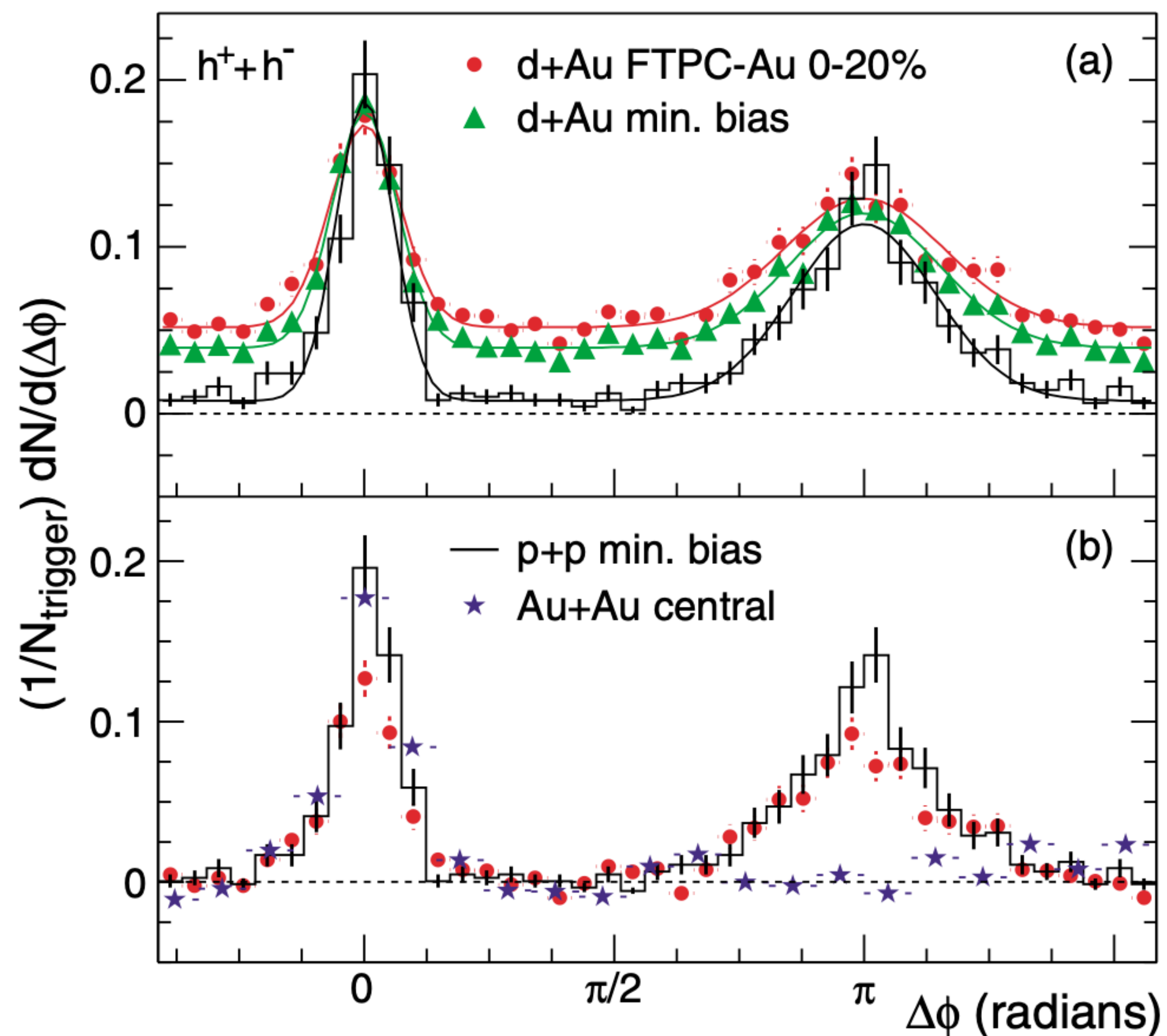
$t = 0$

'01: First paper

'02: R_{AA}

'03: Away side jet

2010: BES-I



$t = 0$

'01: First paper

'02: R_{AA}

'03: Away side jet

'04: NCQ scaling

2010: BES-I

VOLUME 92, NUMBER 5

PHYSICAL REVIEW LETTERS

week ending
6 FEBRUARY 2004

**Particle-Type Dependence of Azimuthal Anisotropy and Nuclear Modification
of Particle Production in Au + Au Collisions at $\sqrt{s_{NN}} = 200$ GeV**

J. Adams,³ C. Adler,¹² M. M. Aggarwal,²⁵ Z. Ahammed,³⁸ J. Amonett,¹⁷ B. D. Anderson,¹⁷ M. Anderson,⁵
D. Arkhipkin,¹¹ G. S. Averichev,¹⁰ S. K. Badyal,¹⁶ J. Balewski,¹³ O. Barannikova,^{28,10} L. S. Barnby,³ J. Baudot,¹⁵
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$t = 0$

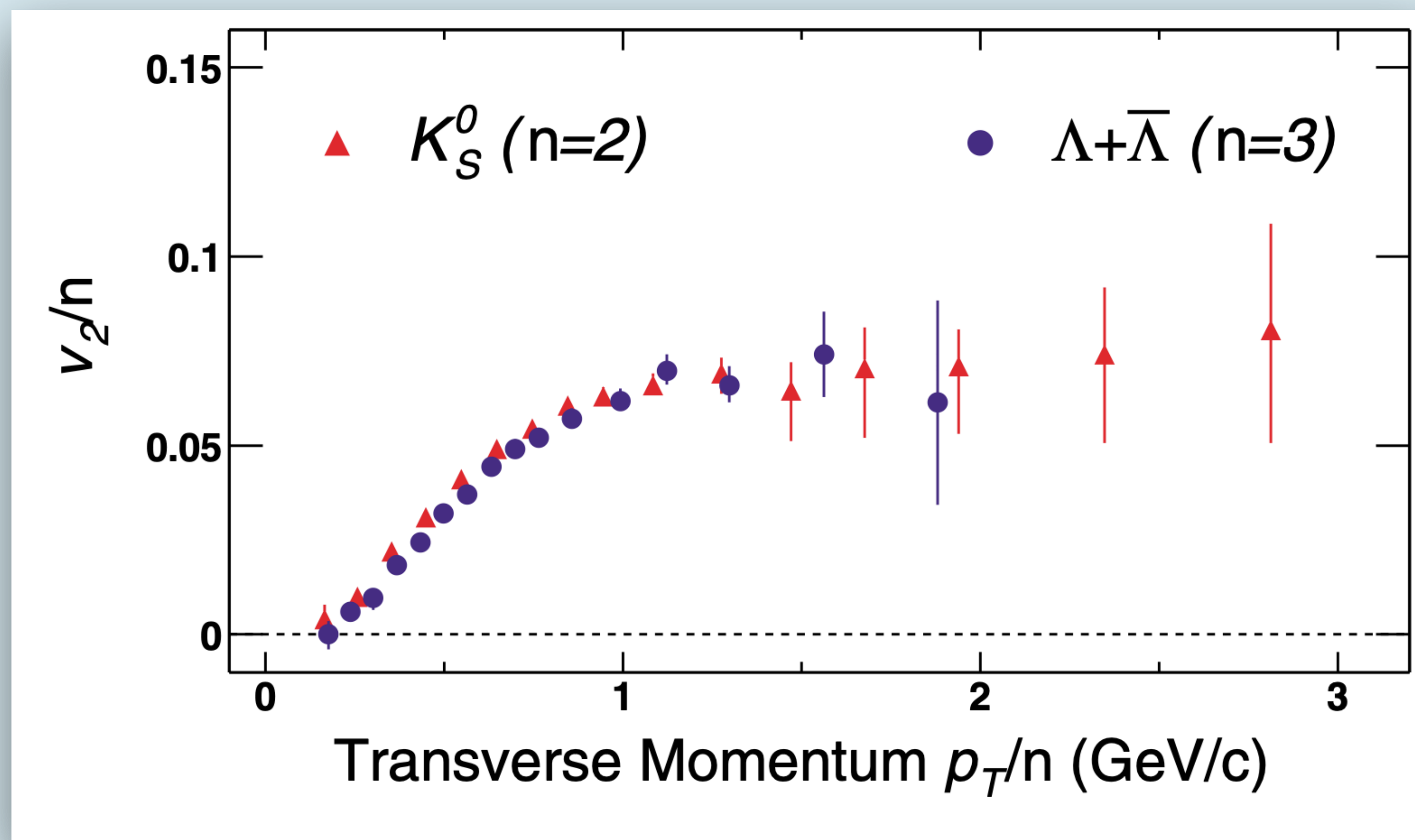
2010: BES-I

'01: First paper

'02: R_{AA}

'03: Away side jet

'04: NCQ scaling



$t = 0$

'01: First paper

'02: R_{AA}

'03: Away side jet

'04: NCQ scaling

'05: White paper

2010: BES-I



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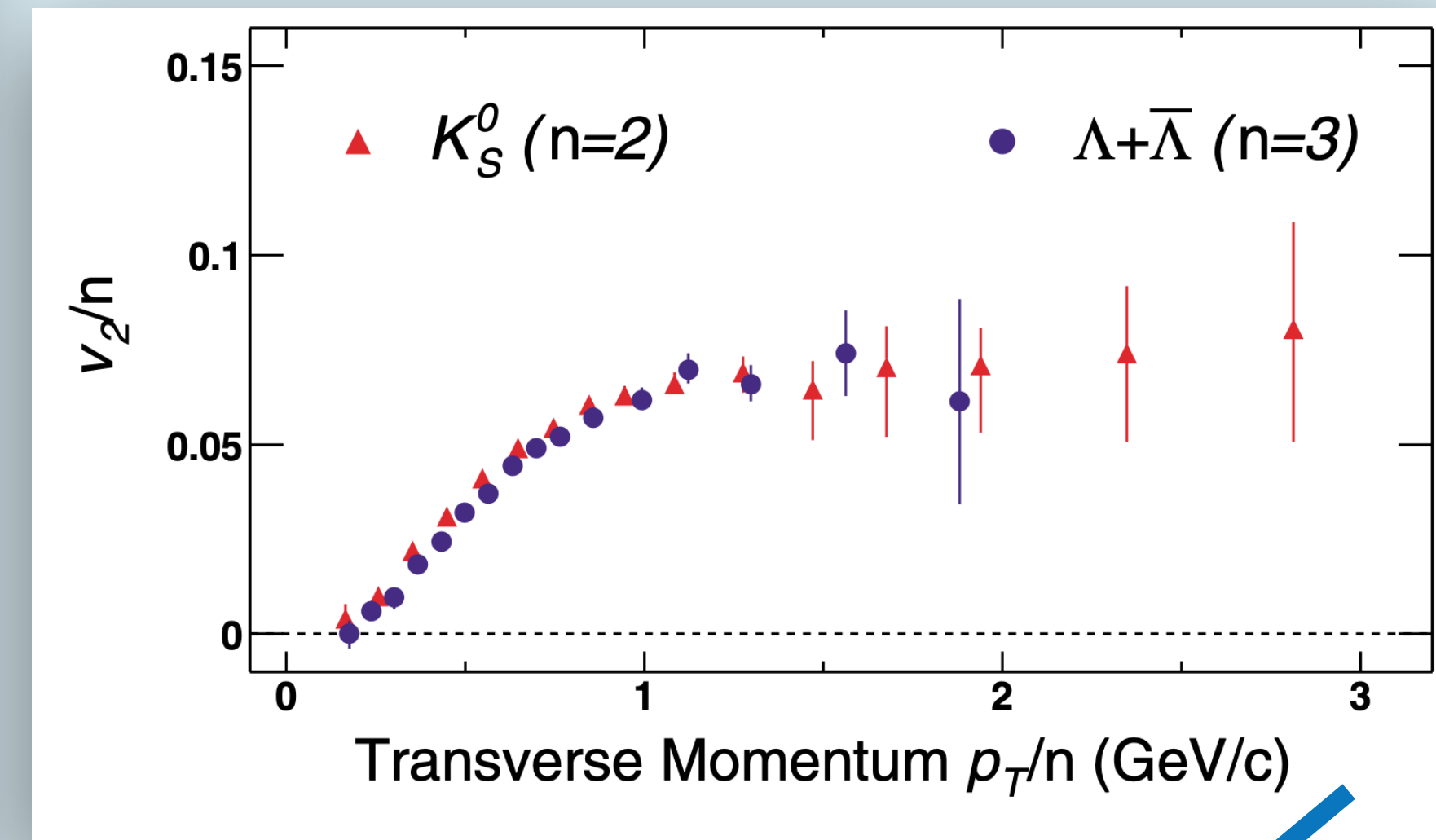
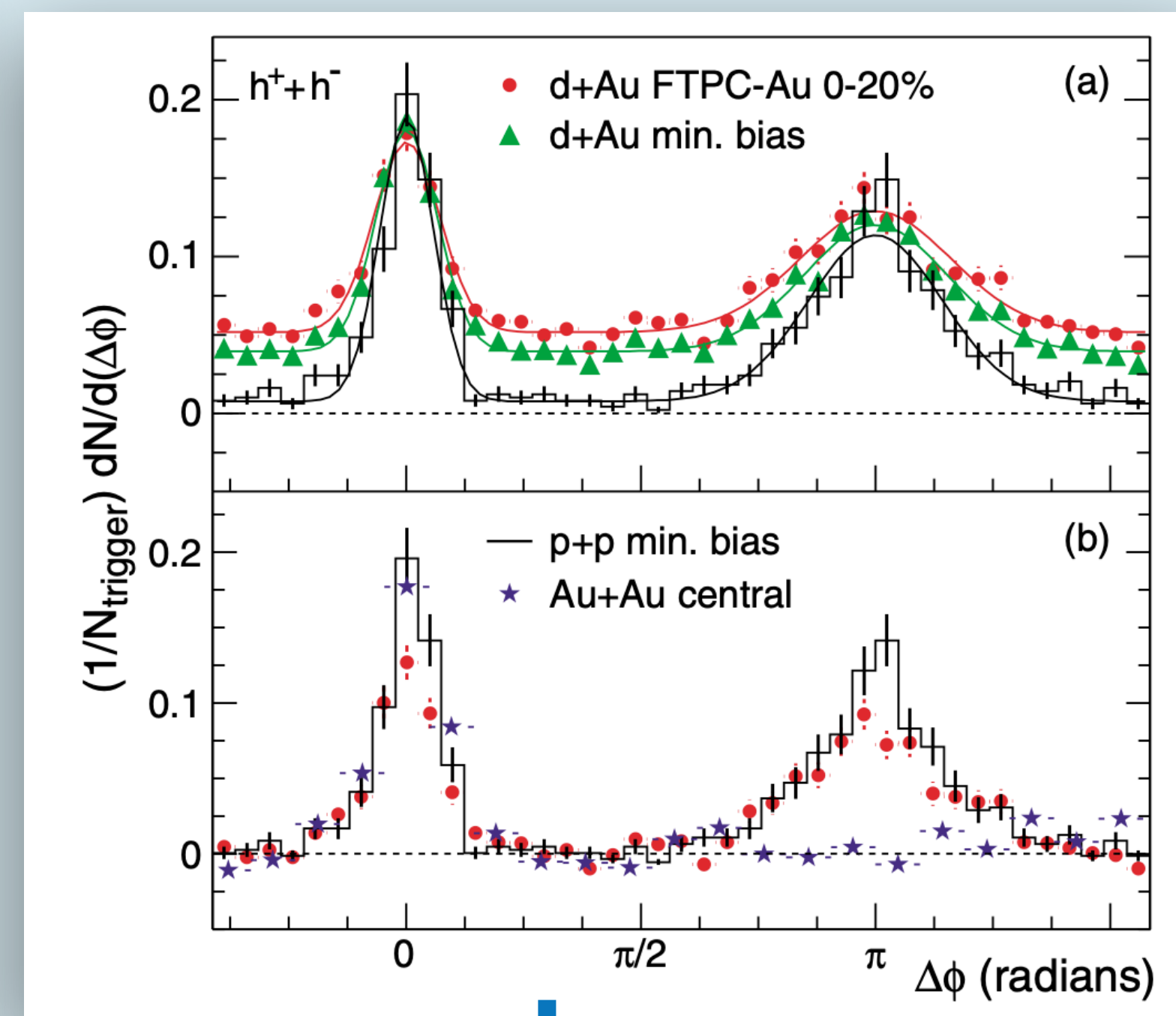
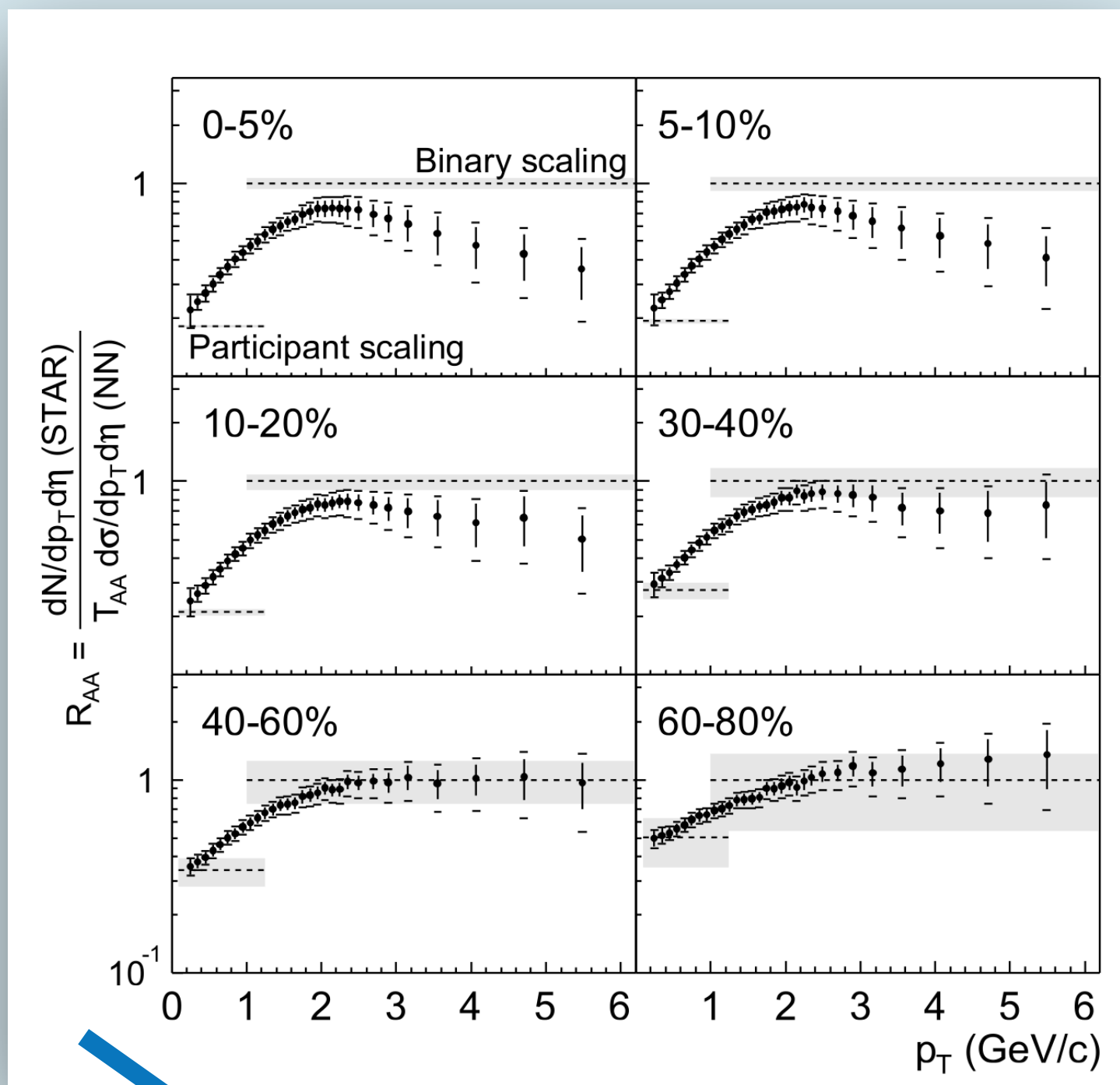
Nuclear Physics A 757 (2005) 102–183

NUCLEAR
PHYSICS A

Experimental and theoretical challenges in the search for the quark–gluon plasma: The STAR Collaboration's critical assessment of the evidence from RHIC collisions

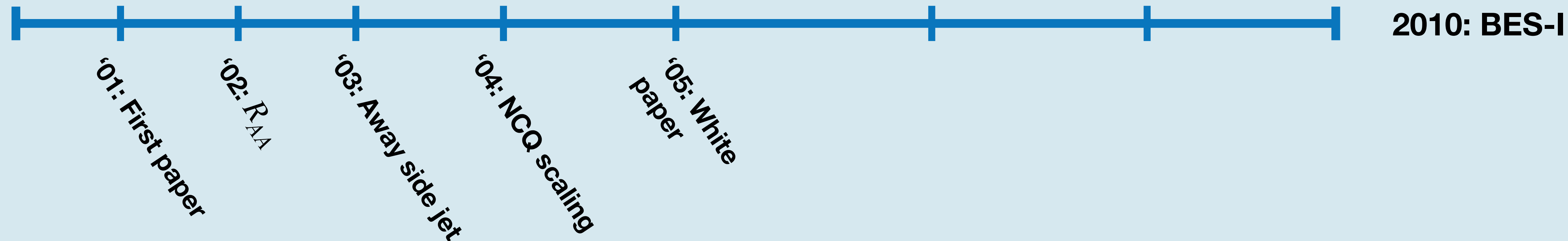
STAR Collaboration

J. Adams^c, M.M. Aggarwal^{ac}, Z. Ahammed^{aq}, J. Amonett^t,
B.D. Anderson^t, D. Arkhipkin^m, G.S. Averichev^l, S.K. Badyal^s,
Y. Bai^{aa}, J. Balewski^q, O. Barannikova^{af}, L.S. Barnby^c, J. Baudot^r,
S. Bekele^{ab}, V.V. Belaga^l, A. Bellingeri-Laurikainen^{al},
R. Bellwied^{at}, J. Bergerⁿ, B.I. Bezverkhny^{av}, S. Bharadwaj^{ag},
A. Bhasin^s, A.K. Bhati^{ac}, V.S. Bhatia^{ac}, H. Bichsel^{as}, J. Bielcik^{av},

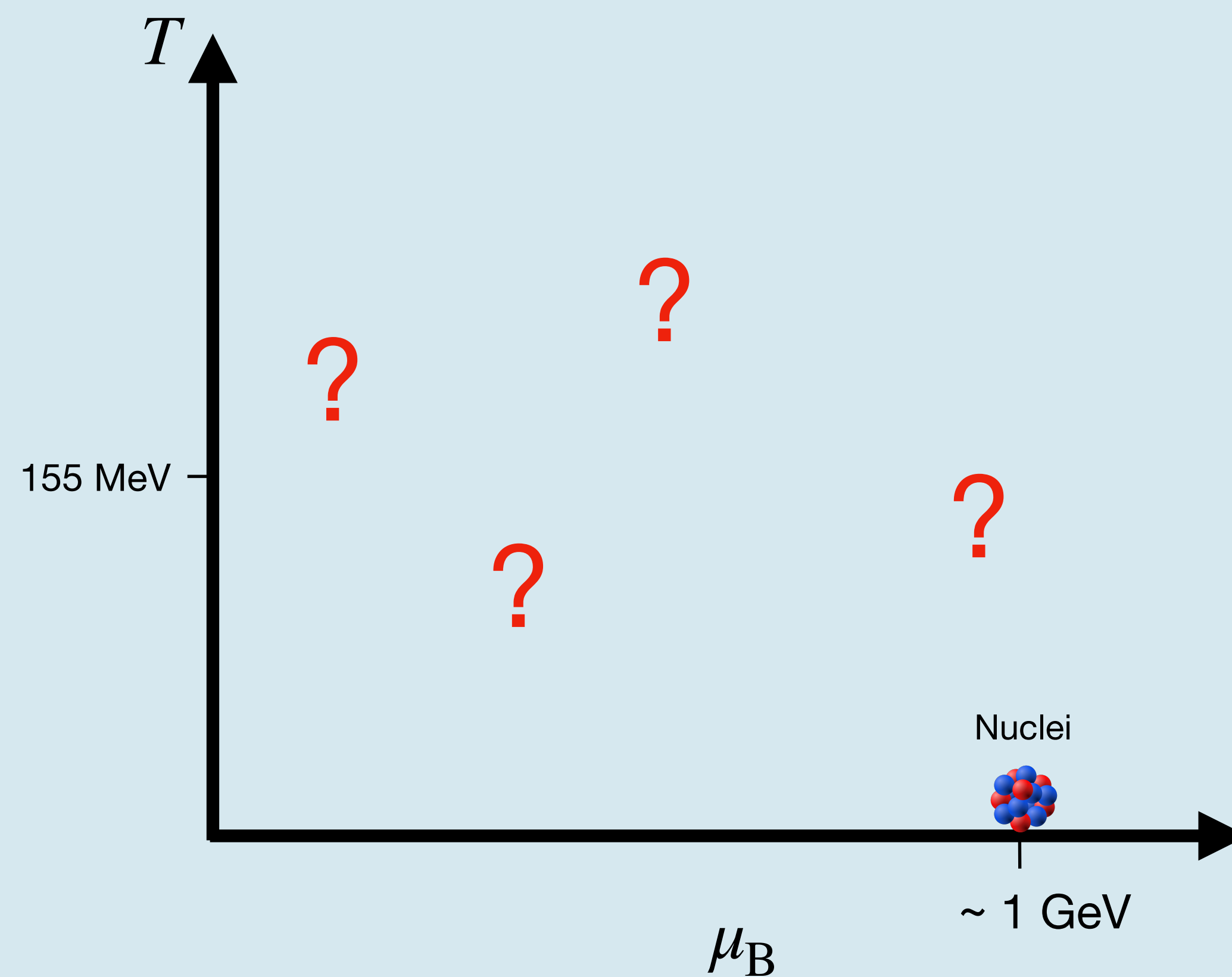


Formation of a strongly interacting QGP at $\mu_B \approx 0$

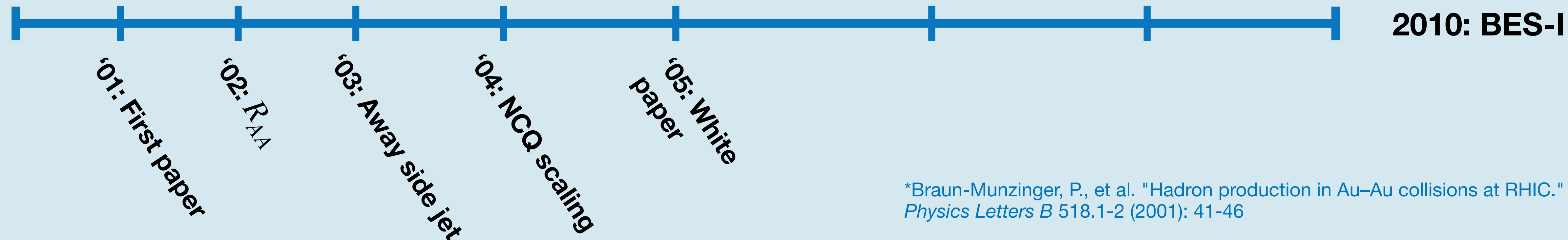
$t = 0$



- **The first 5 years:**
- Established canonical QGP observables
- Characterized the nature of the system produced at top RHIC energies
- Community consensus of a QGP formation
- Established chemical freezeout point*

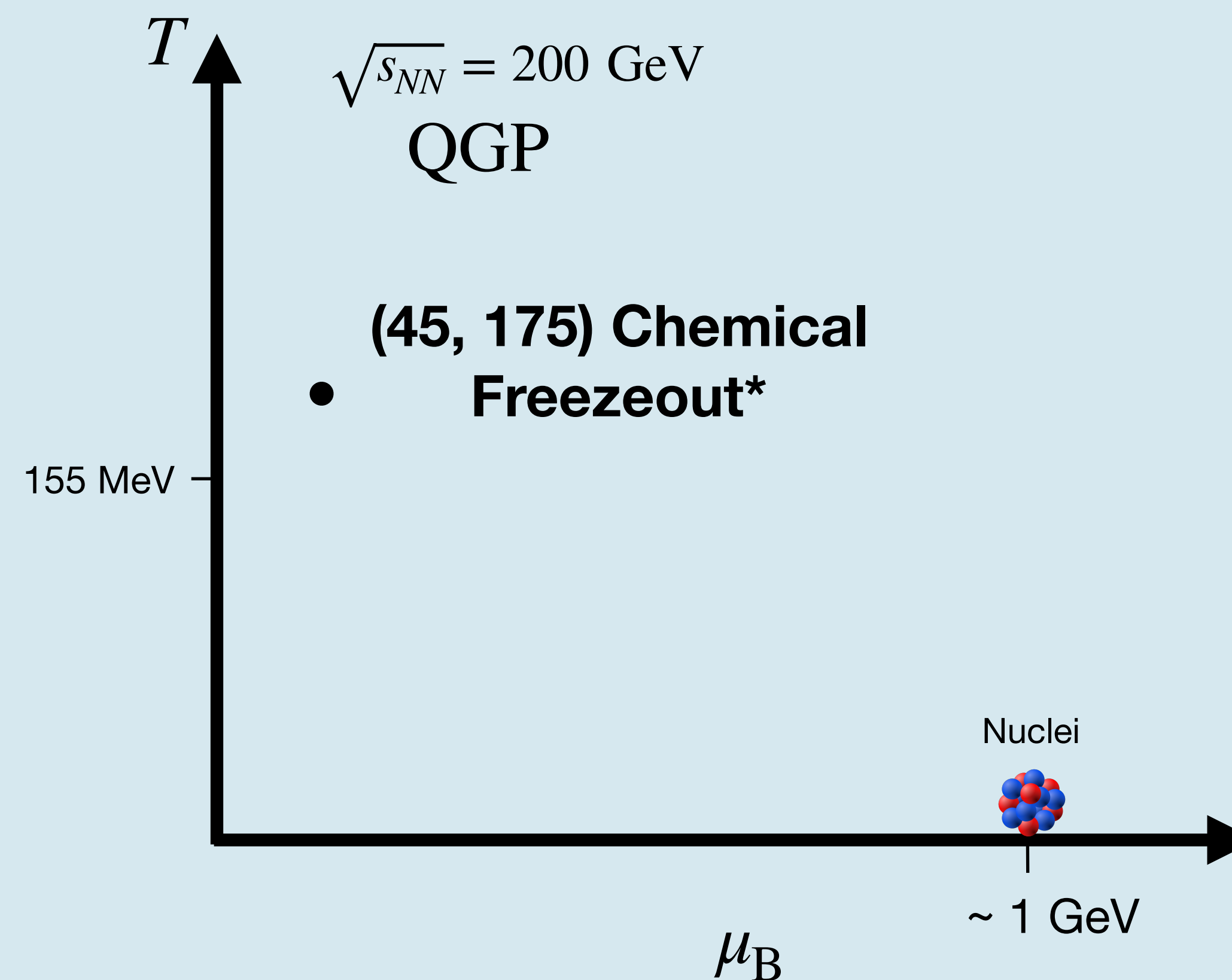


$t = 0$



*Braun-Munzinger, P., et al. "Hadron production in Au–Au collisions at RHIC." *Physics Letters B* 518.1-2 (2001): 41-46

- **The first 5 years:**
- Established canonical QGP observables
- Characterized the nature of the system produced at top RHIC energies
- Community consensus of a QGP formation
- Established chemical freezeout point*



$t = 0$

2010: BES-I

'01: First paper

'02: R_{AA}

'03: Away side jet

'04: NCQ scaling

'05: White paper

'07: 62.4 GeV



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ScienceDirect

Physics Letters B 655 (2007) 104–113

PHYSICS LETTERS B

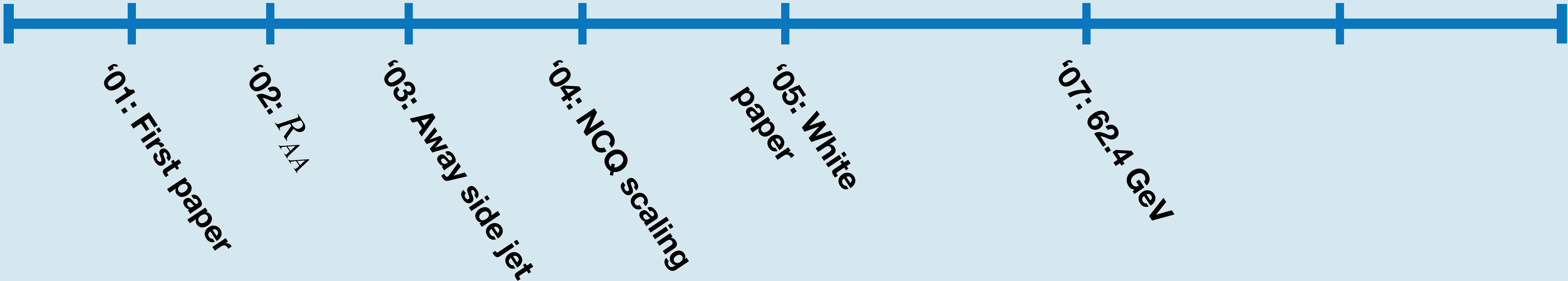
www.elsevier.com/locate/physletb

Energy dependence of $\pi^\pm$, p and $\bar{p}$ transverse momentum spectra for Au + Au collisions at $\sqrt{s_{NN}} = 62.4$ and 200 GeV

STAR Collaboration

B.I. Abelevⁱ, M.M. Aggarwal^{ad}, Z. Ahammed^{as}, B.D. Anderson^t, D. Arkhipkin^m, G.S. Averichev^l, Y. Bai^{ab}, J. Balewski^q, O. Barannikovaⁱ, L.S. Barnby^b, S. Baumgart^{ax}, V.V. Belaga^l, A. Bellingeri-Laurikainen^{an}, R. Bellwied^{av}, F. Benedosso^{ab}, R.R. Bettsⁱ, S. Bharadwaj^{ai}, A. Bhasin^s, A.K. Bhati^{ad}, H. Bichsel^{au}, J. Bielcik^{ax}, J. Bielcikova^{ax}, A. Billmeier^{av}, L.C. Bland^c, S.-L. Blyth^v, M. Bombara^b, B.E. Bonner^{aj}, M. Botje^{ab}, J. Bouchet^{an}, A.V. Brandin^z, A. Bravar^c, T.P. Burton^b, M. Bystersky^k, R.V. Cadman^a, X.Z. Cai^{am}, H. Caines^{ax}, M. Calderón de la Barca Sánchez^f, J. Callnerⁱ, O. Catu^{ax}, D. Cebra^f, Z. Chajecki^{ac}, P. Chaloupka^k,

t = 0



2010: BES-I

PHYSICAL REVIEW C 75, 054906 (2007)

Mass, quark-number, and $\sqrt{s_{NN}}$ dependence of the second and fourth flow harmonics in ultrarelativistic nucleus-nucleus collisions

B. I. Abelev,⁵⁰ M. M. Aggarwal,³⁰ Z. Ahammed,⁴⁵ B. D. Anderson,²⁰ D. Arkhipkin,¹³ G. S. Averichev,¹² Y. Bai,²⁸ J. Balewski,¹⁷ O. Barannikova,⁹ L. S. Barnby,² J. Baudot,¹⁸ S. Baumgart,⁵⁰ S. Bekele,²⁹ V. V. Belaga,¹² A. Bellingeri-Laurikainen,⁴⁰ R. Bellwied,⁴⁸ F. Benedosso,²⁸ R. R. Betts,⁹ S. Bhardwaj,³⁵ A. Bhasin,¹⁹ A. K. Bhati,³⁰ H. Bichsel,⁴⁷ J. Bielcik,⁵⁰ J. Bielcikova,⁵⁰ L. C. Bland,³ S.-L. Blyth,²² M. Bombara,² B. E. Bonner,³⁶ M. Botje,²⁸ J. Bouchet,⁴⁰ A. V. Brandin,²⁶ A. Bravar,³ T. P. Burton,² M. Bystersky,¹¹ R. V. Cadman,¹ X. Z. Cai,³⁹ H. Caines,⁵⁰ M. Calderón de la Barca Sánchez,⁶ J. Callner,⁹ J. Castillo,²⁸ O. Catu,⁵⁰ D. Cebra,⁶ Z. Chajecki,²⁹ P. Chaloupka,¹¹ S. Chattopadhyay,⁴⁵ H. F. Chen,³⁸ J. H. Chen,³⁹ J. Cheng,⁴³ M. Cherney,¹⁰ A. Chikanian,⁵⁰ W. Christie,³ S. U. Chung,³ J. P. Coffin,¹⁸ T. M. Cormier,⁴⁸ M. R. Cosentino,³⁷ J. G. Cramer,⁴⁷ H. J. Crawford,⁵ D. Das,⁴⁵ S. Das,⁴⁵ S. Dash,¹⁵ M. Daugherty,⁴² M. M. de Moura,³⁷ T. G. Dedovich,¹² M. DePhillips,³ A. A. Derevschikov,³² L. Didenko,³ T. Dietel,¹⁴ P. Djawotho,¹⁷ S. M. Dogra,¹⁹ X. Dong,³⁸ J. L. Drachenberg,⁴¹ J. E. Draper,⁶ F. Du,⁵⁰ V. B. Dunin,¹² J. C. Dunlop,³ M. R. Dutta Mazumdar,⁴⁵ V. Eckardt,²⁴ W. R. Edwards,²² L. G. Efimov,¹² V. Emelianov,²⁶ J. Engelage,⁵ G. Eppley,³⁶ B. Erasmus,⁴⁰ M. Estienne,¹⁸ P. Fachini,³ R. Fatemi,²³ J. Fedorisin,¹² K. Filimonov,²² P. Filip,¹³ E. Finch,⁵⁰ V. Fine,³ Y. Fisyak,³ J. Fu,⁴⁹ C. A. Gagliardi,⁴¹ L. Gaillard,² M. S. Ganti,⁴⁵ E. Garcia-Solis,⁹ V. Ghazikhanian,⁷ P. Ghosh,⁴⁵ Y. G. Gorbunov,¹⁰ H. Gos,⁴⁶ O. Grebenyuk,²⁸ D. Grosnick,⁴⁴ S. M. Guertin,⁷ K. S. F. F. Guimaraes,³⁷ N. Gupta,¹⁹ B. Haag,⁶ T. J. Hallman,³ A. Hamed,⁴¹ J. W. Harris,⁵⁰ W. He,¹⁷ M. Heinz,⁵⁰ T. W. Henry,⁴¹ S. Hepplemann,³¹ B. Hippolyte,¹⁸ A. Hirsch,³³ E. Hjort,²² A. M. Hoffman,²³ G. W. Hoffmann,⁴² D. Hofman,⁹ R. Hollis,⁹



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Physics Letters B 655 (2007) 104–113

Energy dependence of $\pi^\pm$, p and $\bar{p}$ transverse
for Au + Au collisions at $\sqrt{s_{NN}} = 62.4$ A

STAR Collaboration

B.I. Abelevⁱ, M.M. Aggarwal^{ad}, Z. Ahammed^{as}, B.D. Anderson^t, I.
Y. Bai^{ab}, J. Balewski^q, O. Barannikovaⁱ, L.S. Barnby^b, S. B.
A. Bellingeri-Laurikainen^{an}, R. Bellwied^{av}, F. Benedosso^{ab}, R.
A. Bhasin^s, A.K. Bhati^{ad}, H. Bichsel^{au}, J. Bielcik^{ax}, J. Bielcikova^a,
S.-L. Blyth^v, M. Bombara^b, B.E. Bonner^{aj}, M. Botje^{ab}, J. Bouchet^a,
T.P. Burton^b, M. Bystersky^k, R.V. Cadman^a, X.Z. Cai^{am}, H. Caines^{ax},
M. Calderón de la Barca Sánchez^f, J. Callnerⁱ, O. Catu^{ax}, D. Cebra^f, Z. Chajecki^{ac}, P. Chaloupka^k,

$t = 0$

2010: BES-I

'01: First p

'02: R A

'03: Awa

'04: NCC

'05: Whi
paper

'07: 62.4



Energy

B.I. Abelevⁱ,
Y. Bai
A. Bellin
A. Bhasin^s,
S.-L. Blyth^v
M. Calderón

QGP signatures still present at 62.4 GeV!
Characterizing more regions of the phase diagram...

onics in

i,²⁸ J. Balewski,¹⁷
aurikainen,⁴⁰
Bielcik,⁵⁰
Brandin,²⁶
rca Sánchez,⁶
J. H. Chen,³⁹
R. Cosentino,³⁷
Dedovich,¹²
L. Drachenberg,⁴¹
L. G. Efimov,¹²
edorisin,¹²
S. Ganti,⁴⁵
S. M. Guertin,⁷
T. W. Henry,⁴¹
n,⁹ R. Hollis,⁹

$t = 0$

2010: BES-I

'01: First

'02: RAA

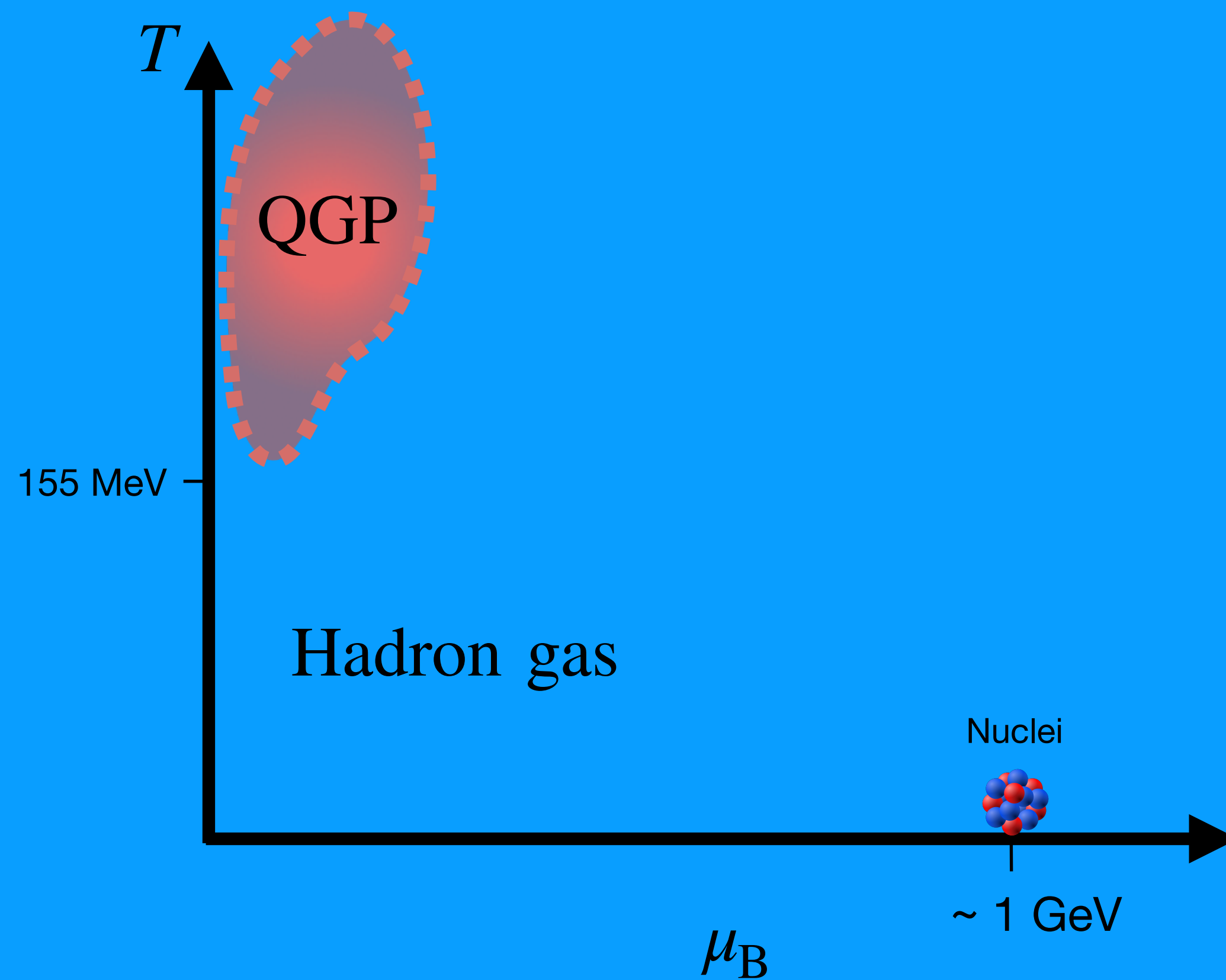
'03: Awa

'04: NCO

'05: White
paper

'07: 62.4

Pushing to higher $\mu_B \rightarrow$

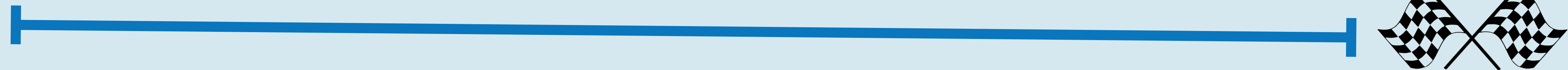


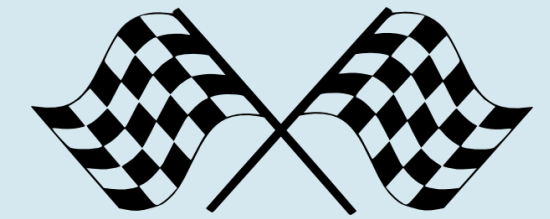
armonics in

Y. Bai,²⁸ J. Balewski,¹⁷
eri-Laurikainen,⁴⁰
l,⁴⁷ J. Bielcik,⁵⁰
A. V. Brandin,²⁶
la Barca Sánchez,⁶
Chen,³⁸ J. H. Chen,³⁹
M. R. Cosentino,³⁷
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³⁸ J. L. Drachenberg,⁴¹
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J. Fedorisin,¹²
M. S. Ganti,⁴⁵
ick,⁴⁴ S. M. Guertin,⁷
Heinz,⁵⁰ T. W. Henry,⁴¹
ofman,⁹ R. Hollis,⁹

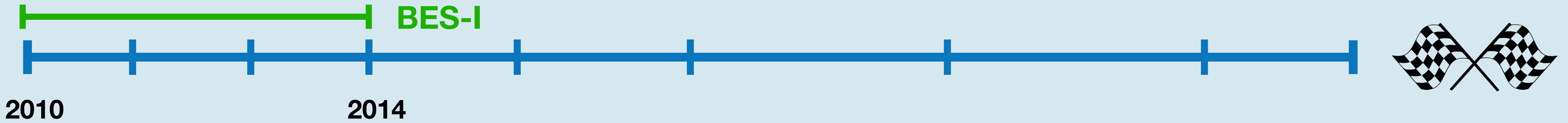
The beam energy scans

2010: BES-I



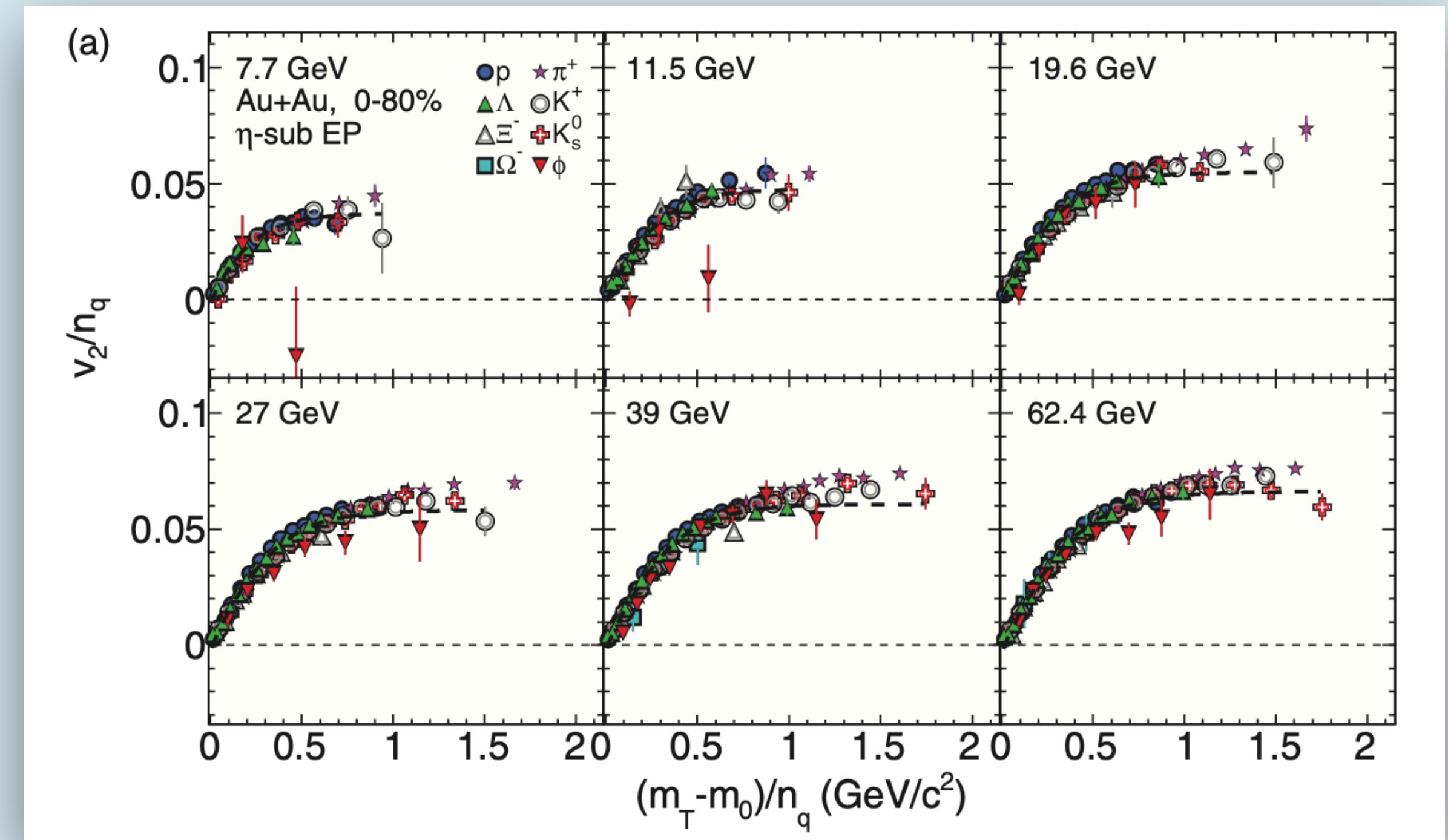
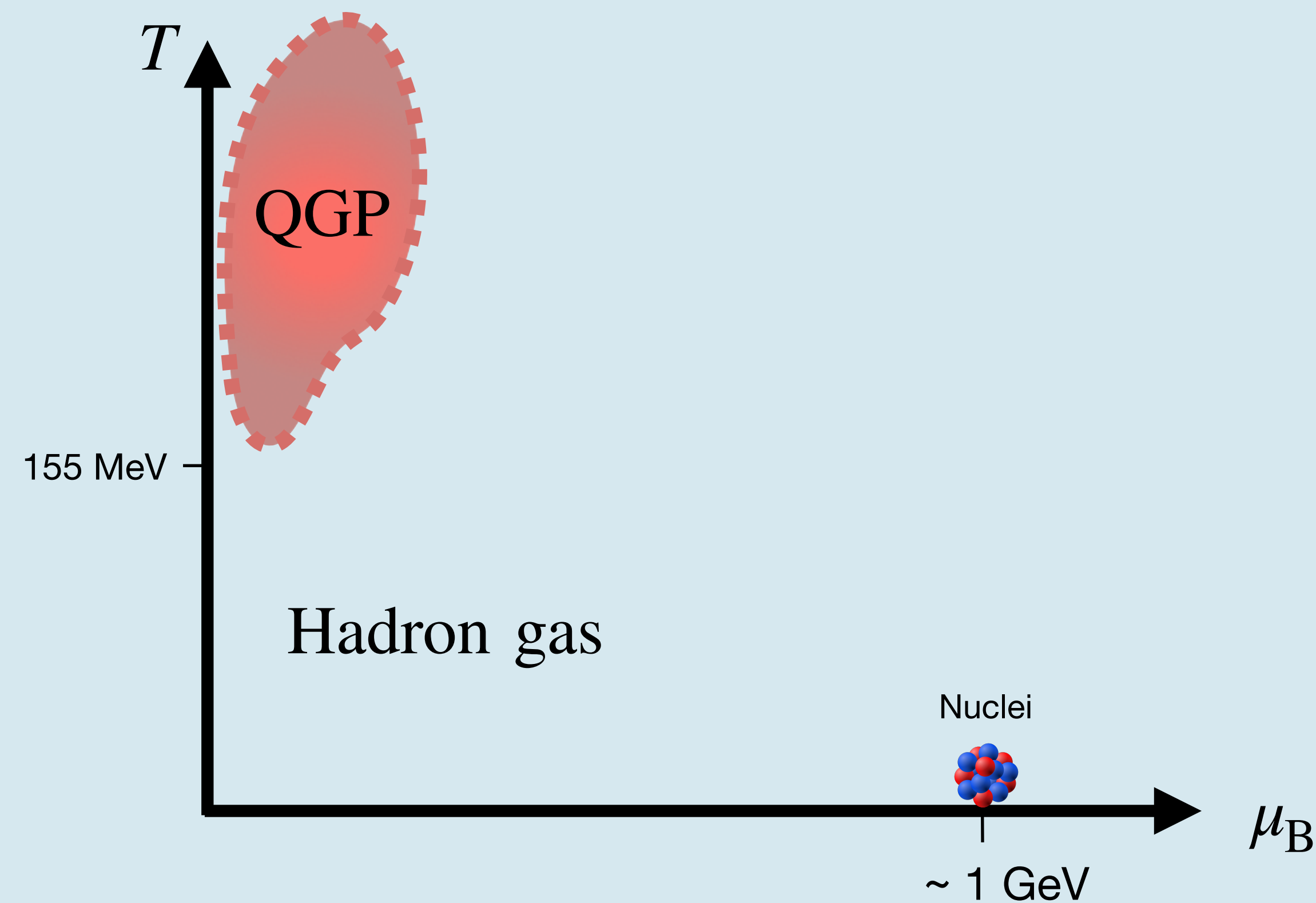


- **Now that there was consensus on the existence of the QGP:**
 - At what temperatures and densities does it form?
 - What is the nature of the phase transition between QGP and hadron gas?
 - If it is first order, where is the critical point?
 - Can we build an empirical map of the QCD phase diagram?
 - These questions can be answered with beam-energy scans

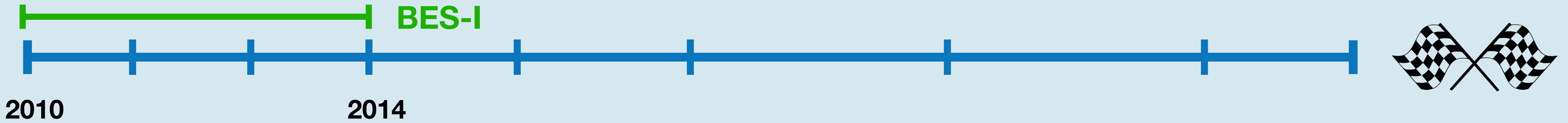


- BES-I:**

- QGP signatures exist down to 7.7 GeV

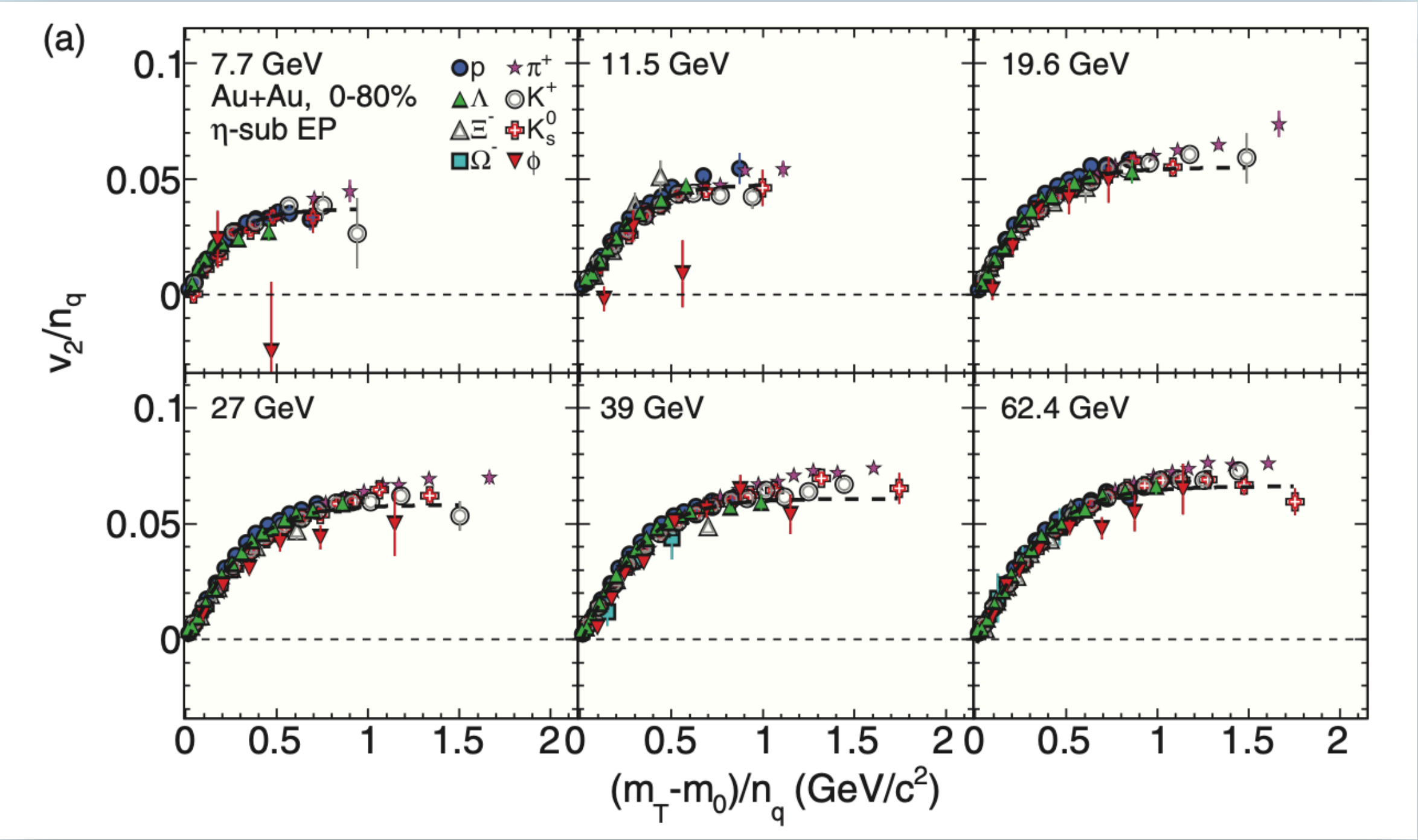
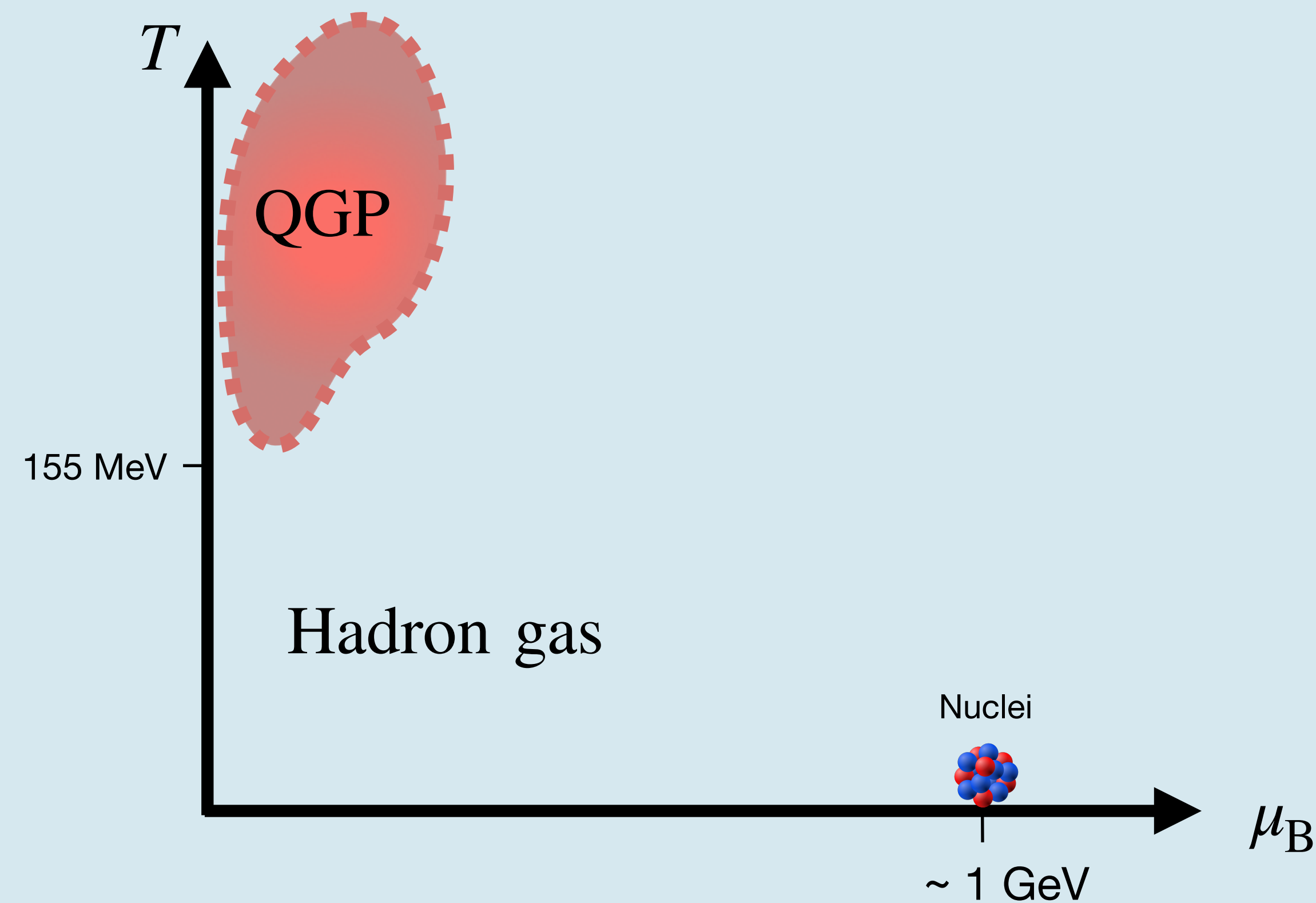


Adamczyk, L., et al. "Elliptic flow of identified hadrons in Au+ Au collisions at s NN= 7.7–62.4 GeV." *Physical Review C—Nuclear Physics* 88.1 (2013): 014902.

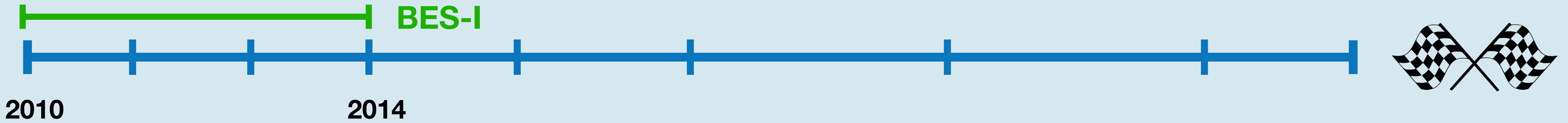


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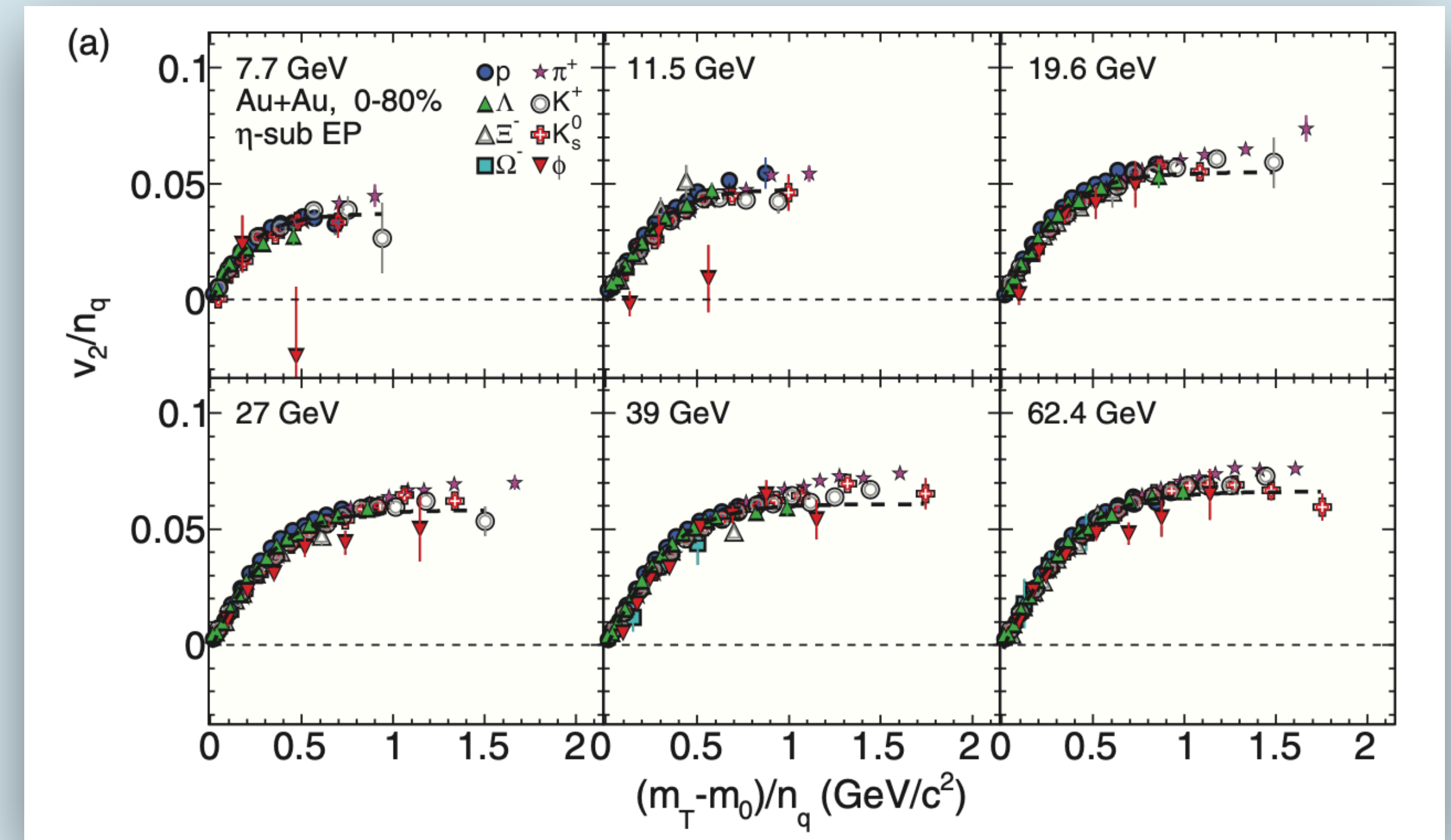
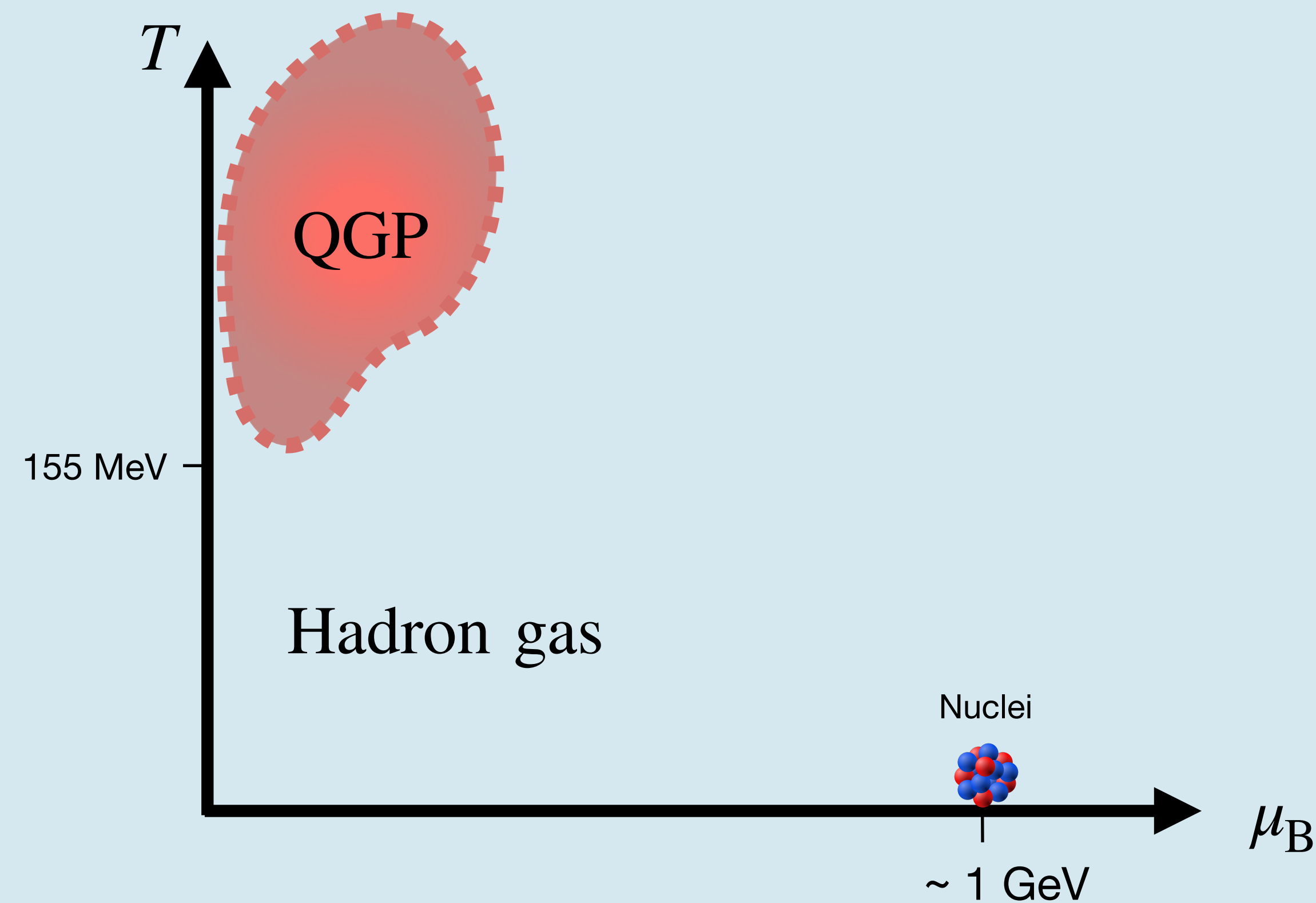


Adamczyk, L., et al. "Elliptic flow of identified hadrons in Au+ Au collisions at s NN= 7.7–62.4 GeV." *Physical Review C—Nuclear Physics* 88.1 (2013): 014902.

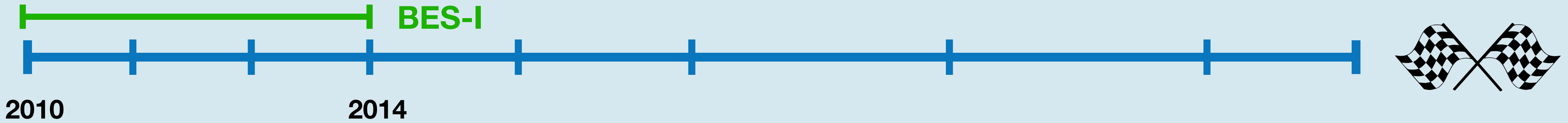


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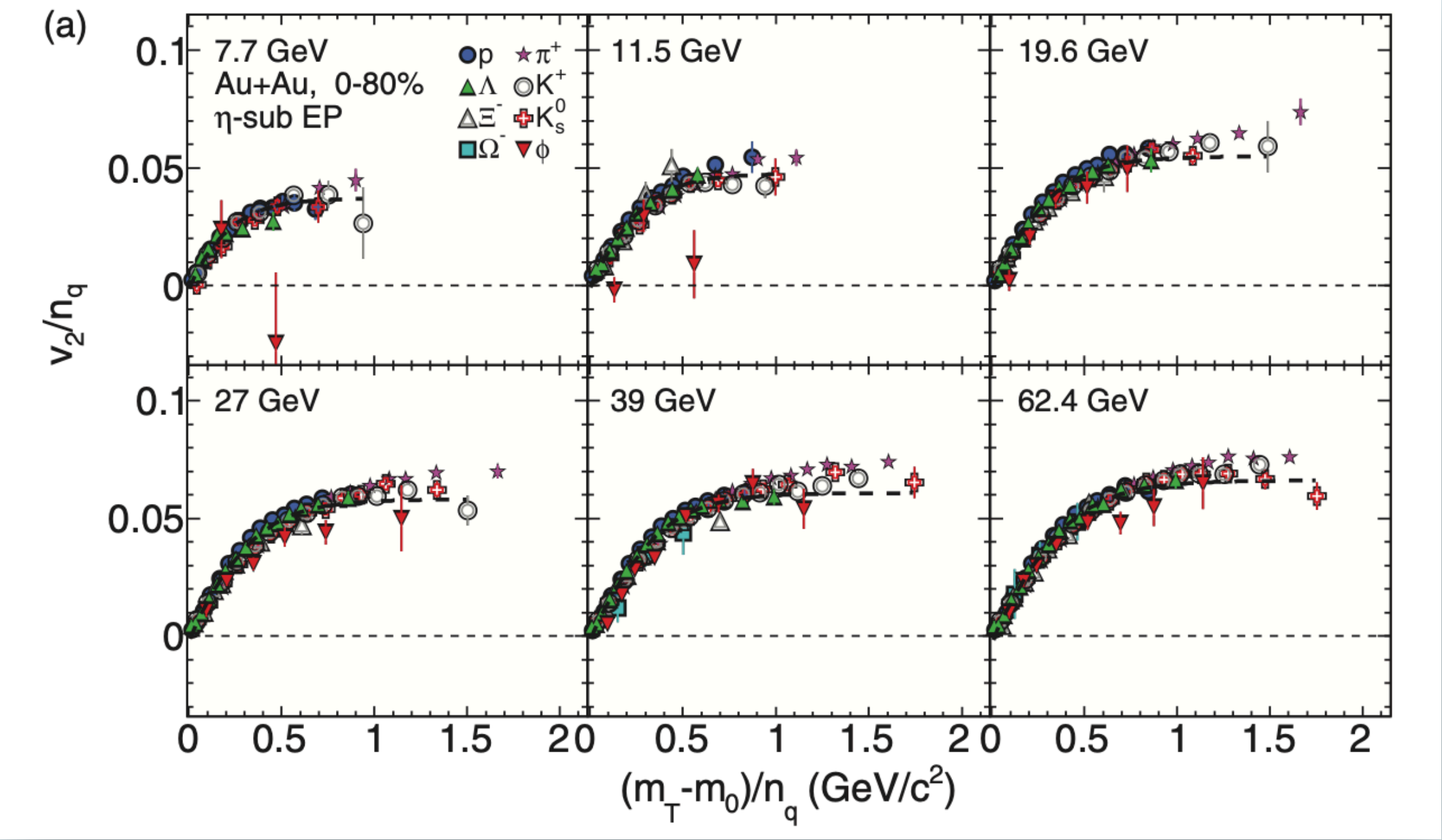
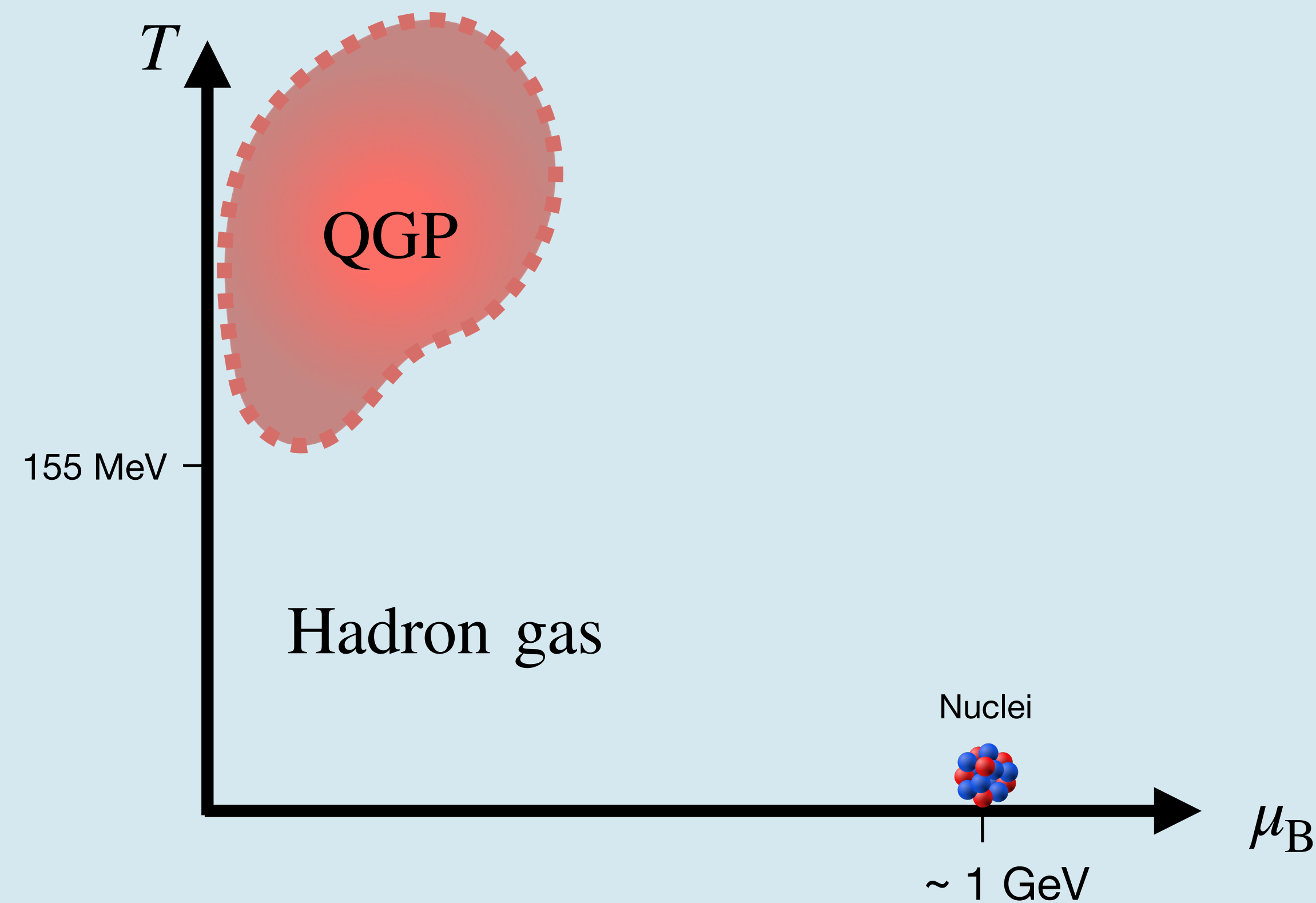


Adamczyk, L., et al. "Elliptic flow of identified hadrons in Au+ Au collisions at s NN= 7.7–62.4 GeV." *Physical Review C—Nuclear Physics* 88.1 (2013): 014902.

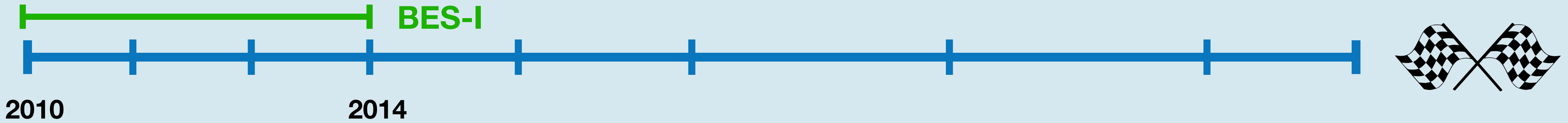


- BES-I:**

- QGP signatures exist down to 7.7 GeV

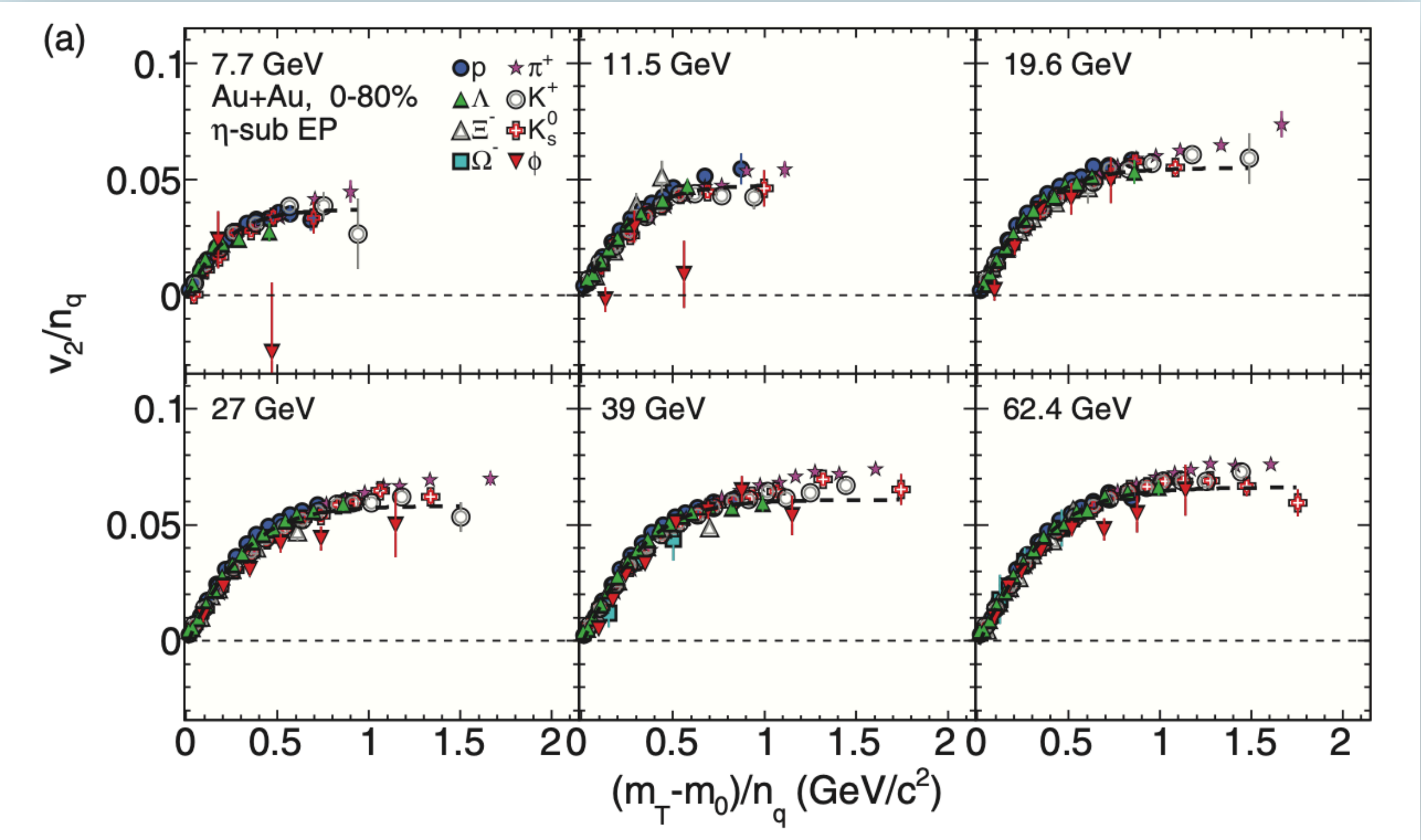
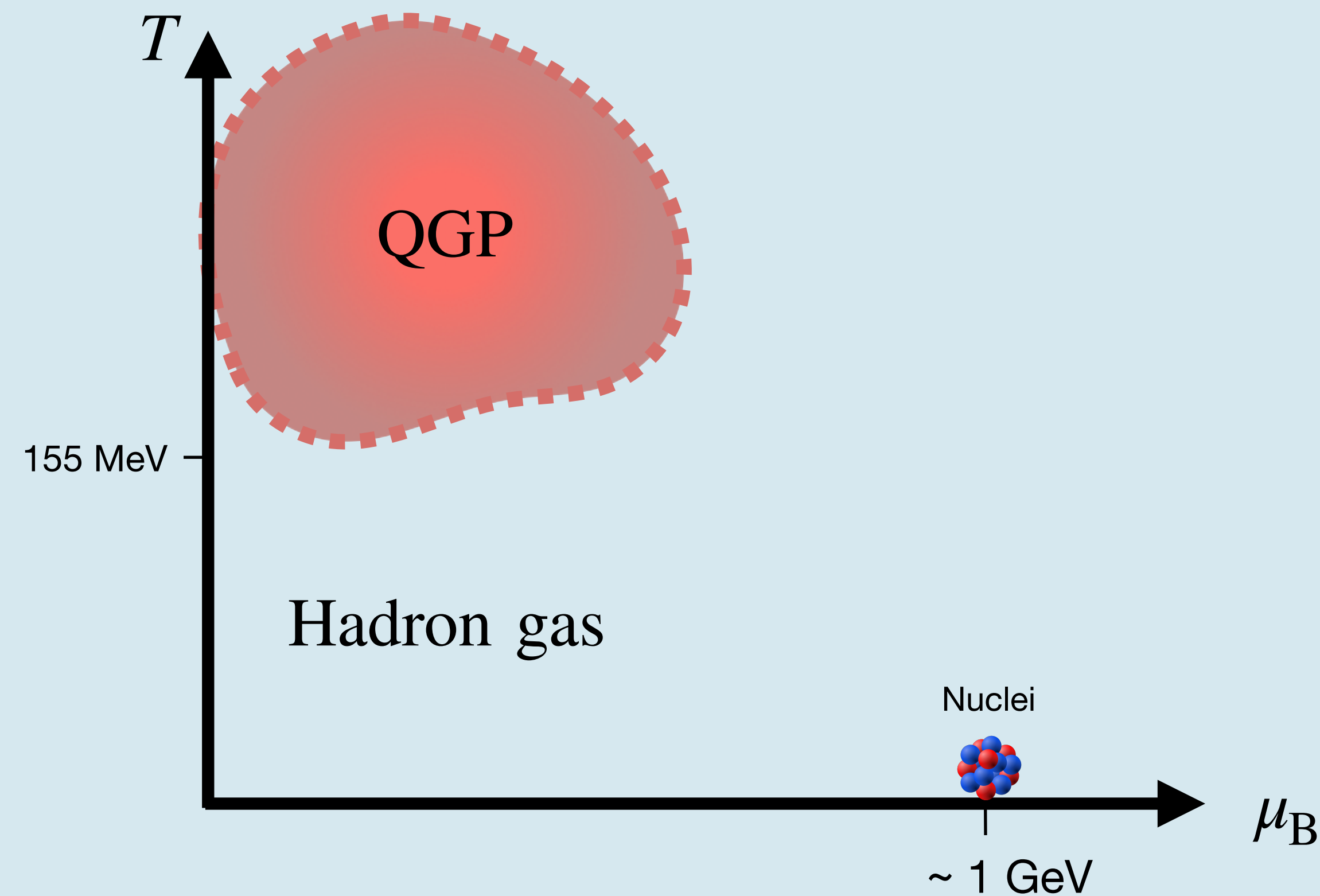


Adamczyk, L., et al. "Elliptic flow of identified hadrons in Au+ Au collisions at s NN= 7.7–62.4 GeV." *Physical Review C—Nuclear Physics* 88.1 (2013): 014902.

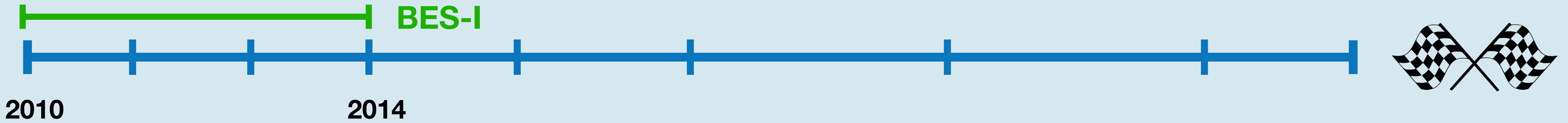


• **BES-I:**

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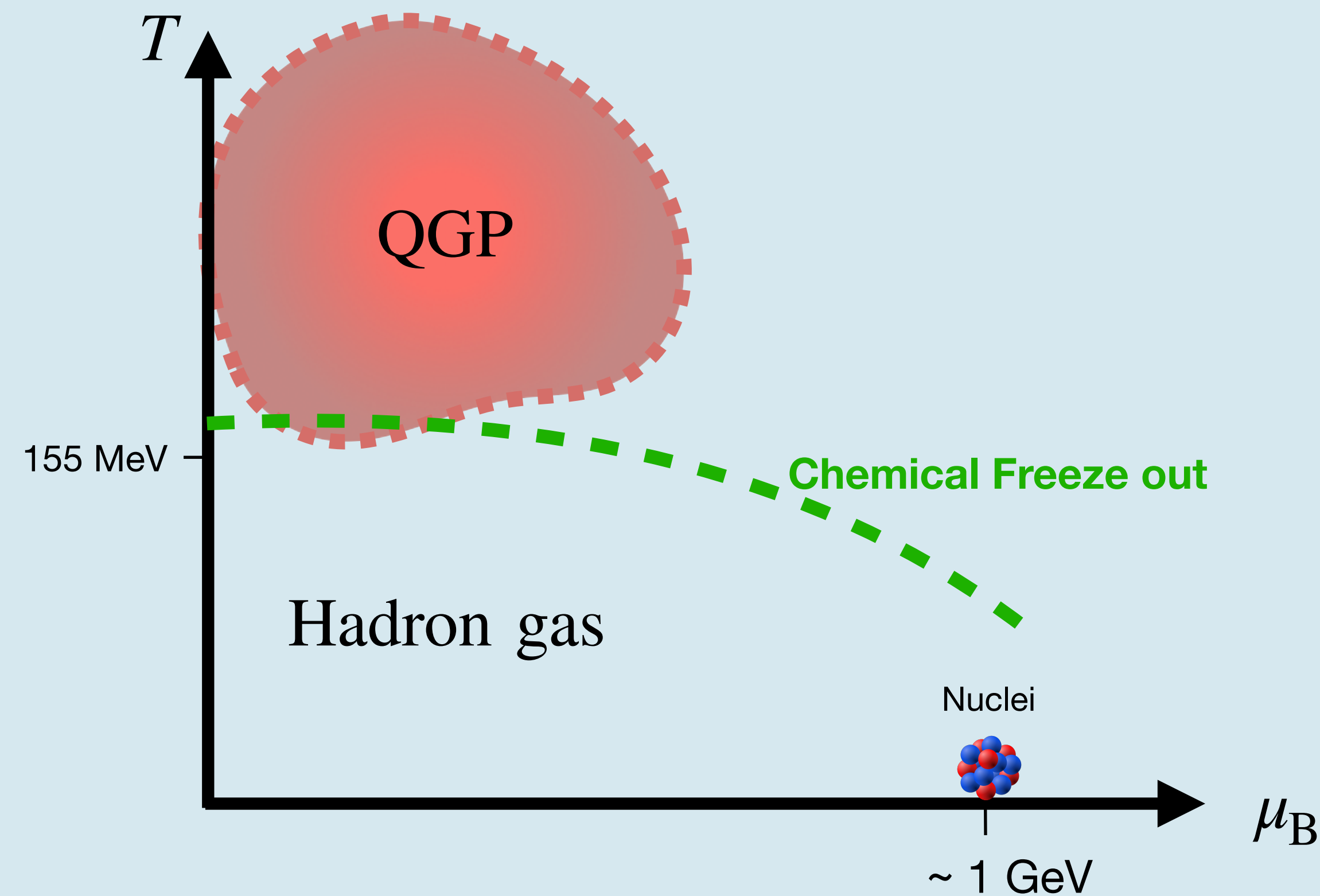


Adamczyk, L., et al. "Elliptic flow of identified hadrons in Au+ Au collisions at s NN= 7.7–62.4 GeV." *Physical Review C—Nuclear Physics* 88.1 (2013): 014902.

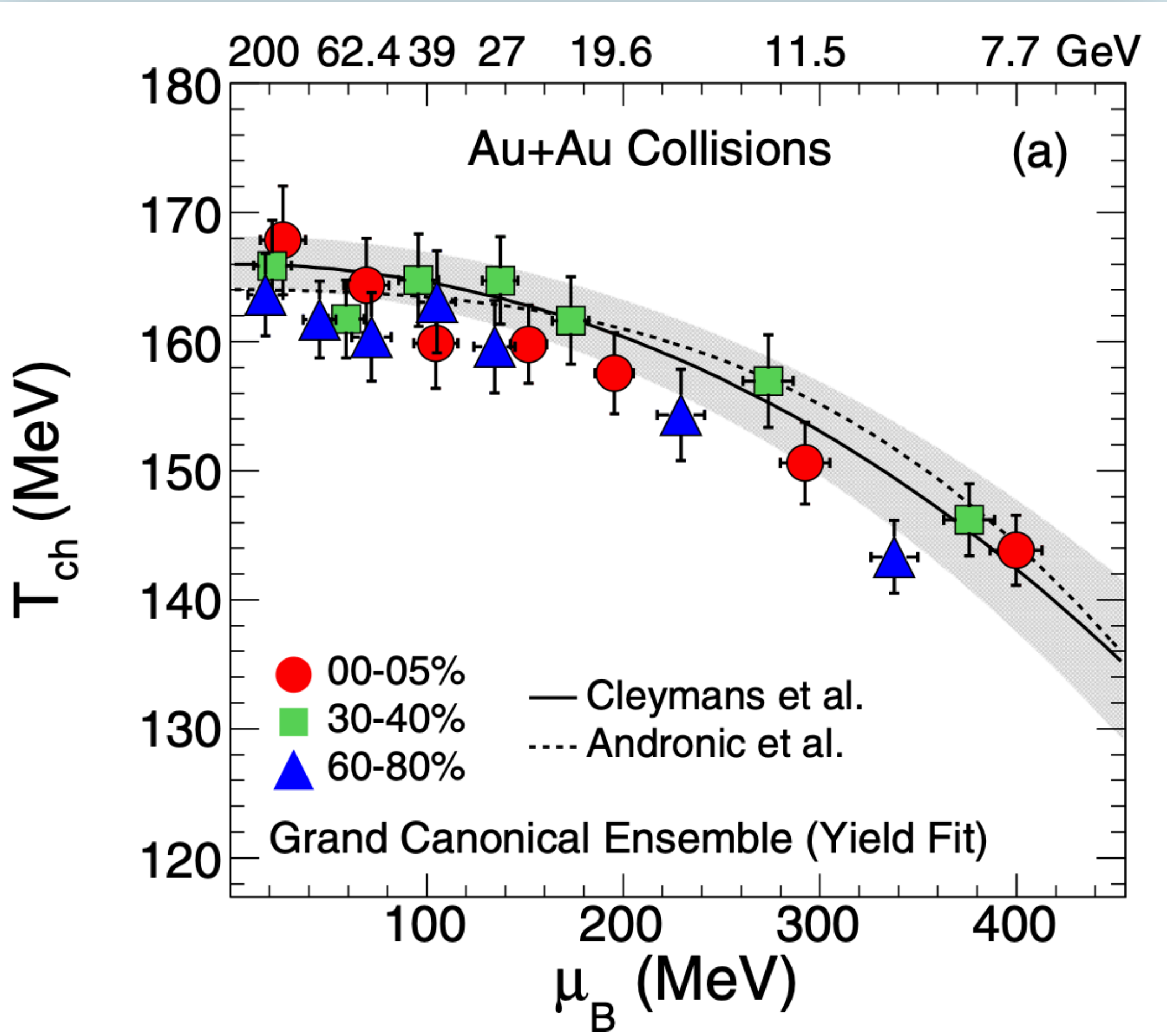


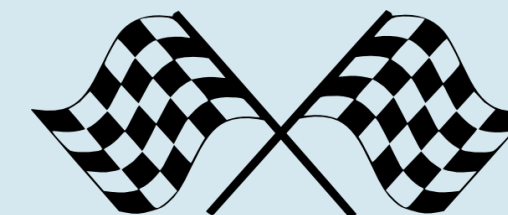
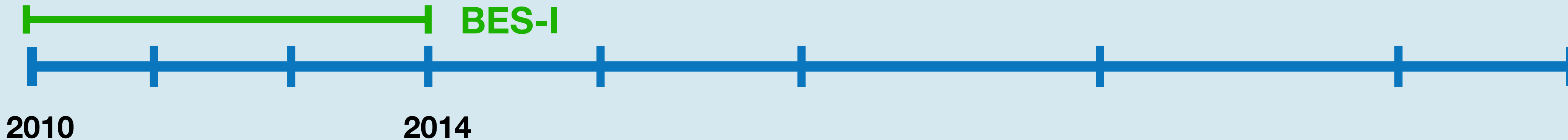
• **BES-I:**

- Established a *chemical* freezeout line



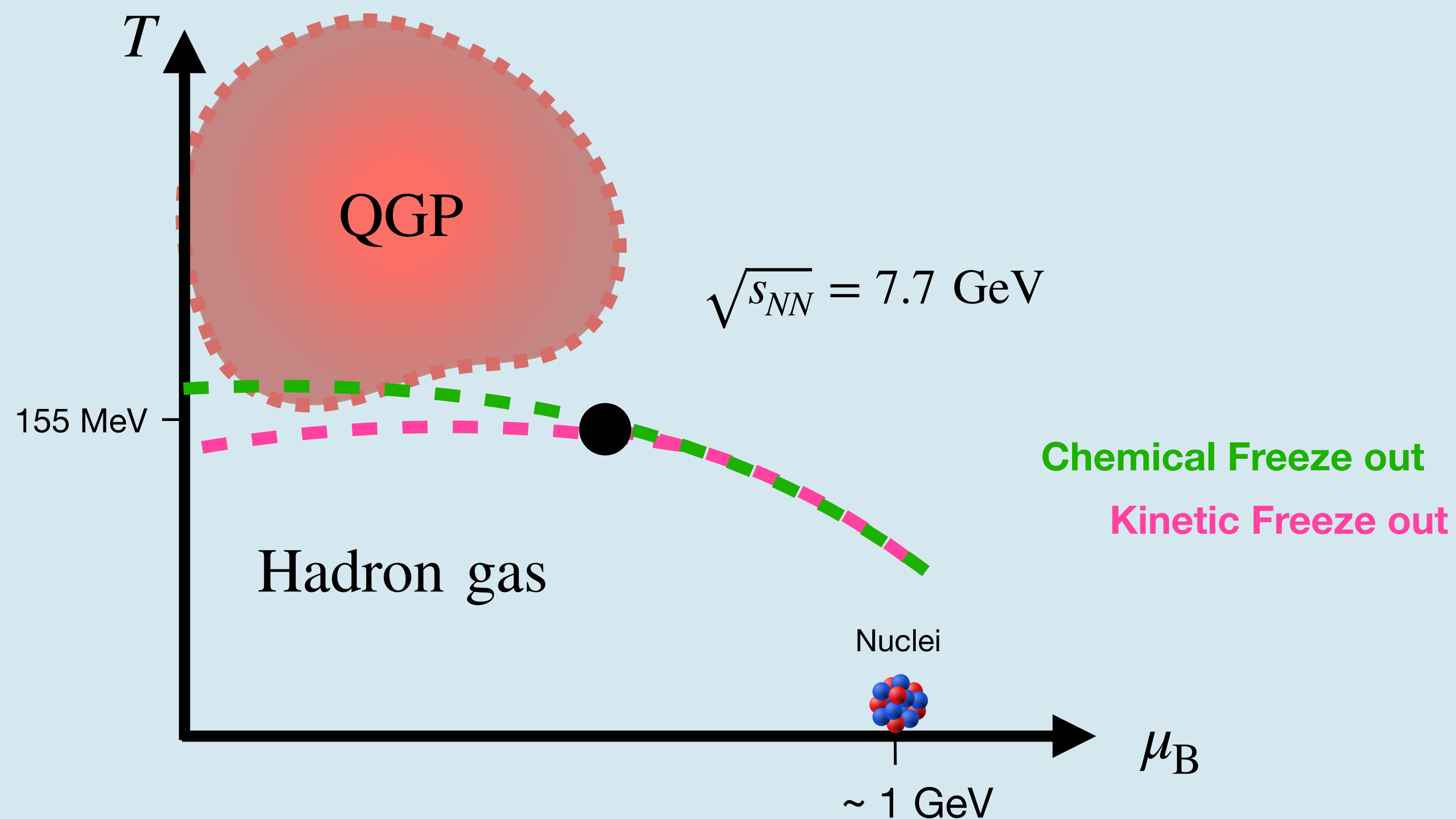
STAR Collaboration (2017). Bulk properties of the medium produced in relativistic heavy-ion collisions from the beam energy scan program. *Physical Review C*, 96(4), 044904



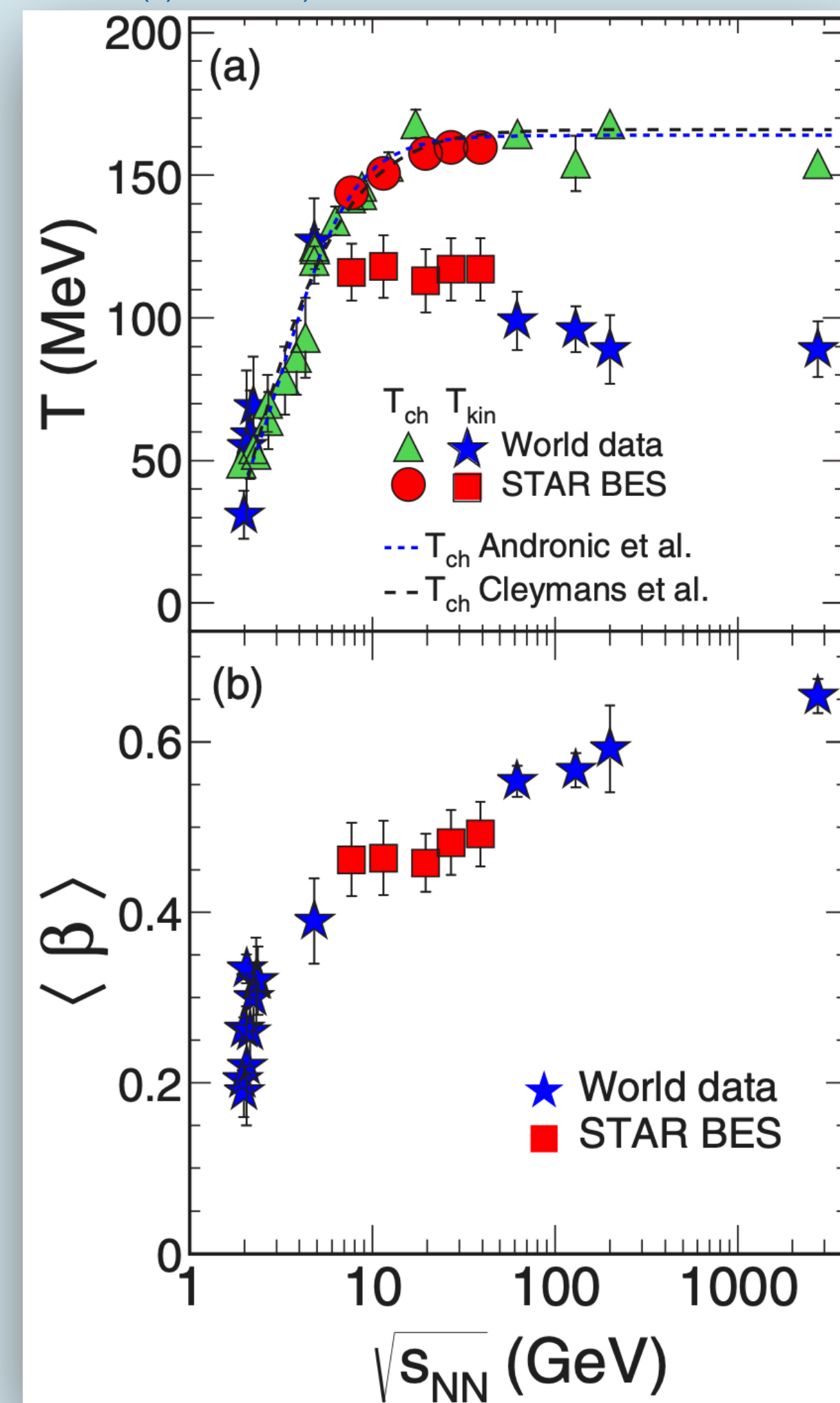


- BES-I:**

- Established a *kinetic* freezeout line



STAR Collaboration (2017). Bulk properties of the medium produced in relativistic heavy-ion collisions from the beam energy scan program. *Physical Review C*, 96(4), 044904)





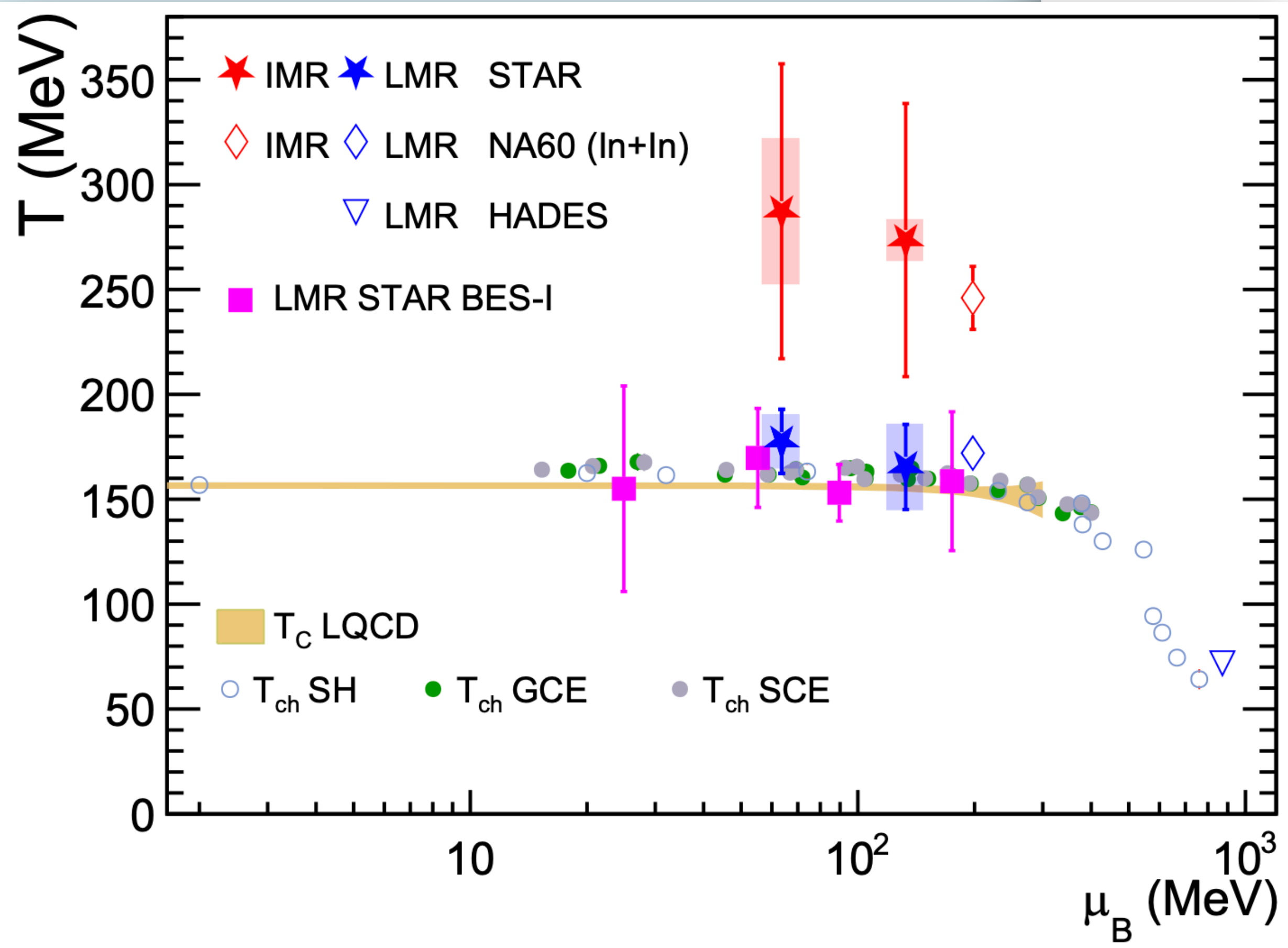
nature communications



Article

<https://doi.org/10.1038/s41467-025-63216-5>

Temperature measurement of Quark-Gluon plasma at different stages



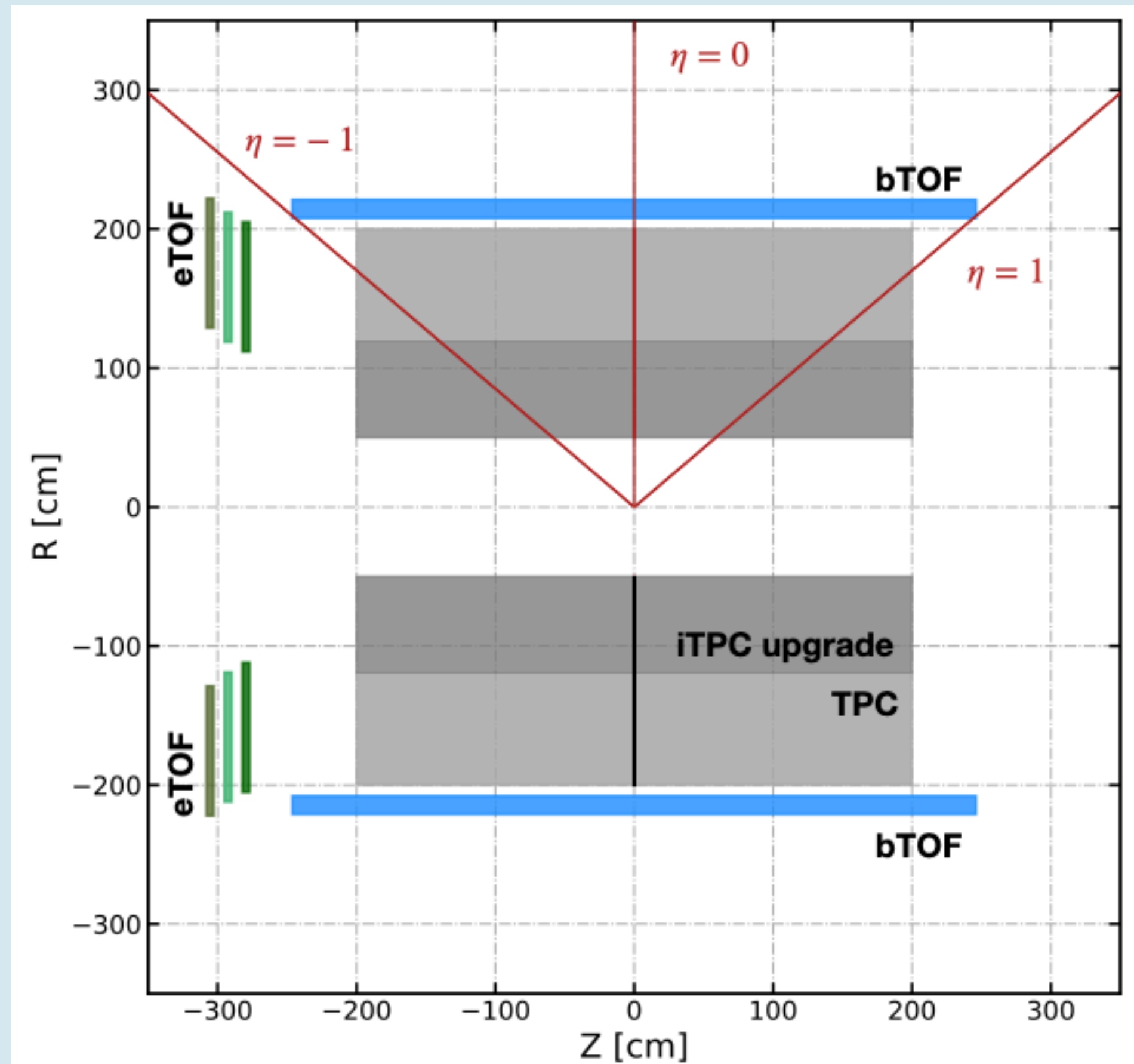
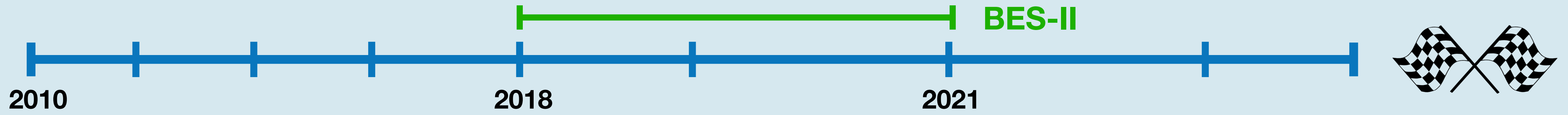
nature communications



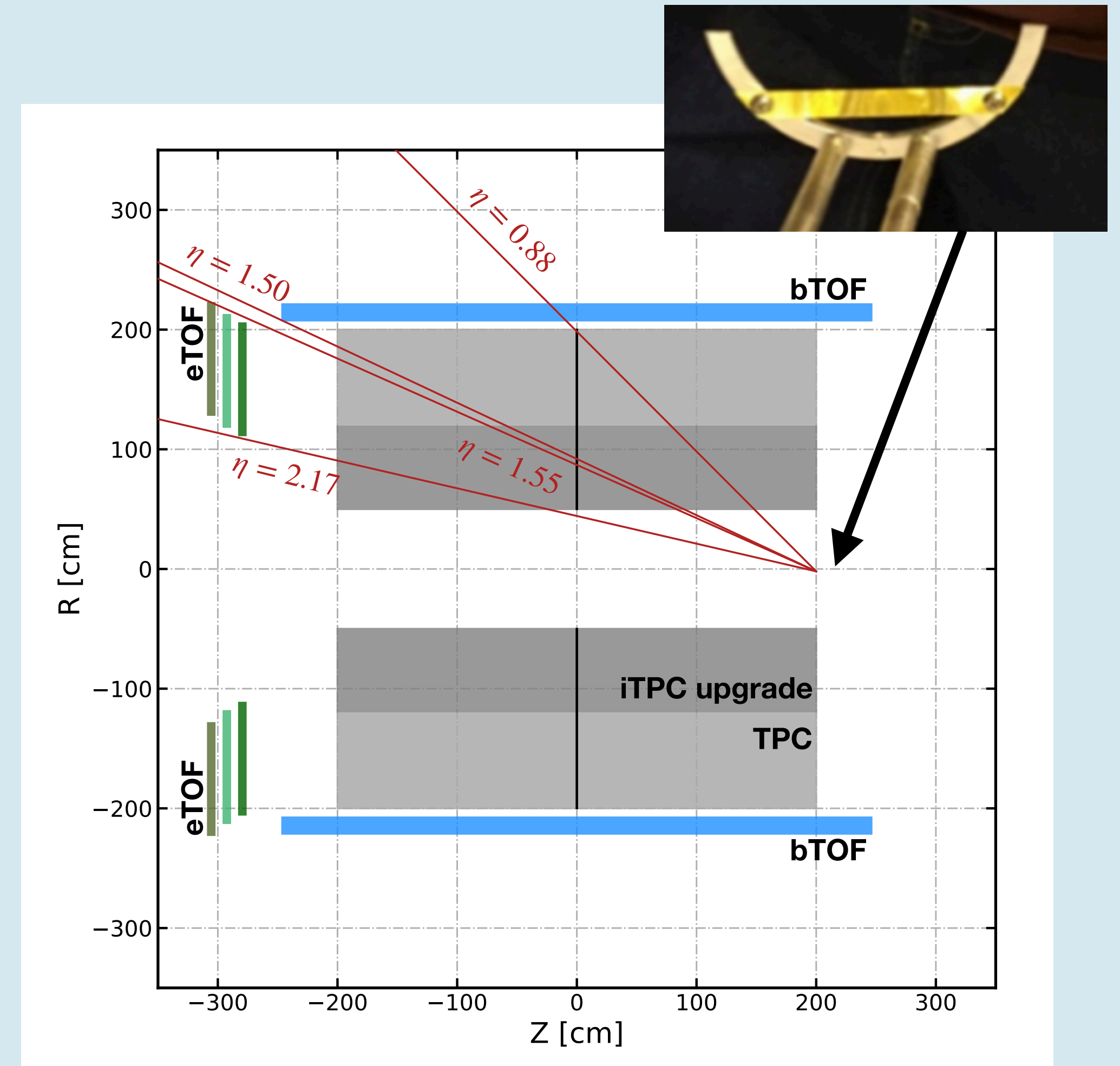
<https://doi.org/10.1038/s41467-025-63216-5>

Temperature measurement of Quark-Gluon at different stages

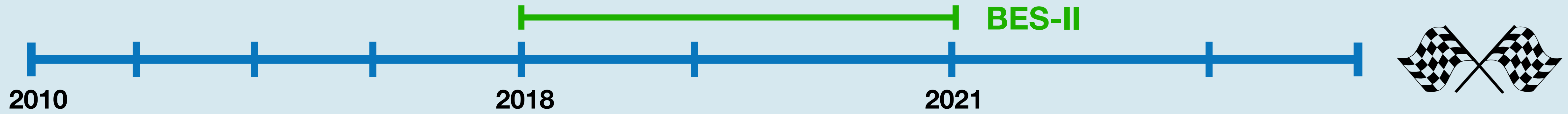
Constraining the
evolution of the system



Collider



FXT



• **Hot topics (so far) from BES-II:**

- Critical point search in FXT and collider modes
- Pinning down the onset of NCQ scaling

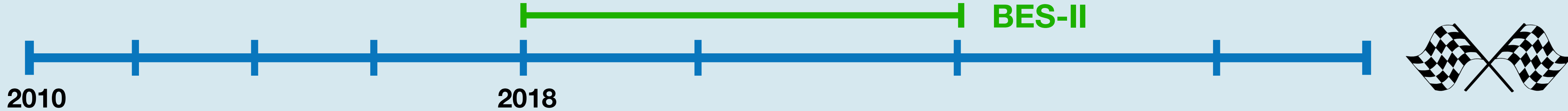
PHYSICAL REVIEW LETTERS 135, 142301 (2025)

Editors' Suggestion

Featured in Physics

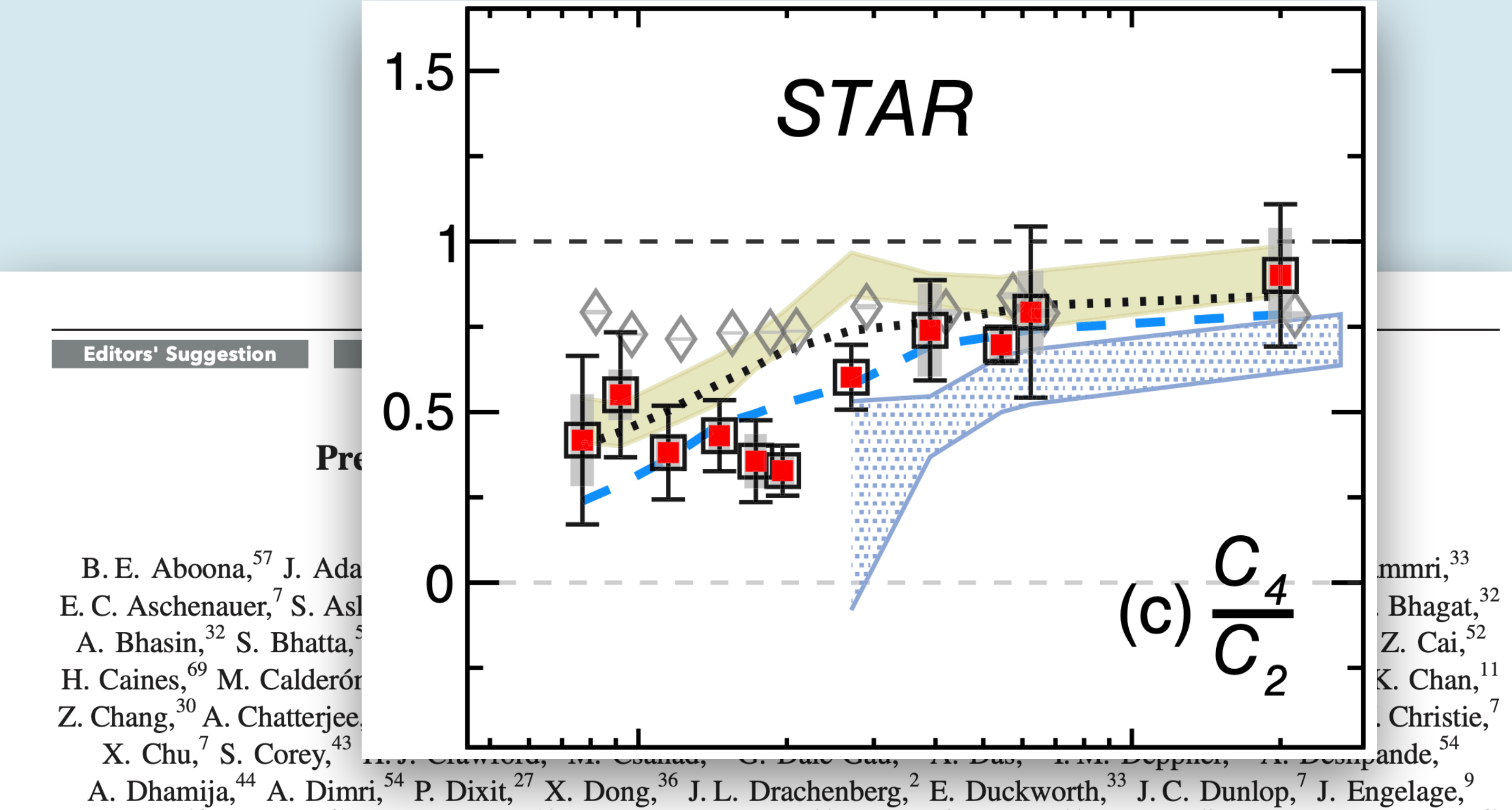
Precision Measurement of Net-Proton-Number Fluctuations in Au + Au Collisions at RHIC

B. E. Aboona,⁵⁷ J. Adam,¹⁷ L. Adamczyk,³ I. Aggarwal,⁴⁴ M. M. Aggarwal,⁴⁴ Z. Ahammed,⁶⁵ A. K. Alshammri,³³ E. C. Aschenauer,⁷ S. Aslam,²² J. Atchison,² V. Bairathi,⁵⁵ X. Bao,⁵¹ K. Barish,¹² S. Behera,²⁸ R. Bellwied,²⁵ P. Bhagat,³² A. Bhasin,³² S. Bhatta,⁵⁴ S. R. Bhosale,³ J. Bielcik,¹⁷ J. Bielcikova,⁴² J. D. Brandenburg,⁴³ C. Broodo,²⁵ X. Z. Cai,⁵² H. Caines,⁶⁹ M. Calderón de la Barca Sánchez,¹⁰ D. Cebra,¹⁰ J. Ceska,¹⁷ I. Chakaberia,³⁶ P. Chaloupka,¹⁷ B. K. Chan,¹¹ Z. Chang,³⁰ A. Chatterjee,¹⁹ D. Chen,¹² J. Chen,⁵¹ J. H. Chen,²² Q. Chen,²³ Z. Chen,⁵¹ J. Cheng,⁶⁰ Y. Cheng,¹¹ W. Christie,⁷ X. Chu,⁷ S. Corey,⁴³ H. J. Crawford,⁹ M. Csanád,²⁰ G. Dale-Gau,¹⁴ A. Das,¹⁷ I. M. Deppner,²⁴ A. Deshpande,⁵⁴ A. Dhamija,⁴⁴ A. Dimri,⁵⁴ P. Dixit,²⁷ X. Dong,³⁶ J. L. Drachenberg,² E. Duckworth,³³ J. C. Dunlop,⁷ J. Engelage,⁹



- **Hot topics (so far) from BES-II:**

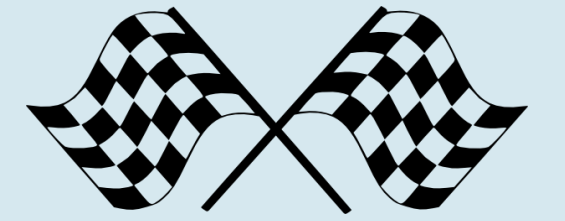
- Critical point search in FXT and collider
- Pinning down the onset of NCQ scaling



2010

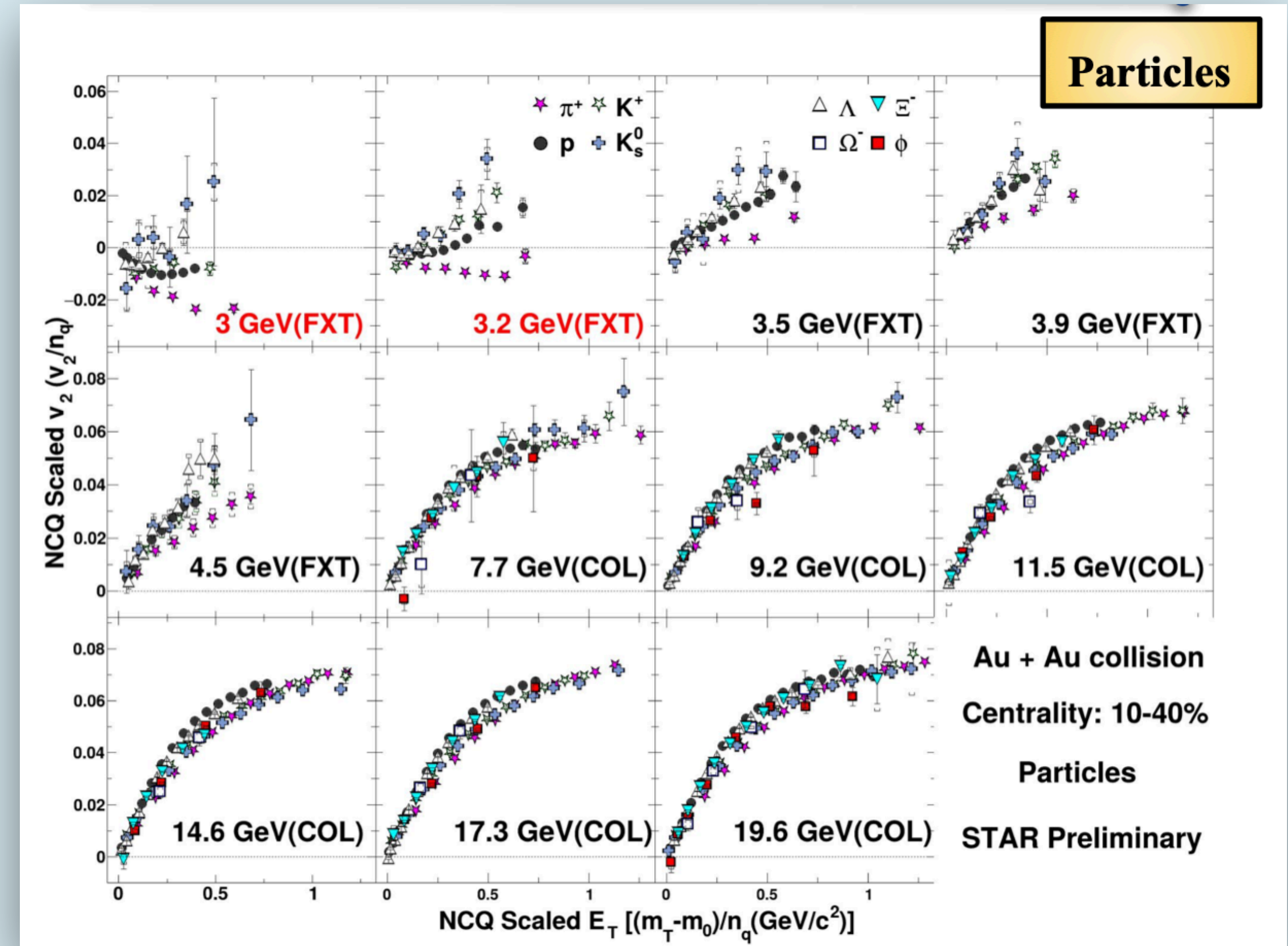
2018

BES-II



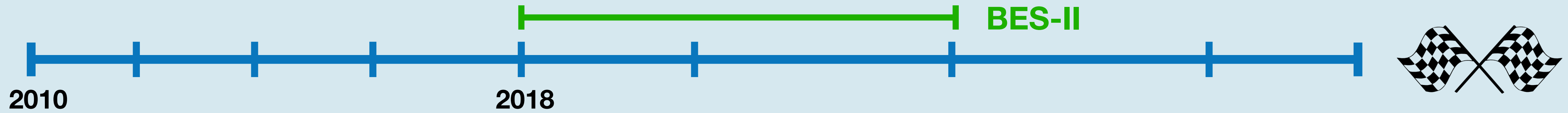
- Hot topics (so far) from BES-II:

- Critical point search in FXT and collider
- Pinning down the onset of NCQ scaling

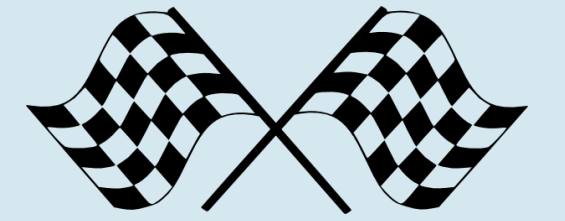


S.R Sharma, Quark Matter 2025

https://indico.cern.ch/event/1334113/contributions/6369544/attachments/3048394/5386954/Sharang_Quark_Matter_2025.pdf



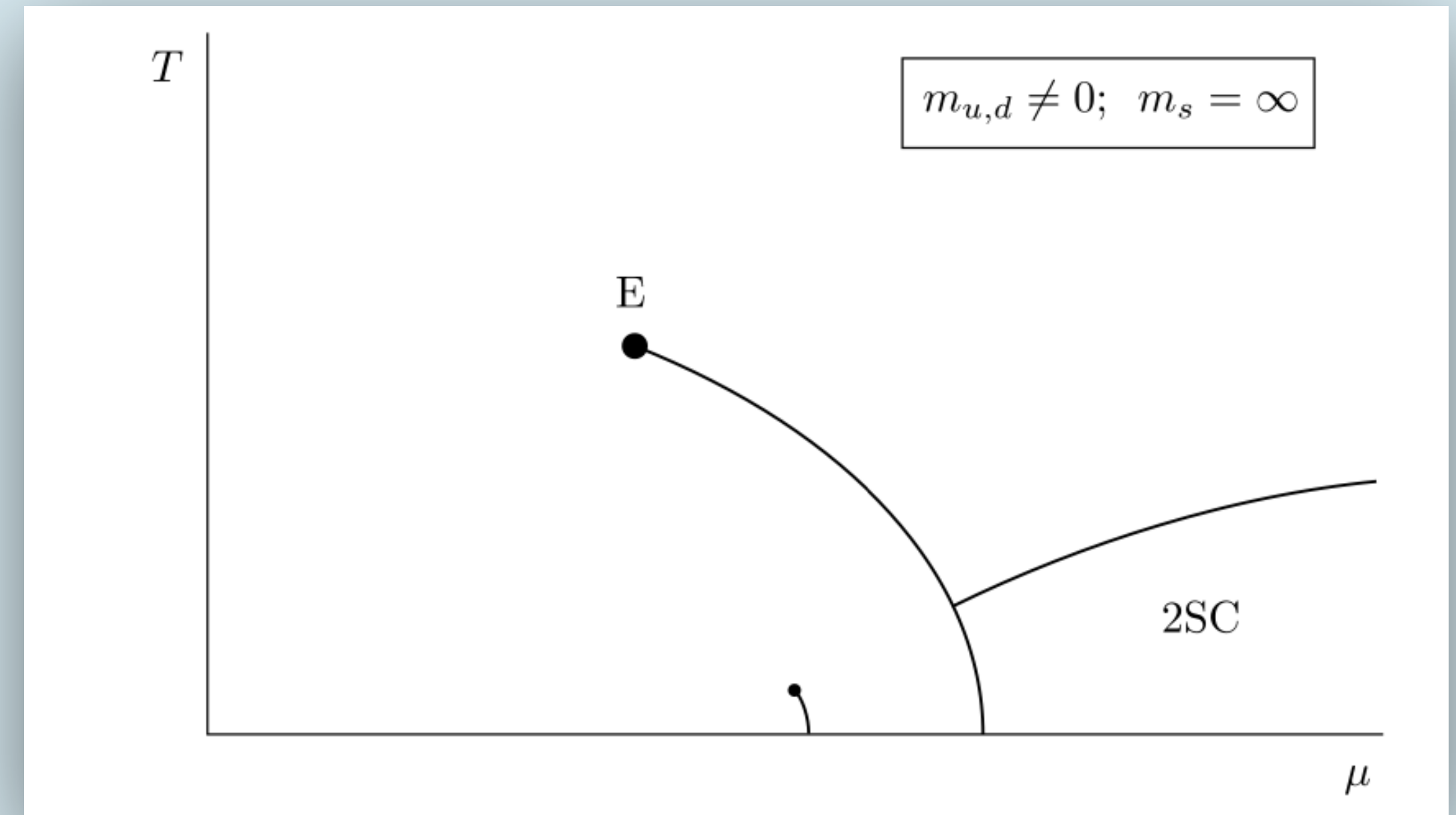
- **Scientific potential in BES-II**
 - Extensive comparisons with AGS and SPS
 - Extend kinetic and chemical freeze out lines
 - Definitive onset of deconfinement
 - First order phase transition
 - Critical point



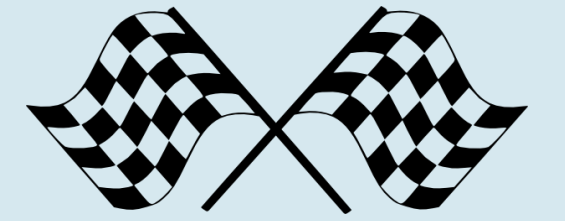
2000

- **Mostly qualitative theoretical predictions**

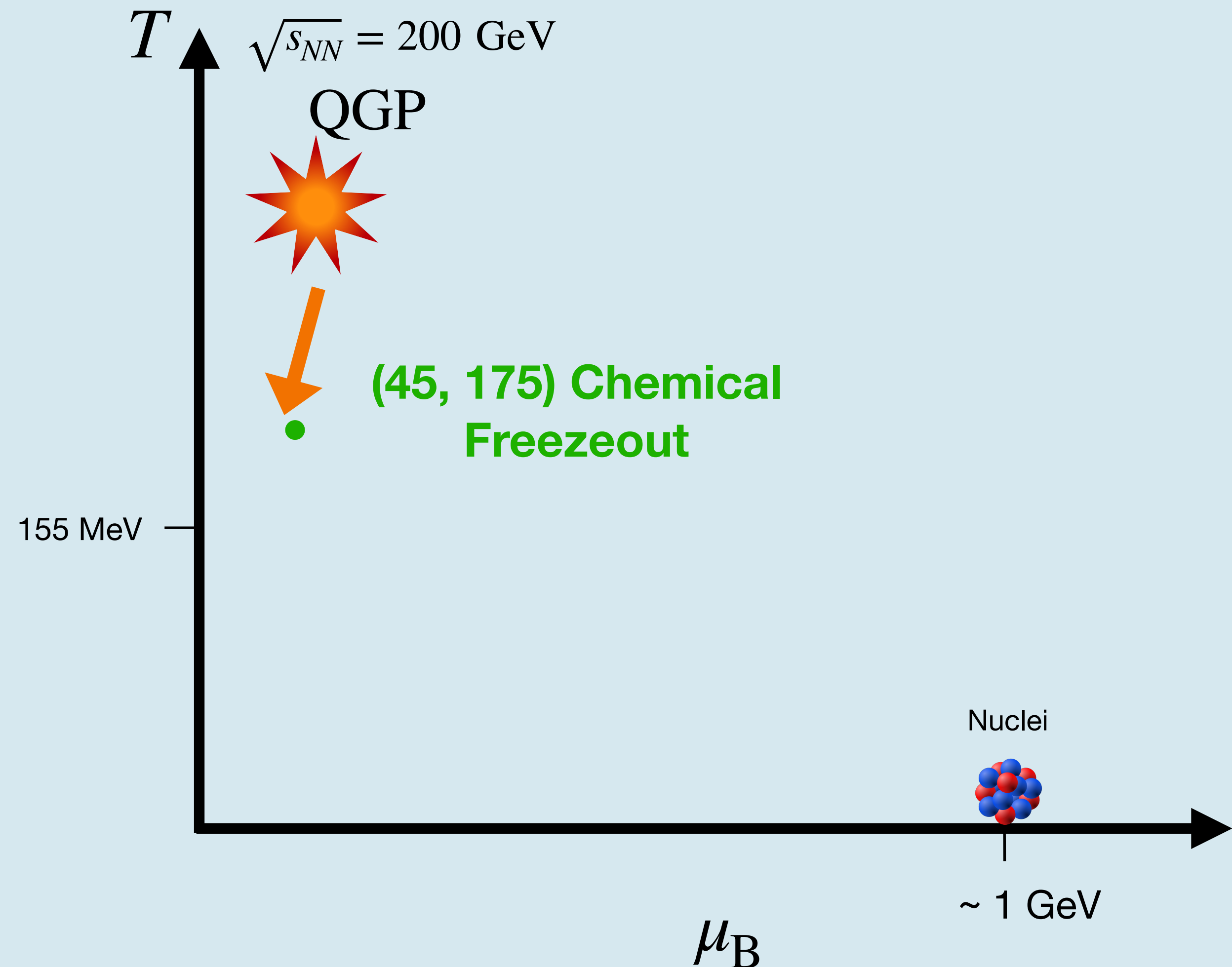
Rajagopal, K., & Wilczek, F. (2001). The condensed matter physics of QCD. In *At The Frontier of Particle Physics: Handbook of QCD (In 3 Volumes)* (pp. 2061-2151).

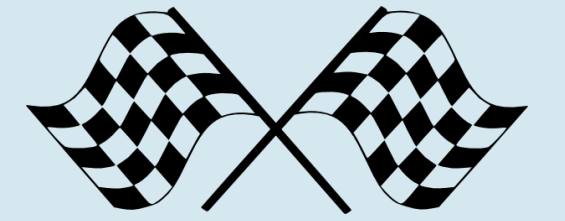


2005



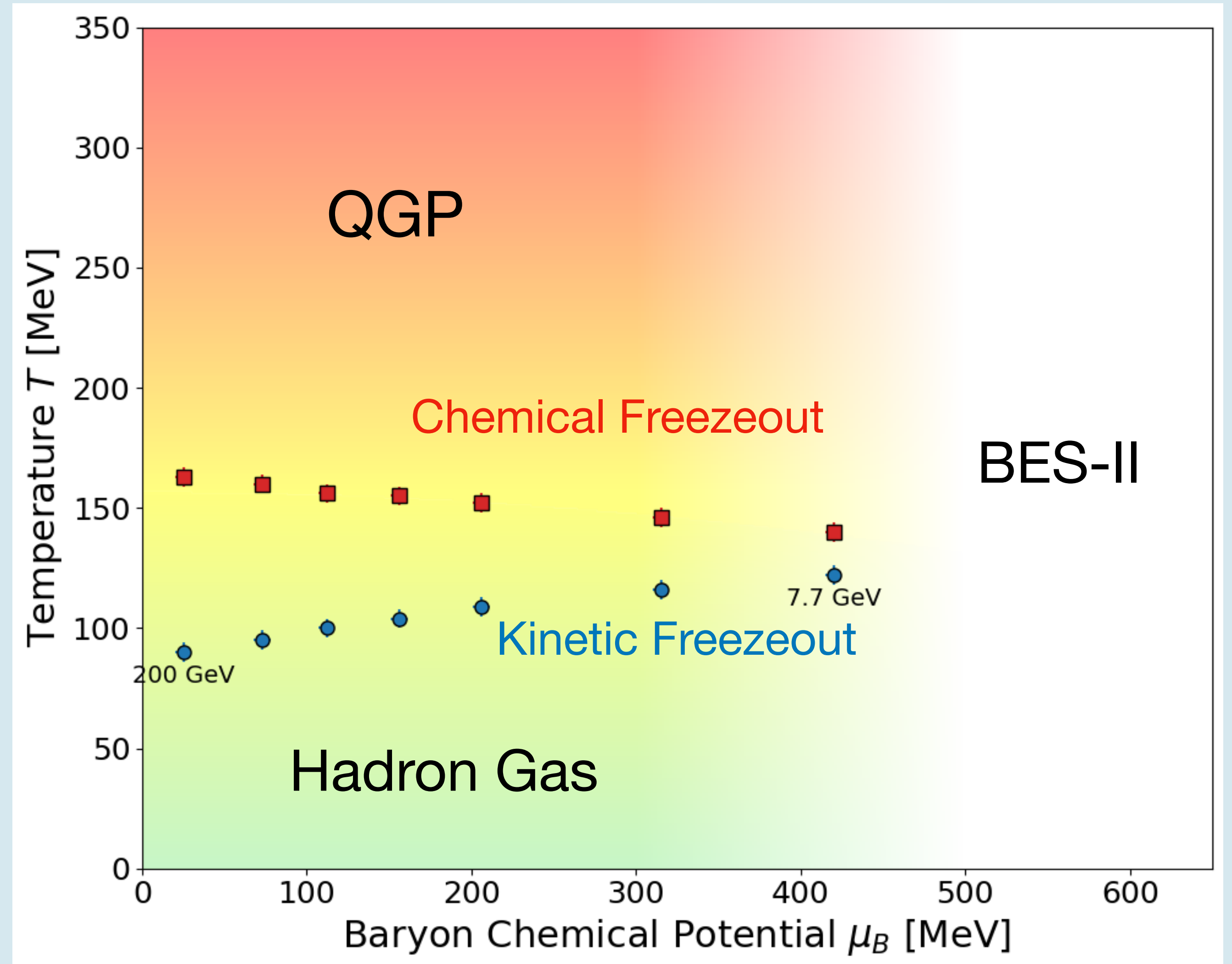
- First experimental probes of the phase diagram at RHIC energies
- Canonical QGP probes established

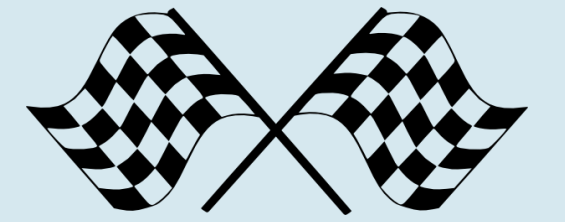




BES-I

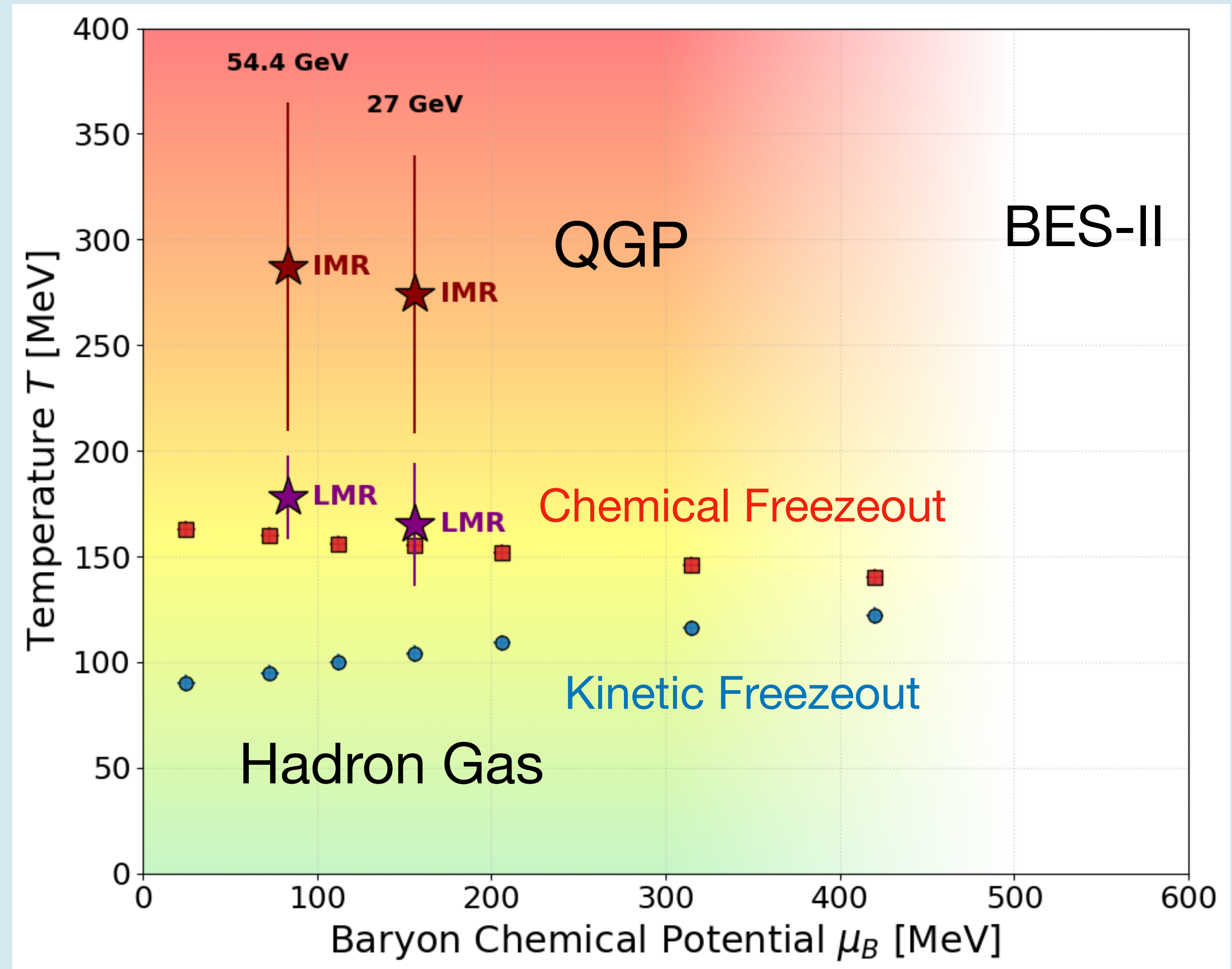
- No longer a cartoon
- Freeze-out lines established
- QGP signatures existing to larger μ_B

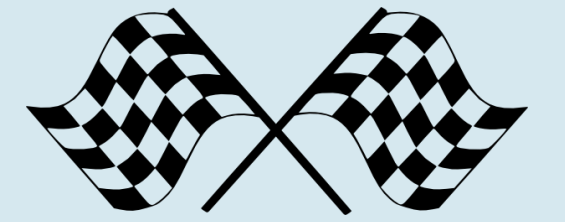




Today

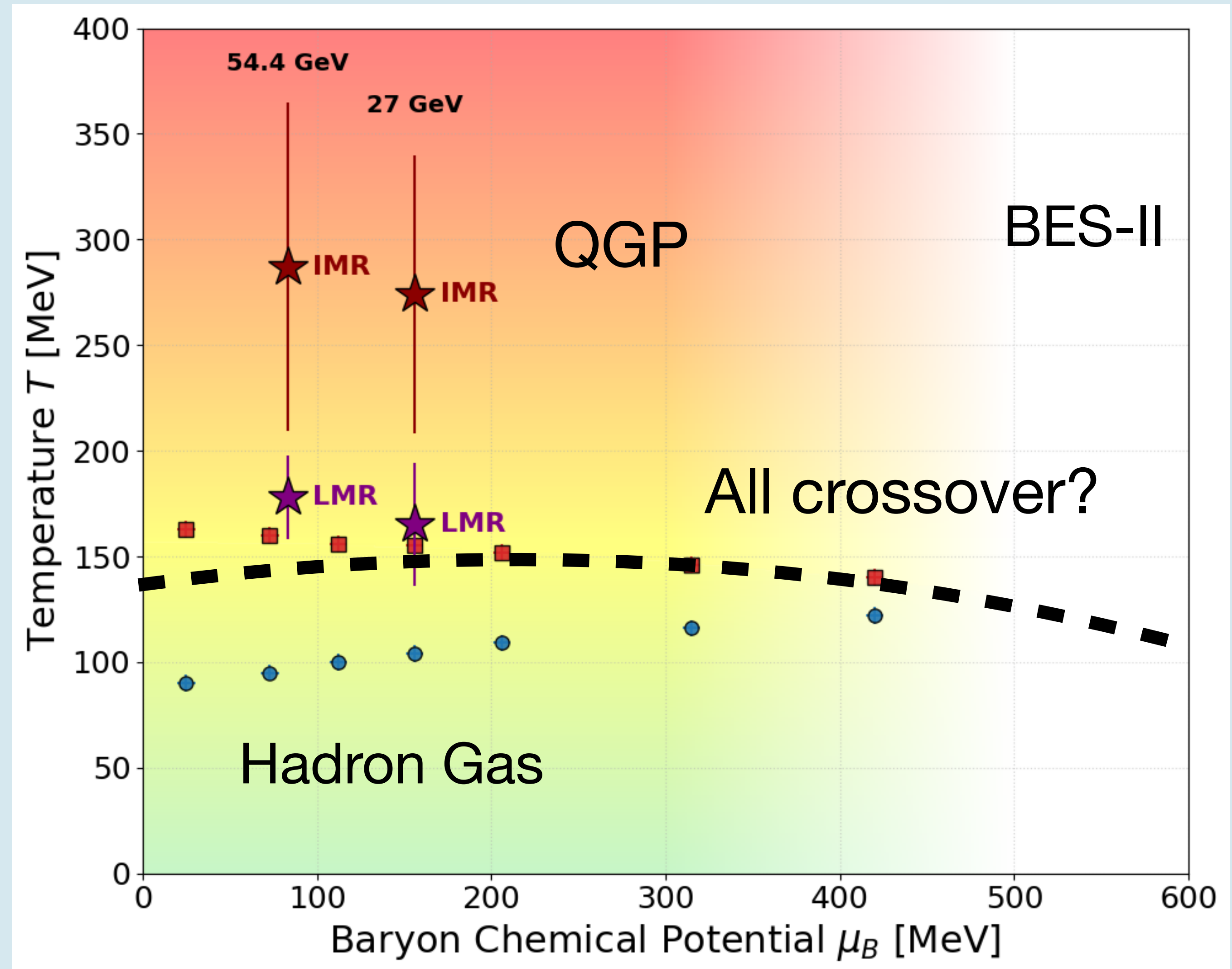
- Temperature over system evolution
- Will we see a critical point?
- Onset of deconfinement?

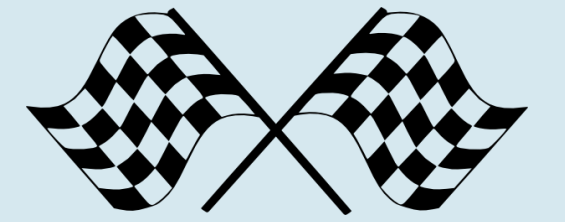




Today

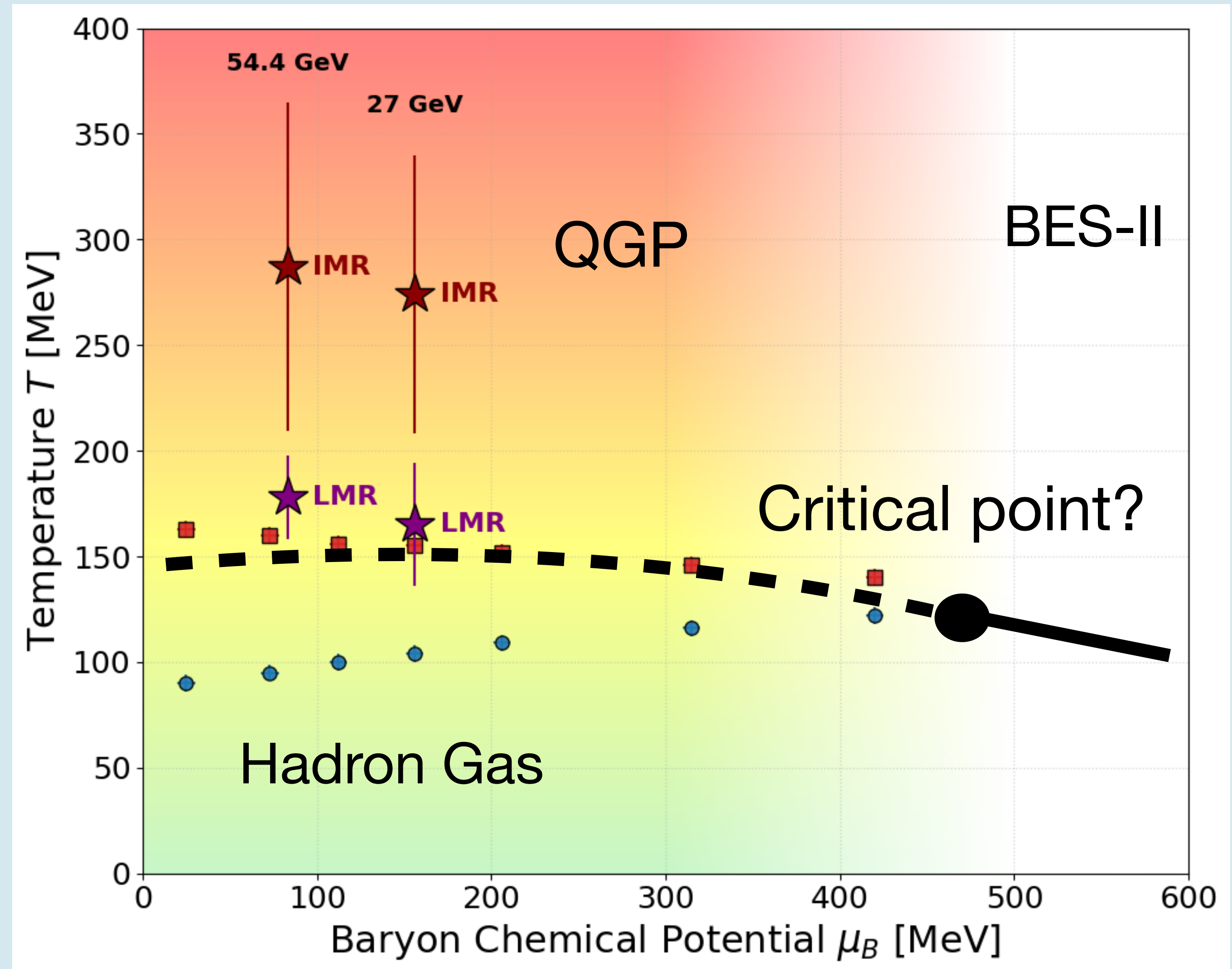
- Temperature over system evolution
- Will we see a critical point?
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Today

- Temperature over system evolution
- Will we see a critical point?
- Onset of deconfinement?



Thank you