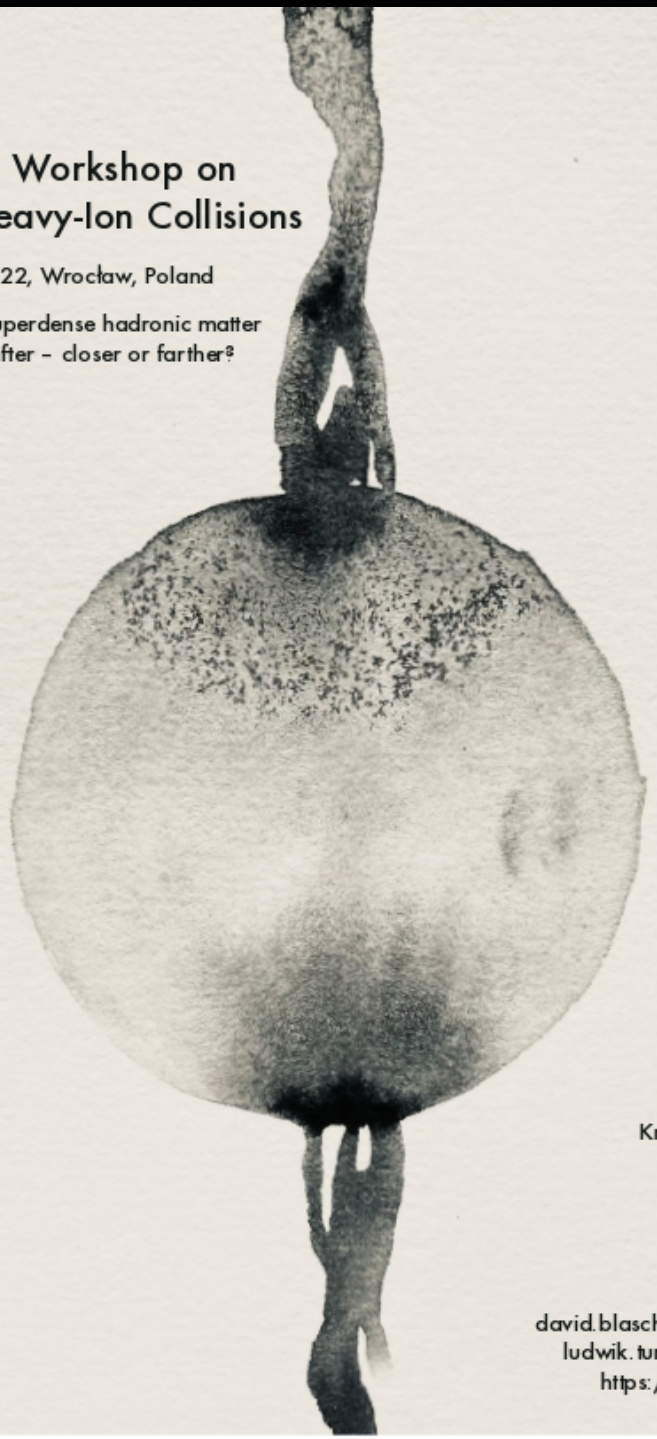
XV Polish Workshop on Relativistic Heavy-Ion Collisions

24-25.09.2022, Wrocław, Poland

Unified view of superdense hadronic matter
Twenty years after – closer or farther?



Painted by Aleksandra Niewczas

ORGANISERS

Chihiro Sasaki
David Blaschke
Krzysztof Redlich
Ludwik Turko
Pasi Huovinen

CONTACT

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Uniwersytet Wrocławski

RESEARCH UNIVERSITY
EXCELLENCE INITIATIVE

CSSF
INCUBATOR OF SCIENTIFIC EXCELLENCE

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What is CSSF?

Pasi Huovinen

Incubator of Scientific Excellence—Centre for Simulations of Superdense Fluids
University of Wrocław

XV Polish Workshop on Relativistic Heavy-Ion Collisions

September 24, 2022, Wrocław, Poland

with Michał Marczenko and Etele Molnár

Incubator of Scientific Excellence—Centre for Simulations of Superdense Fluids (CSSF)

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- **new research group at UWr, established in September 2021**

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  - **this meeting**
  - **58. Karpacz Winter School of Theoretical Physics, June 19-25**

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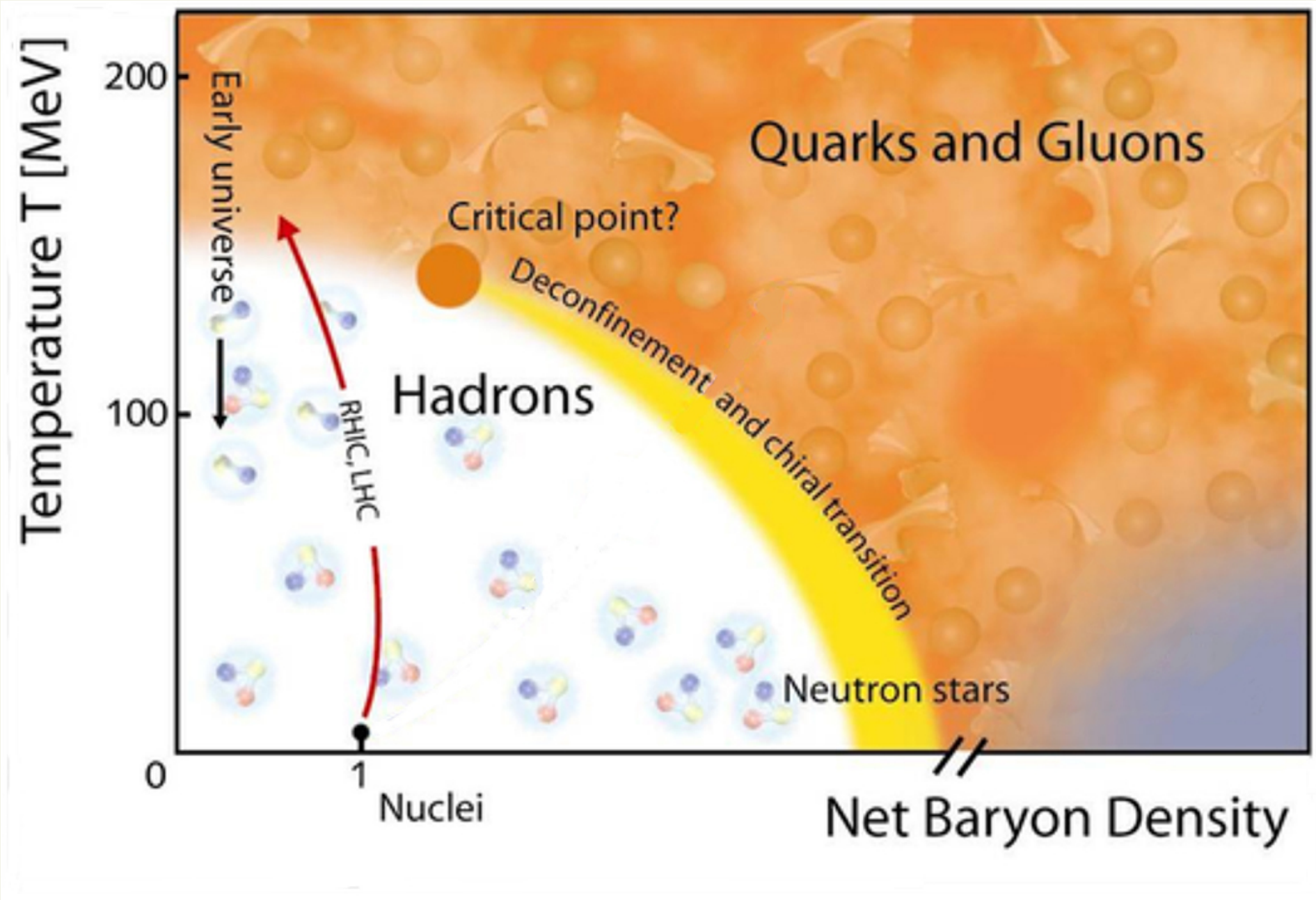
- **funding until the end of 2025**

Phase diagram



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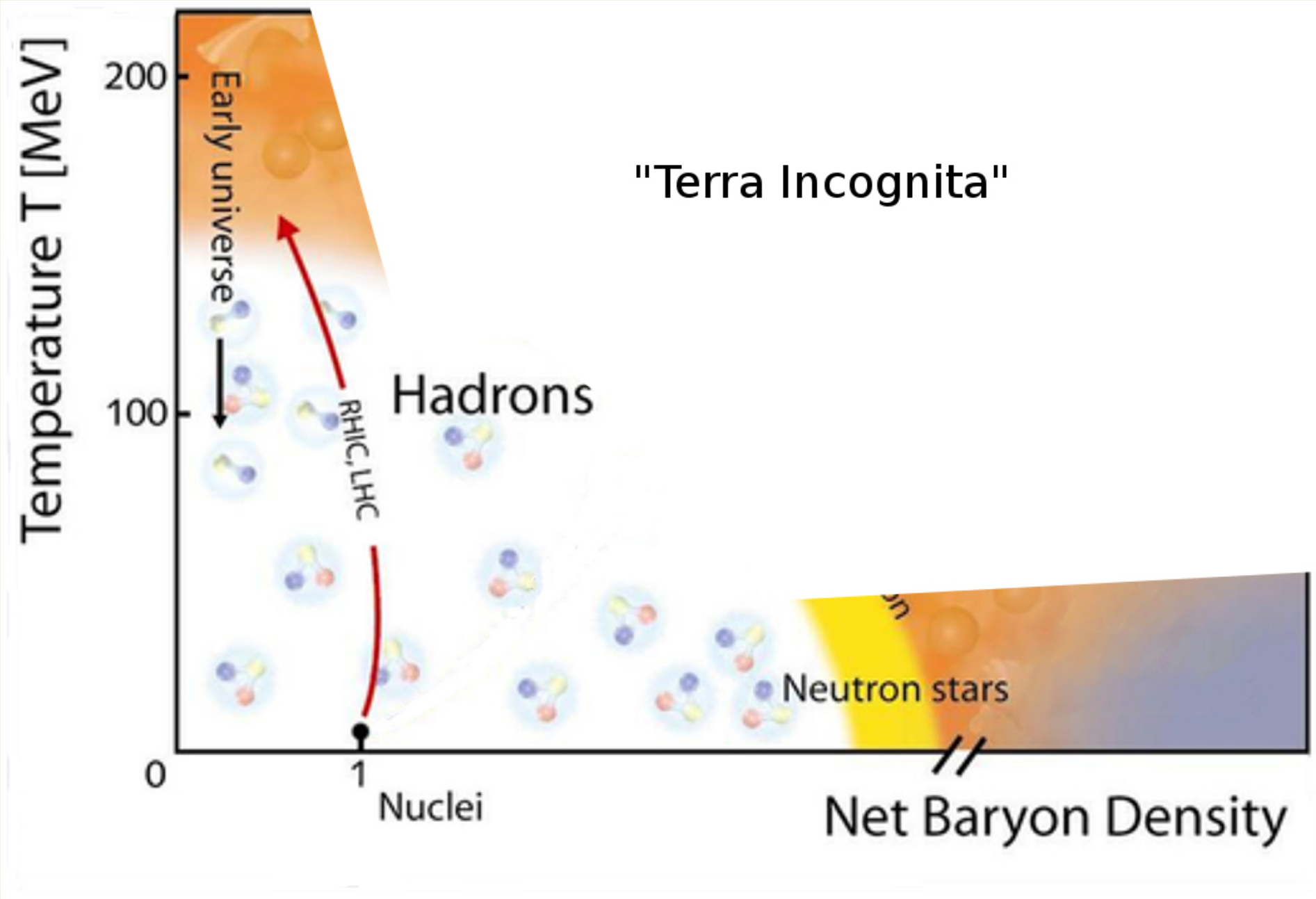

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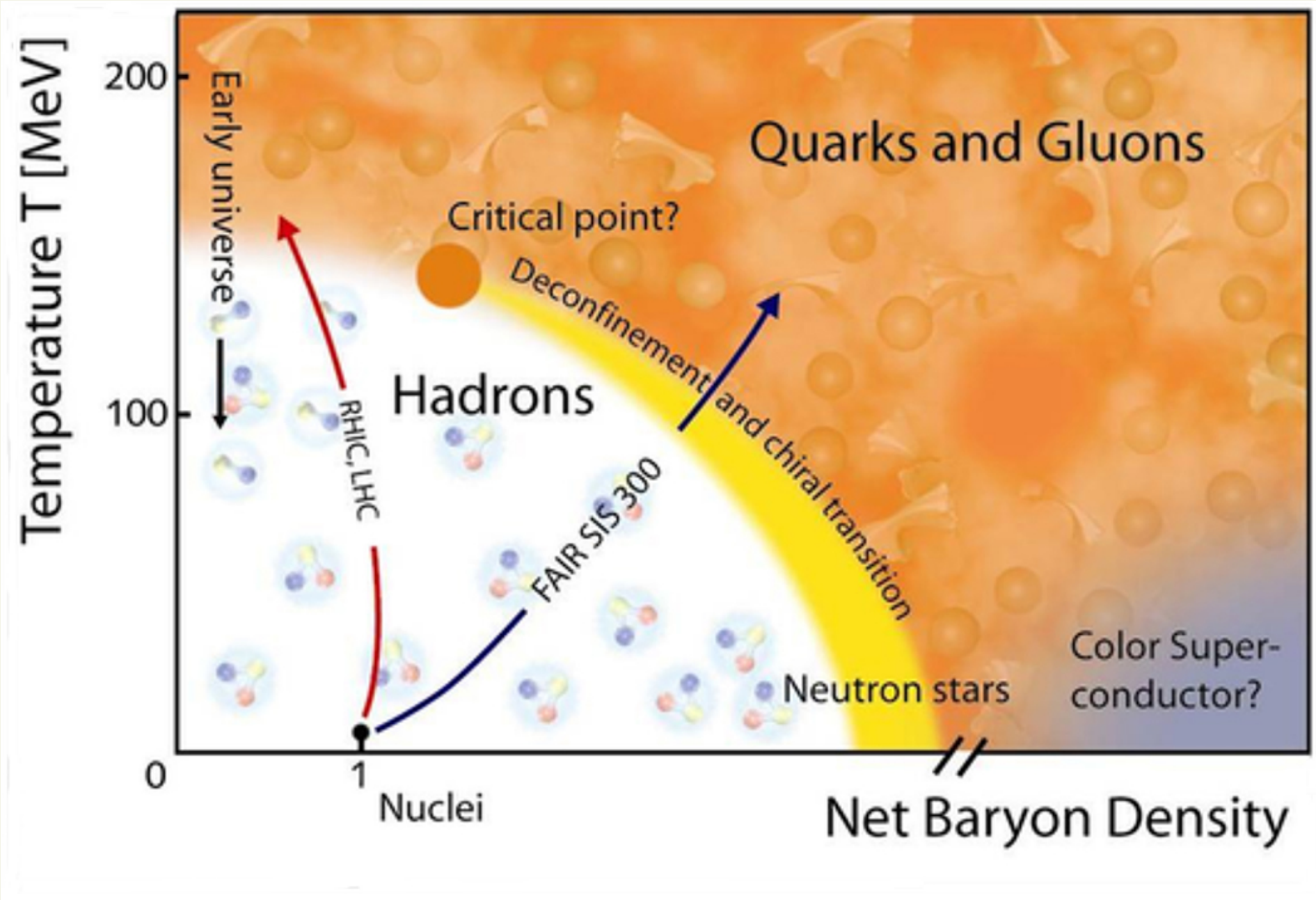

Challenges

1. **lower multiplicity $\Longrightarrow$ smaller system**
   $\Longrightarrow$ larger deviations from equilibrium?

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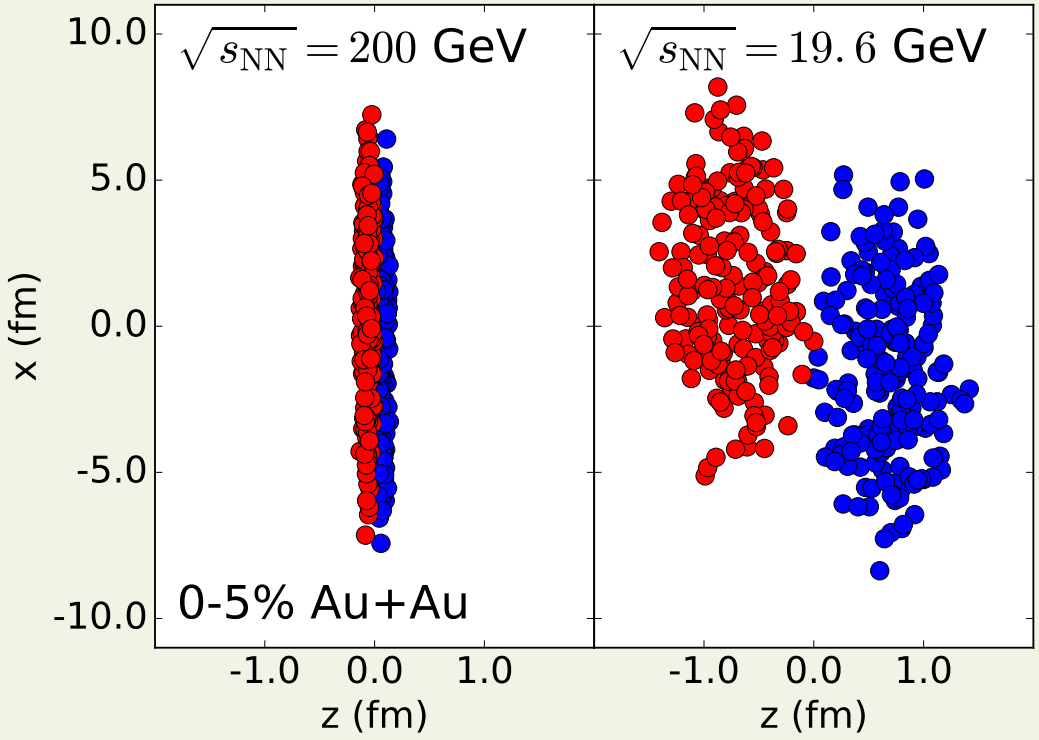

Shen & Schenke, PRC97, 024907 (2018)

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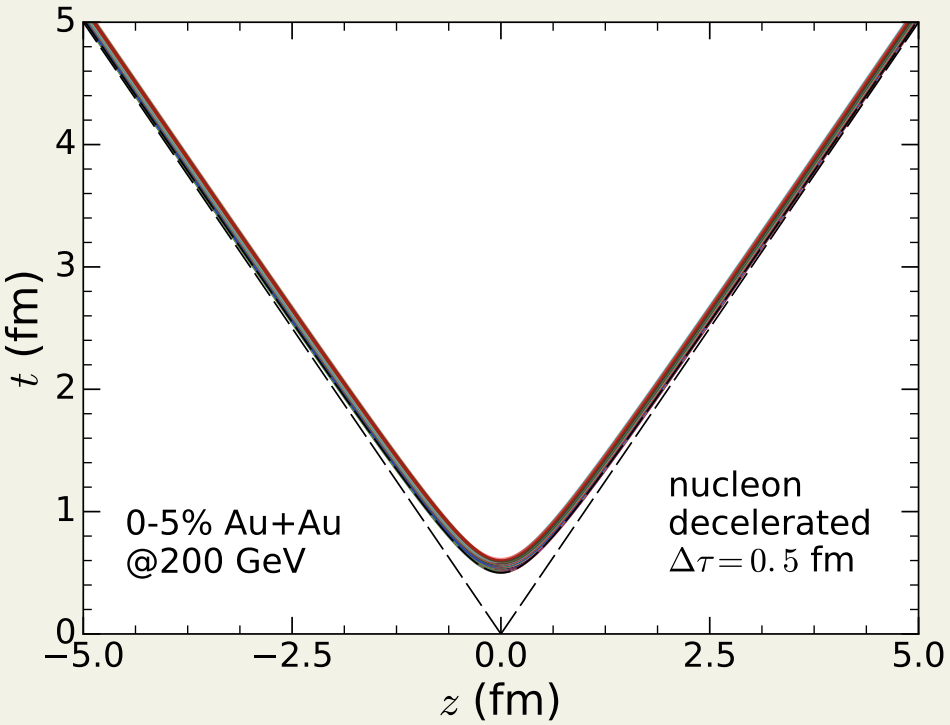

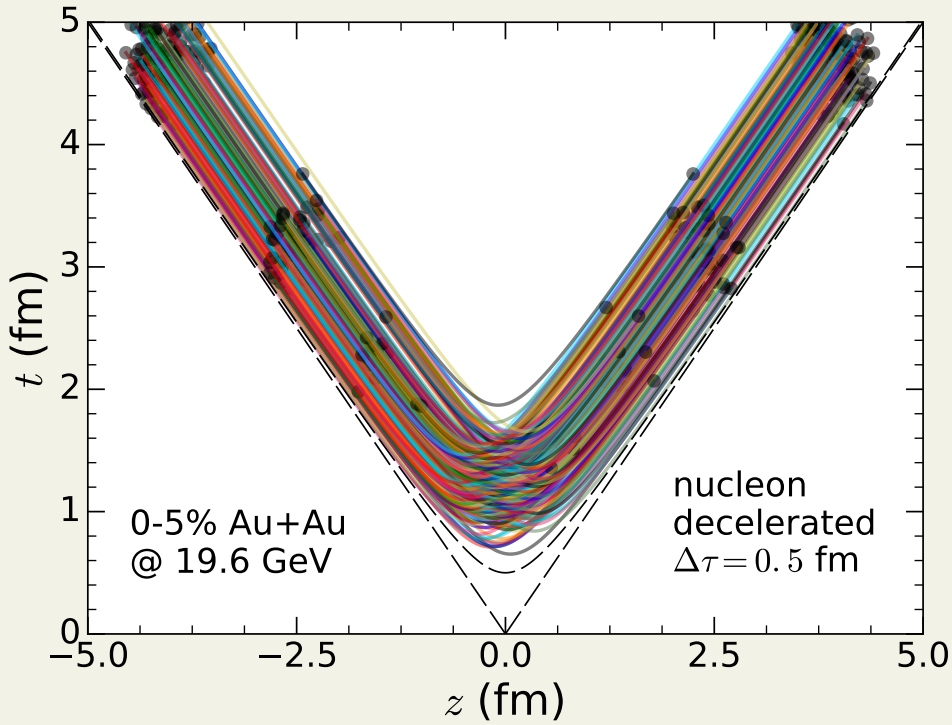

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3-fluid dynamics

in collaboration with Iurii Karpenko and Jakub Cimerman at CVUT Prague

$$0 \;=\; \partial_\mu T^{\mu\nu}$$

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$$
\begin{aligned}
0 &= \partial_\mu T^{\mu\nu} \\
&= \partial_\mu T_{\rm t}^{\mu\nu}
\end{aligned}
$$

$T_{\rm t}^{\mu\nu}$ = **target fluid**

3-fluid dynamics

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$$
\begin{aligned}
0 &= \partial_\mu T^{\mu\nu} \\
&= \partial_\mu T^{\mu\nu}_{\mathrm{t}} + \partial_\mu T^{\mu\nu}_{\mathrm{p}}
\end{aligned}
$$

$T^{\mu\nu}_{\mathrm{t}}$ = **target fluid**

$T^{\mu\nu}_{\mathrm{p}}$ = **projectile fluid**

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\begin{aligned}
0 &= \partial_\mu T^{\mu\nu} \\
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\end{aligned}
$$

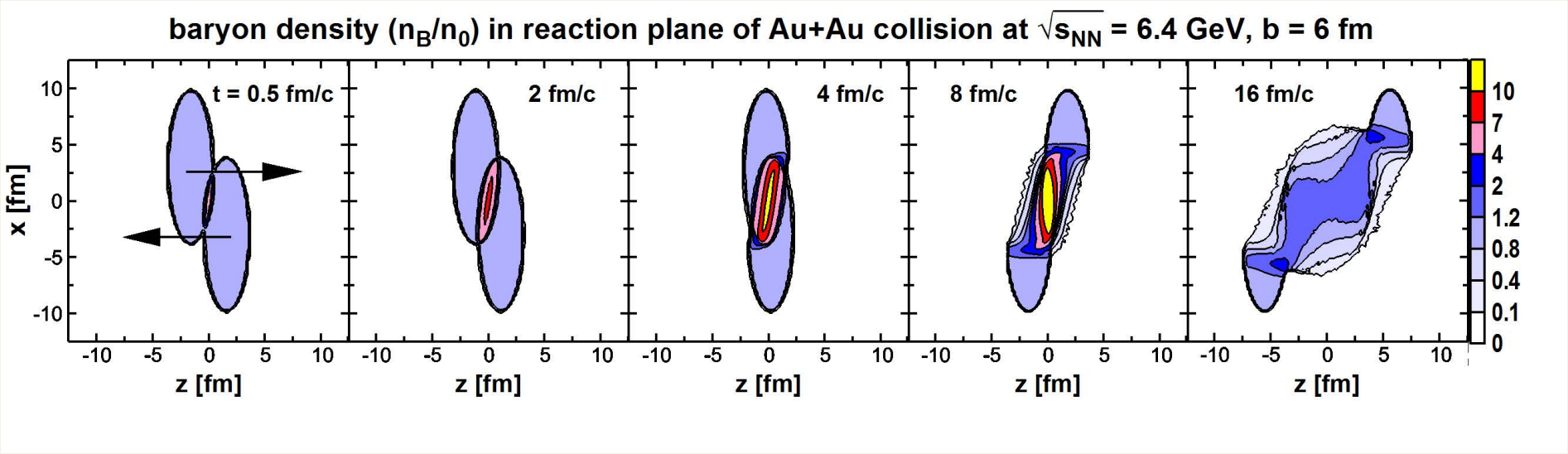
$T^{\mu\nu}_{\mathrm{t}}$ = **target fluid**
$T^{\mu\nu}_{\mathrm{p}}$ = **projectile fluid**
$T^{\mu\nu}_{\mathrm{fb}}$ = **fireball fluid**

3-fluid dynamics

$$
\begin{aligned}
\partial_\mu T^{\mu\nu}_{\mathrm{t}}(x) &= -F^{\nu}_{\mathrm{t}}(x) + F^{\nu}_{\mathrm{ft}}(x) \\
\partial_\mu T^{\mu\nu}_{\mathrm{p}}(x) &= -F^{\nu}_{\mathrm{p}}(x) + F^{\nu}_{\mathrm{fp}}(x) \\
\partial_\mu T^{\mu\nu}_{\mathrm{fb}}(x) &= F^{\nu}_{\mathrm{p}}(x) + F^{\nu}_{\mathrm{t}}(x) - F^{\nu}_{\mathrm{fp}}(x) - F^{\nu}_{\mathrm{ft}}(x)
\end{aligned}
$$

3-fluid dynamics

$$
\begin{aligned}
\partial_\mu T^{\mu\nu}_{\rm t}(x) &= -F^\nu_{\rm t}(x) + F^\nu_{\rm ft}(x) \\
\partial_\mu T^{\mu\nu}_{\rm p}(x) &= -F^\nu_{\rm p}(x) + F^\nu_{\rm fp}(x) \\
\partial_\mu T^{\mu\nu}_{\rm fb}(x) &= F^\nu_{\rm p}(x) + F^\nu_{\rm t}(x) - F^\nu_{\rm fp}(x) - F^\nu_{\rm ft}(x)
\end{aligned}
$$



dissipative fluid with 3 conserved charges

derive equations of motion from Boltzmann equation

$$k_i^\mu \partial_\mu f_{i,\mathbf{k}} = 0 \quad \Rightarrow \quad \dot{\Pi},\ \dot{V}_q^{\langle\nu\rangle}\ \dot{\pi}^{\langle\mu\nu\rangle}$$

where q = {B,S,Q}

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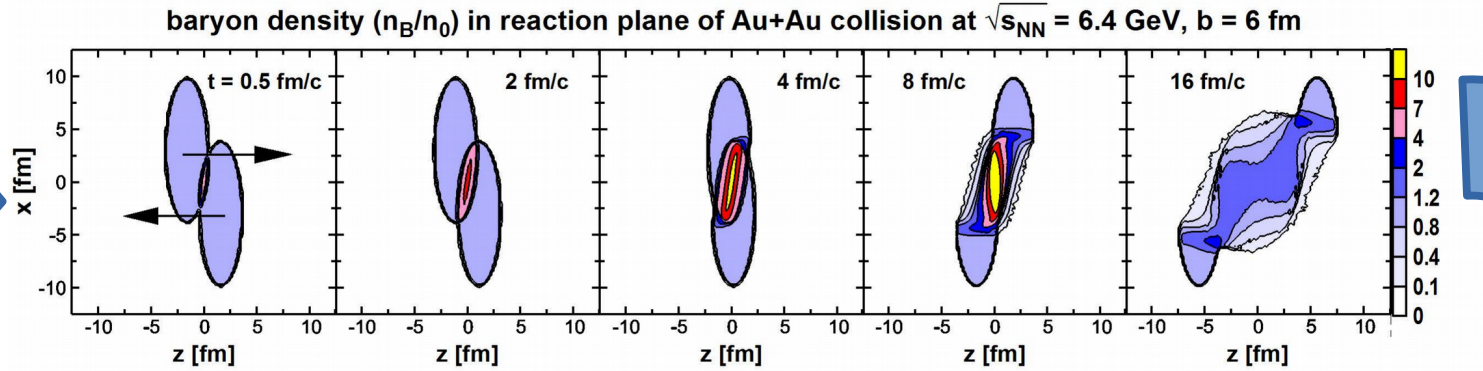
where q = {B,S,Q}

dynamical initialisation utilising source terms

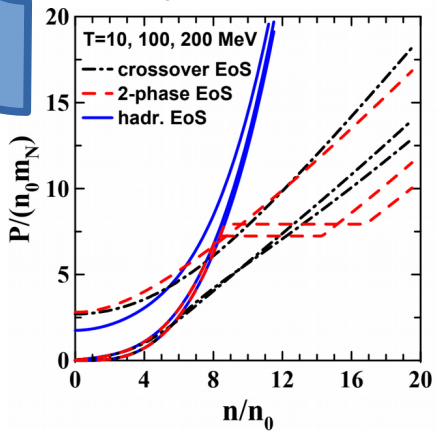
$$\begin{aligned}
\partial_\mu T_{\mathrm{t}}^{\mu\nu}(x) &= -F_{\mathrm{t}}^{\nu}(x) \\
\partial_\mu T_{\mathrm{p}}^{\mu\nu}(x) &= -F_{\mathrm{p}}^{\nu}(x) \\
\partial_\mu T_{\mathrm{fb}}^{\mu\nu}(x) &= F_{\mathrm{p}}^{\nu}(x) + F_{\mathrm{t}}^{\nu}(x)
\end{aligned}$$

where T_{t} and T_{p} are not fluids but currents

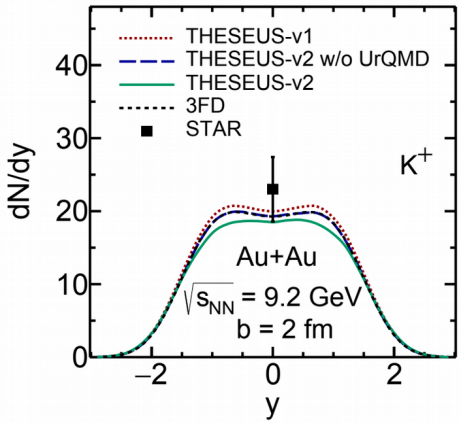
3-fluid hydrodynamics simulation



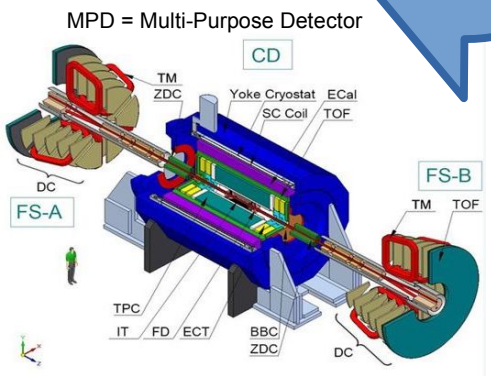
1. Initialization of Projectile and Target fluids → 2. Creation of Fireball fluid → 3.Hydrodynamic Evolution → 4.Particlization → 5.Hadronic Cascade



0. EoS input



7. Particle Distributions; Compare with Experiment



6. Detector Response

CSSF

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- **for fluid dynamical modeling of heavy-ion collisions**
- **stay tuned!**

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