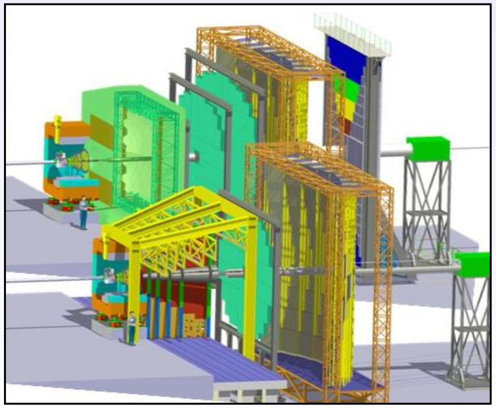
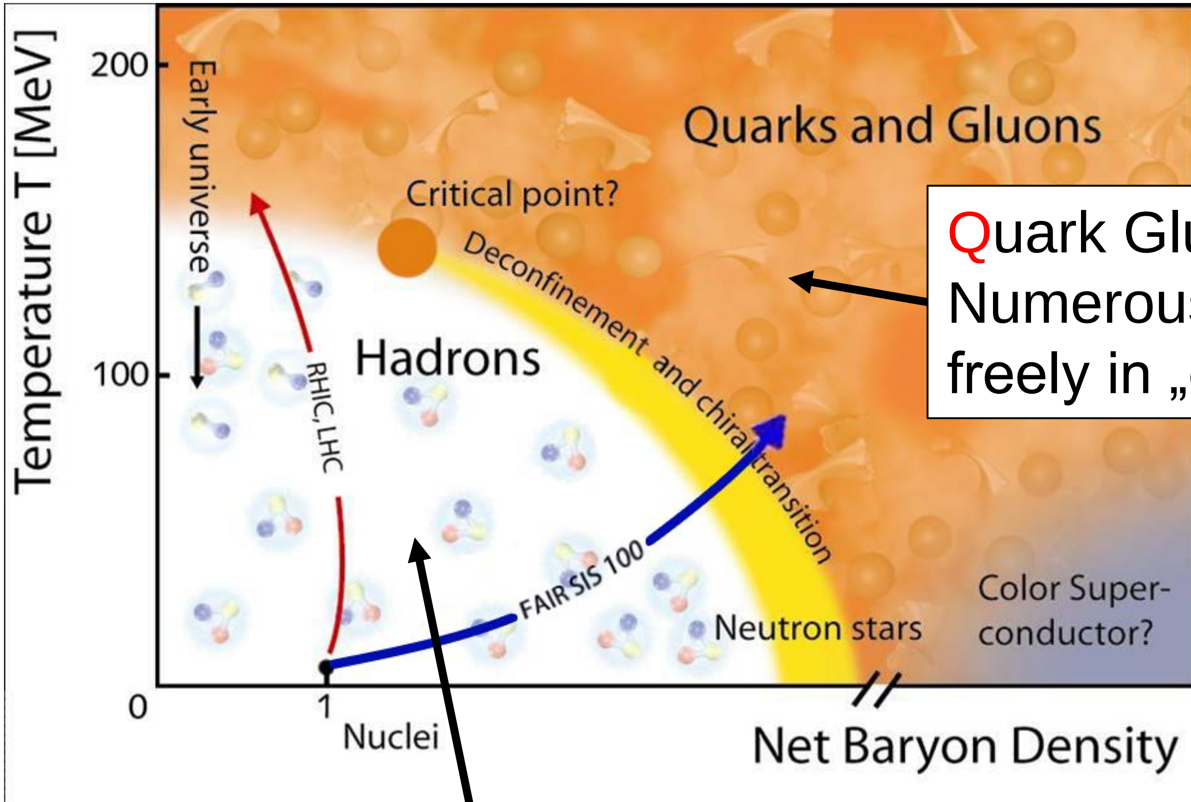
Charm measurements below top SPS energy

M. Deveaux, Goethe University Frankfurt



www.uni-frankfurt.de

What means quark gluon plasma

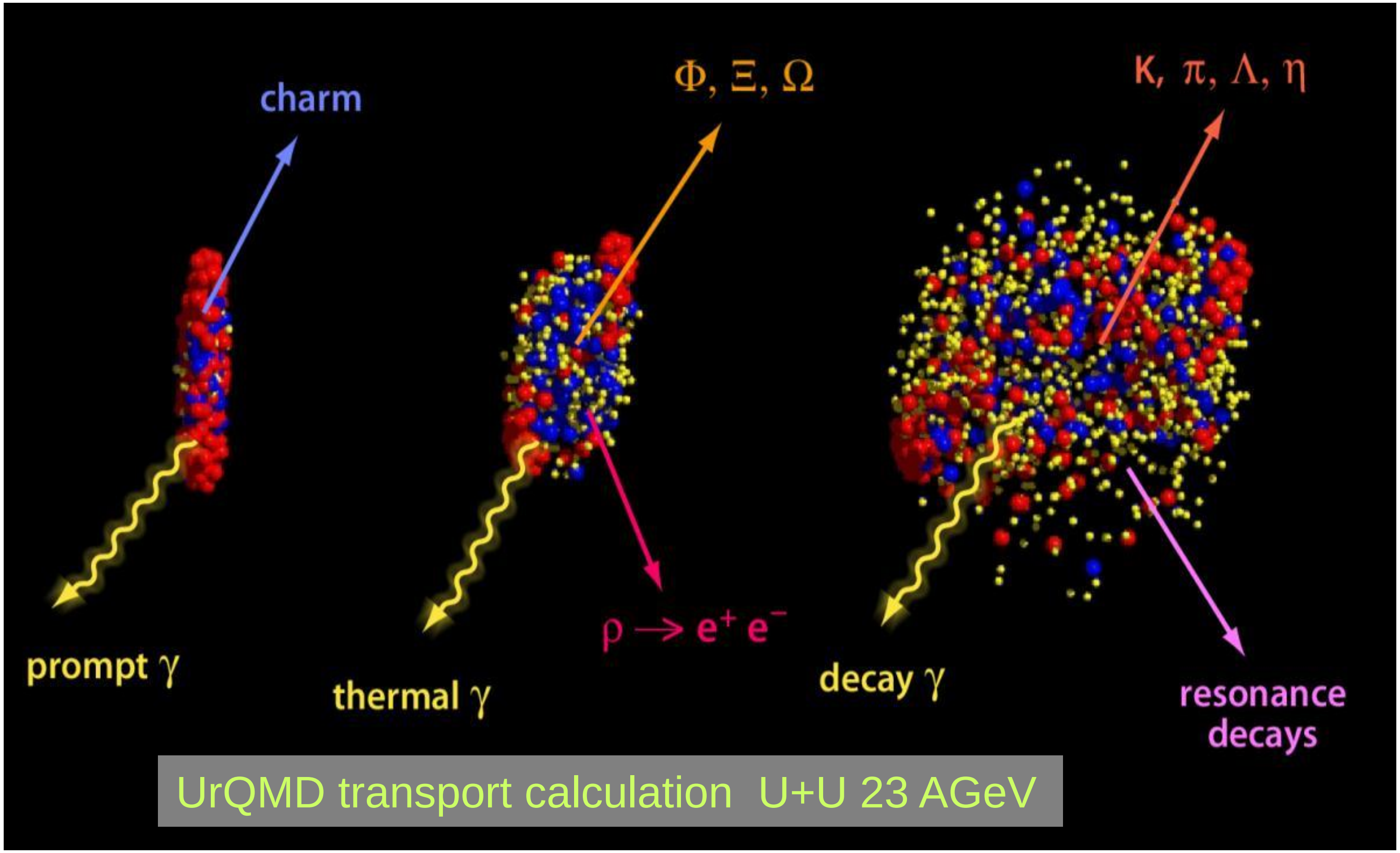


Quark Gluon Plasma:
Numerous quarks move freely in „common potential“.

Hadronic phase:
2 or 3 quarks are confined to hadrons.
They cannot be separated

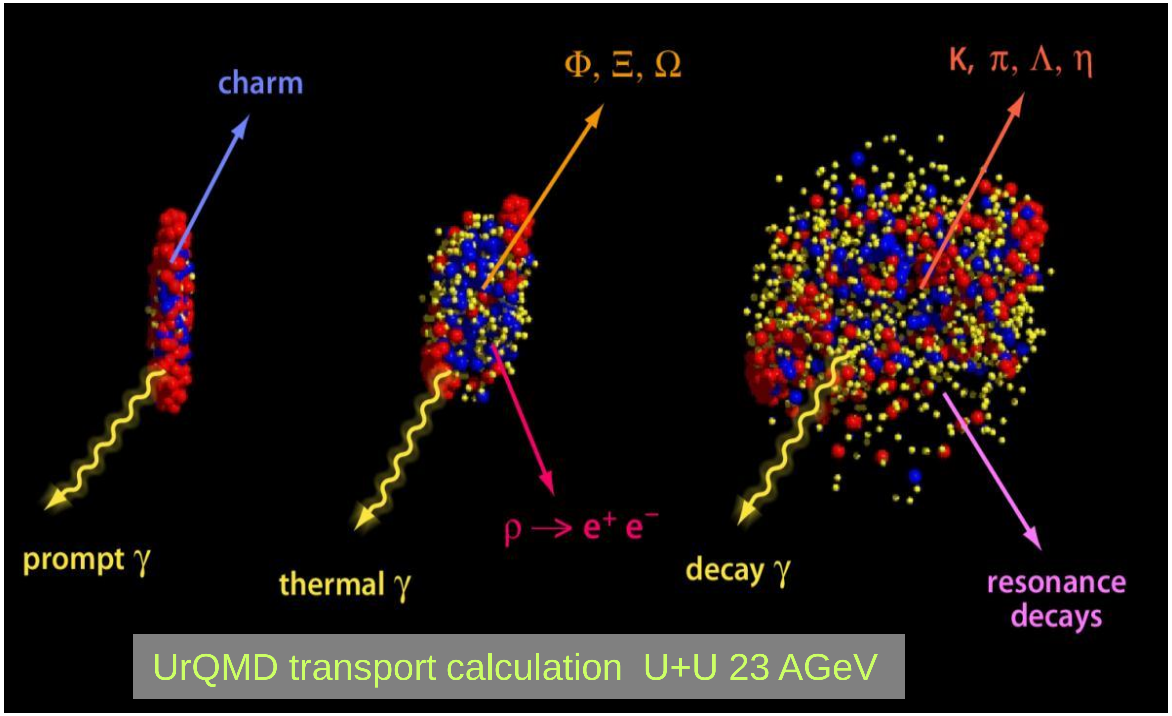
How to produce QGP

Need high temperatures and/or high pressure.
Idea: Collide heavy ions at high beam energies



Nuclear fireball created may undergo phase transition.

How to recognize QGP



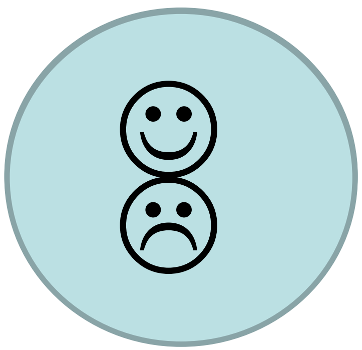
Challenge:
Nuclear fireball cools down before reaching detector
Most information is lost during cooling

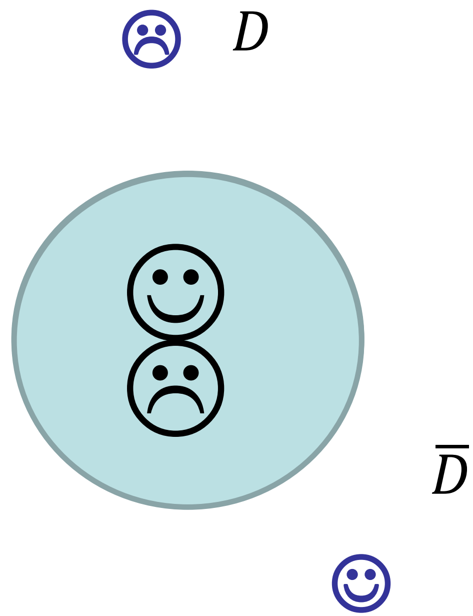
Idea:
Find probes, which carry information out.

J/Ψ as a probe for a phase transition

Initial idea:

$c - \bar{c} \Rightarrow J/\Psi$





T. Matsui, H. Satz, "J/ψ suppression by quark-gluon plasma formation", Phys. Let. B, Vol 178, PP 416-422 (1986)

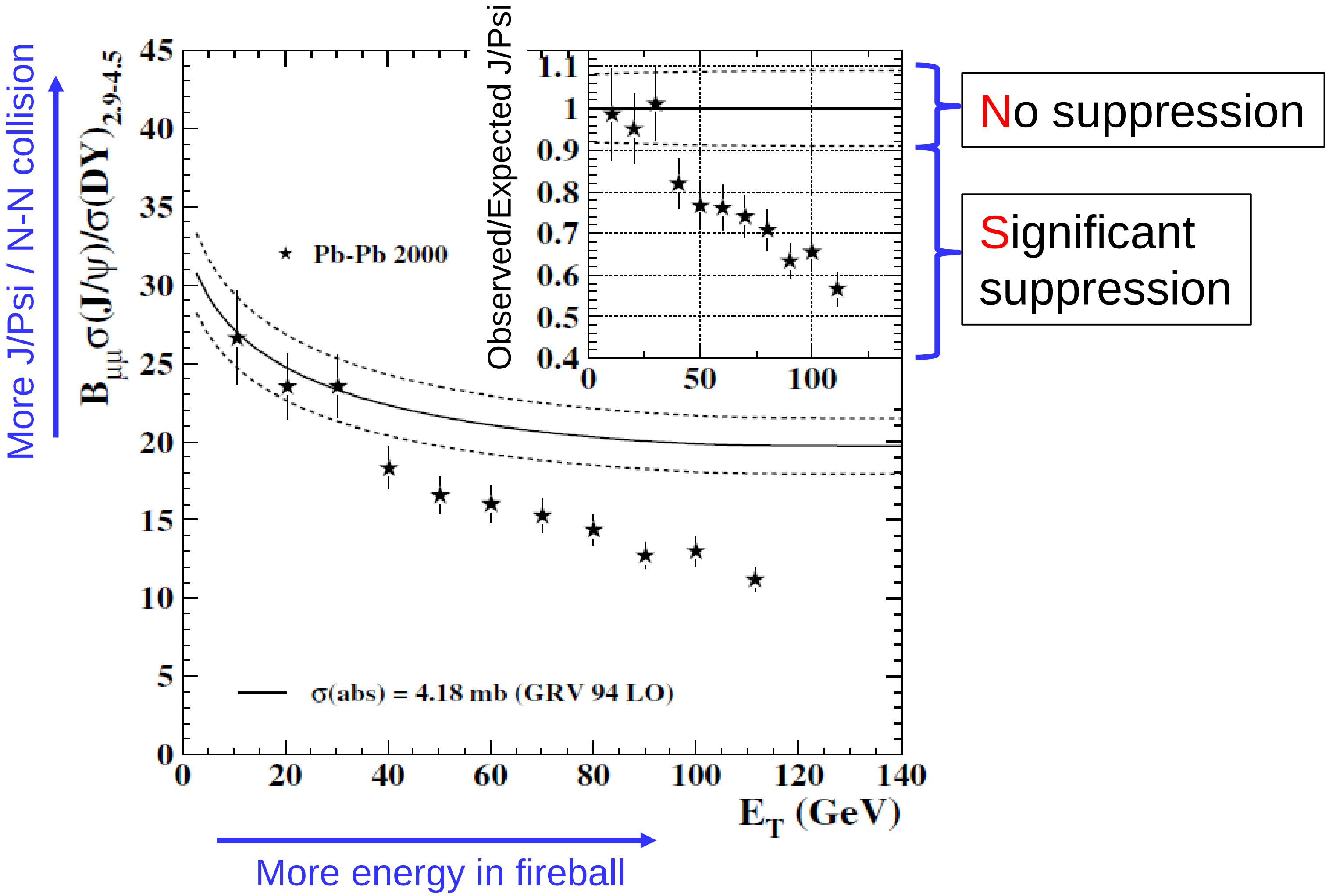
Hadronic medium:

$c - \bar{c}$ likely to bind to J/Ψ particle.

Quark Gluon Plasma

Binding not possible J/Ψ dissapear

J/Psi suppression



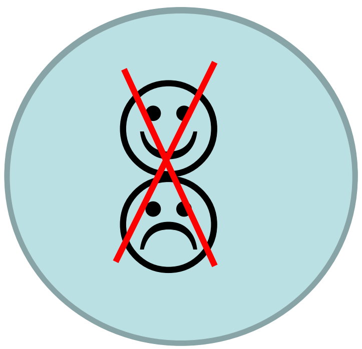
NA50 Eur. Phys. J. C 39, 335–345 (2005)

Observation of J/Ψ suppression is commonly accepted.
What about the origin?

Alternative explanation

Alternative explanation (1):

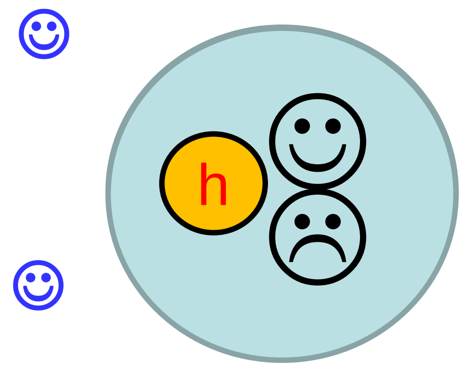
Modification of $c-\bar{c}$ production cross section in nuclear matter.



The production of $c-\bar{c}$ is modified.
J/Ψ suppression is trivial consequence.

Alternative explanation (2):

Destruction of J/Ψ by collision with nuclear matter.



J/Ψ is formed but destroyed by normal nuclear matter.
J/Ψ suppression occurs in absence of QGP.

To confirm/rule out alternative explanations, additional measurements are needed.

p-A as system of measuring CME

What do we know: J/Ψ dissapears… but we don‘t know why.
How to find out?

- $c-\bar{c}$ production:

Measure all particles containing charm quarks
(Easy for J/Ψ, hard for open charm)

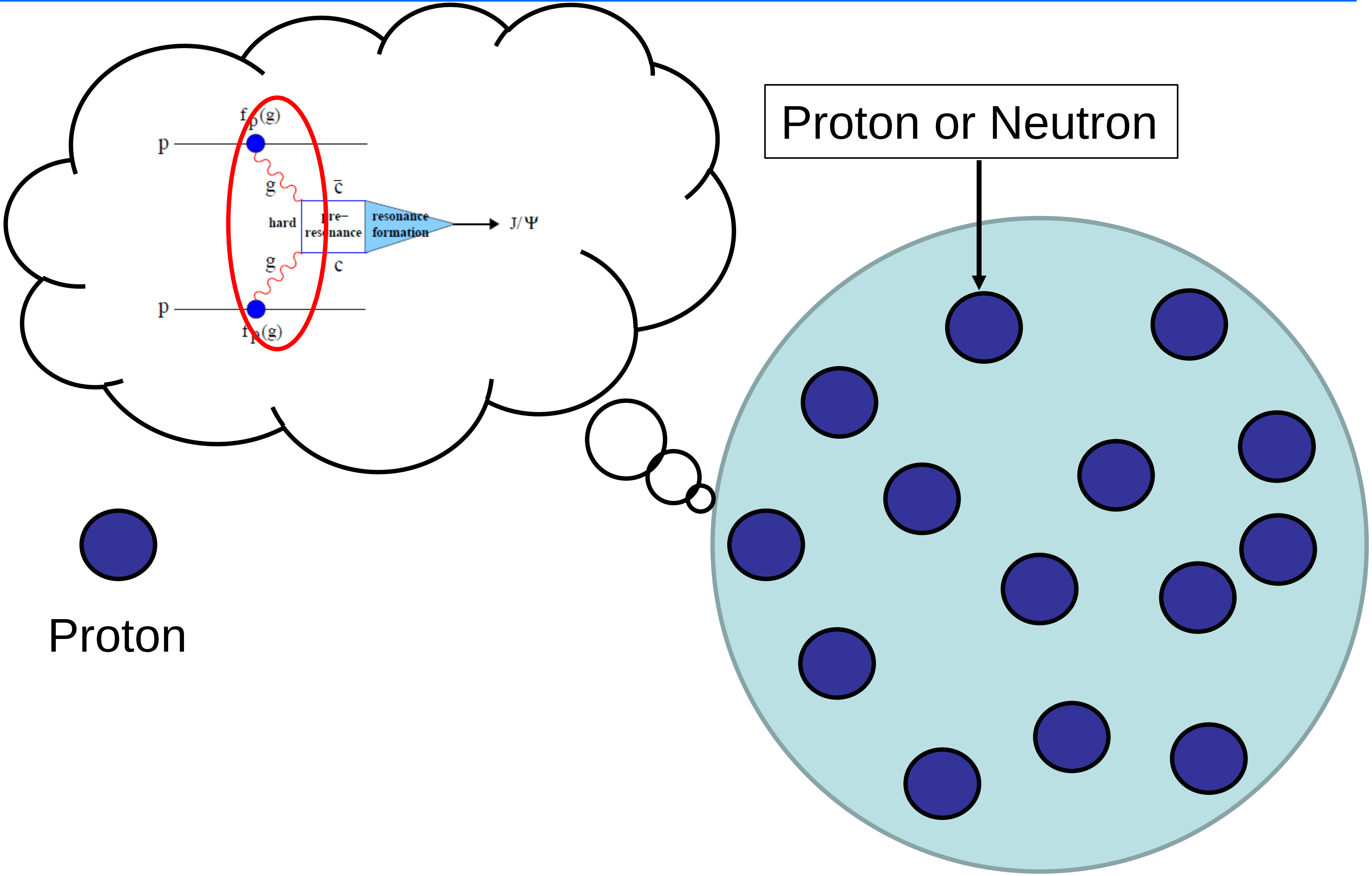
- Destruction of J/Ψ:

Check, if the presence of hadrons changes relative amount of charm particles.

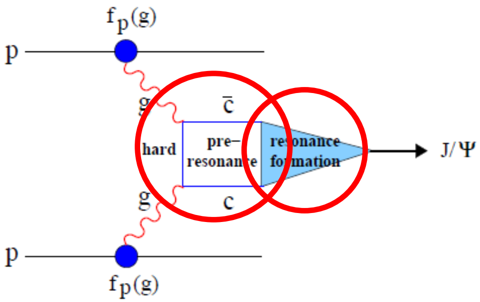
Suited collision system: p-A collisions

- $c-\bar{c}$ is produced in p-N collision
- Charm particle travels remaining nuclear core
- Nuclear core does not contain QGP (no energy to produce it)

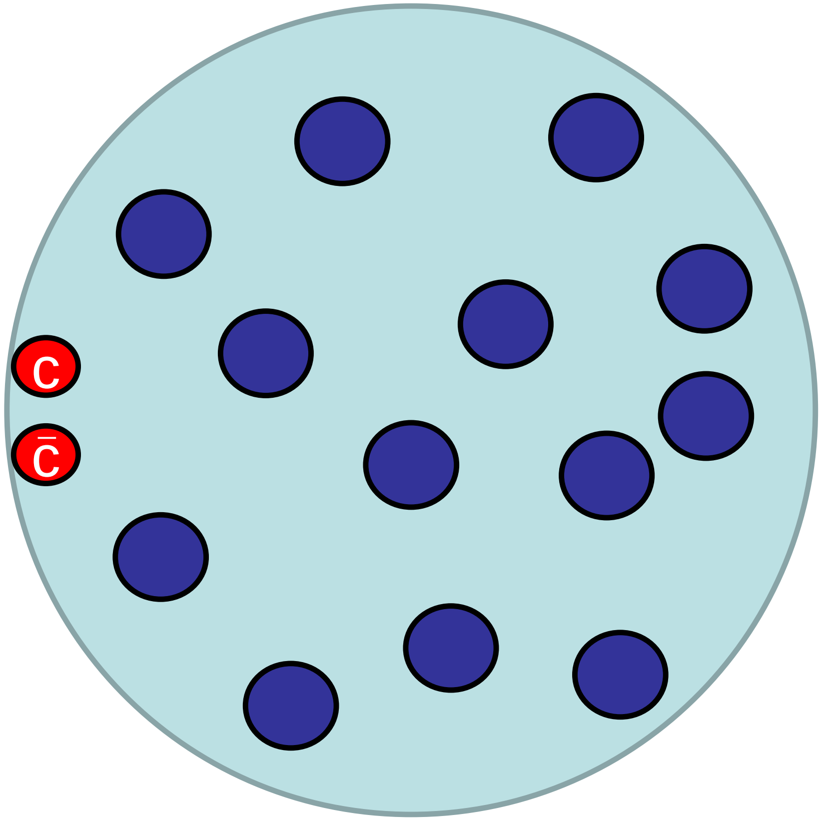
Measuring $\sigma(J/\Psi + \mathrm{N} \rightarrow \overline{\mathrm{D}} + X)$



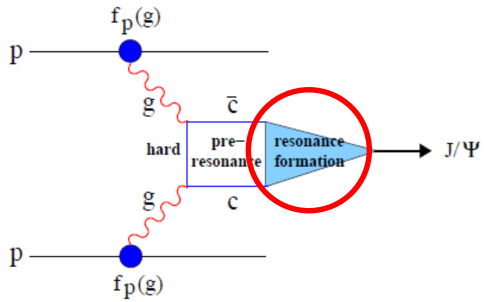
Measuring $\sigma(J/\Psi + \mathrm{N} \rightarrow \mathrm{D} + \bar{\mathrm{D}})$

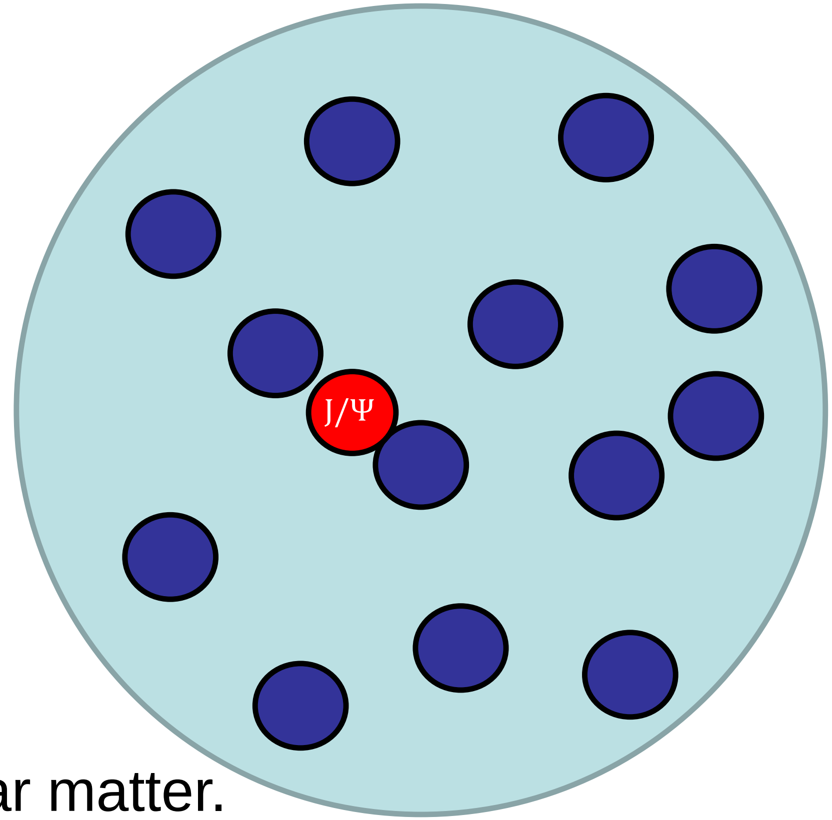


Phase 1: $c-\bar{c}$ formation.
Time needed: ~0.25 fm/c



Measuring $\sigma(J/\Psi + \mathrm{N} \rightarrow \mathrm{D} + \bar{\mathrm{D}})$





Phase 1: $c - \bar{c}$ formation.
Time needed: ~0.25 fm/c

Phase 2: J/Ψ formation.
Time needed: ~0.25 fm/c

Phase 3: J/Ψ travel through nuclear matter.

Measuring $\sigma(J/\Psi + \mathrm{N} \rightarrow \mathrm{D} + \bar{\mathrm{D}})$

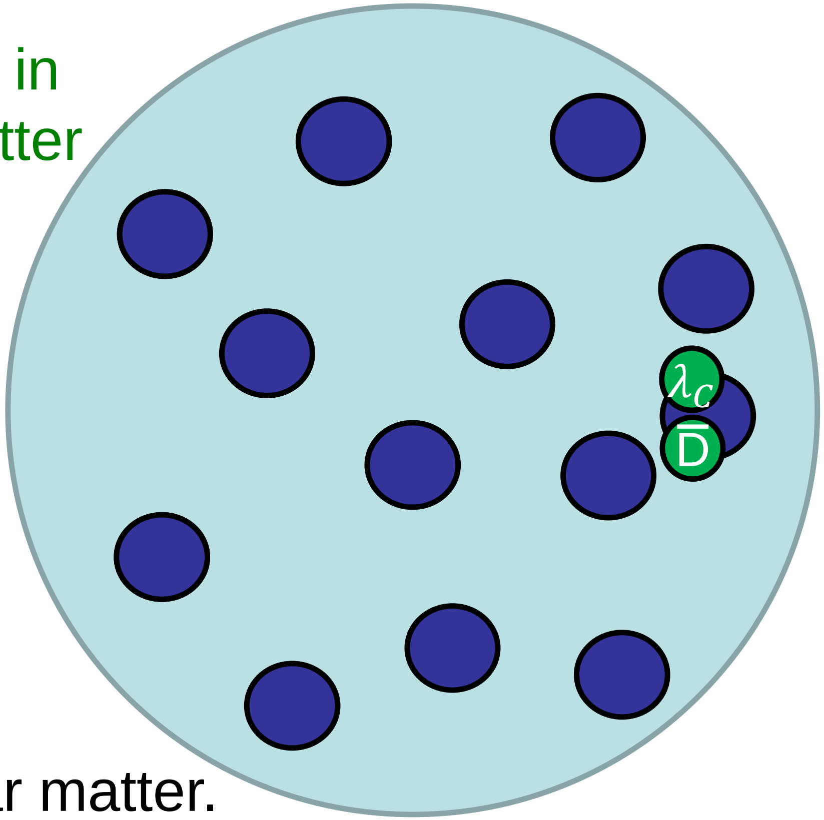
Dissociation cross section:

$$S_{J/\Psi} = \exp(-n_0\ \sigma_{J/\Psi}\ L_A)$$

Nuclear density

Cross section

Path of J/Ψ in nuclear matter



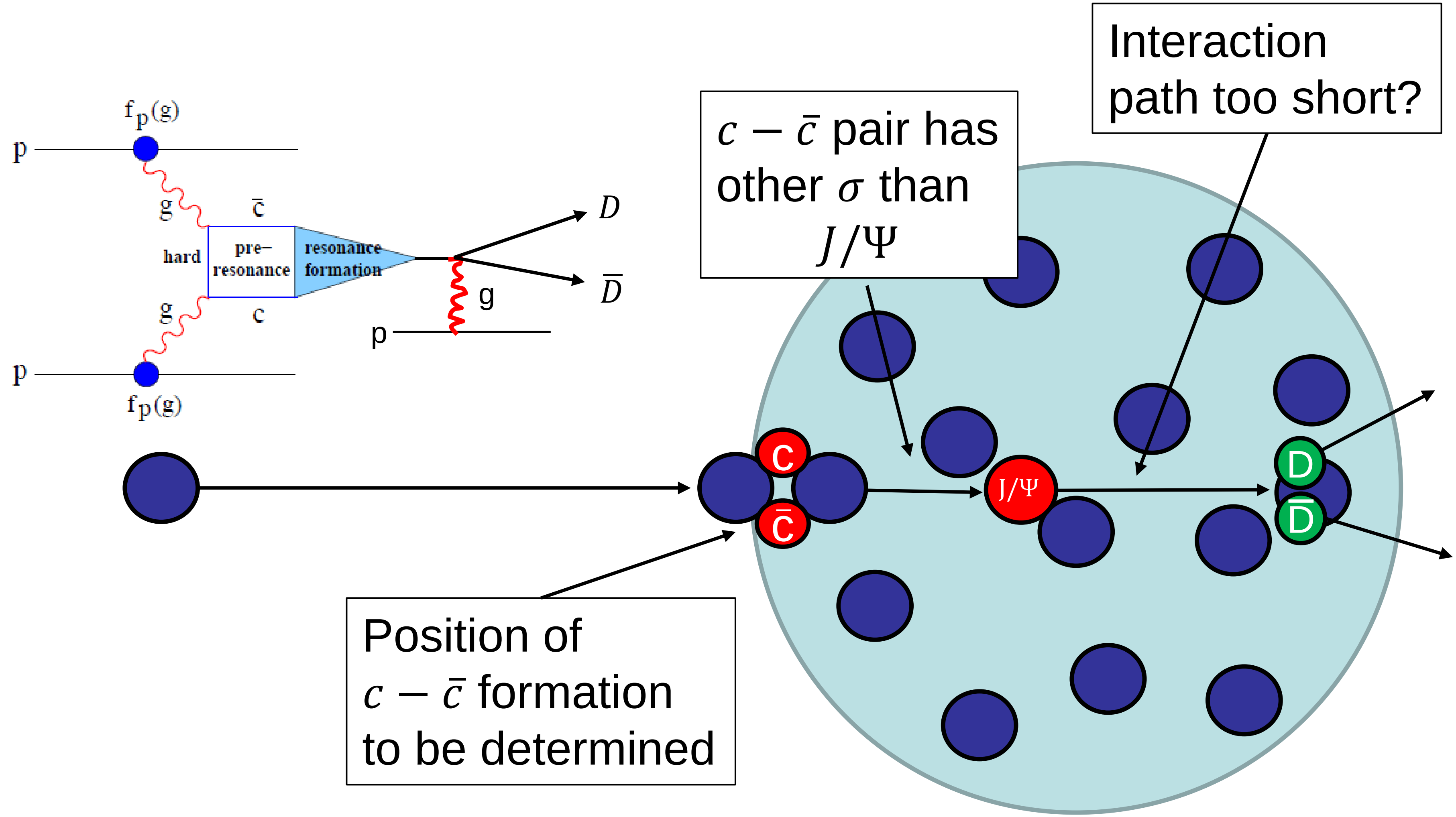
Phase 1: $c - \bar{c}$ formation.
Time needed: ~0.25 fm/c

Phase 2: J/Ψ formation.
Time needed: ~0.25 fm/c

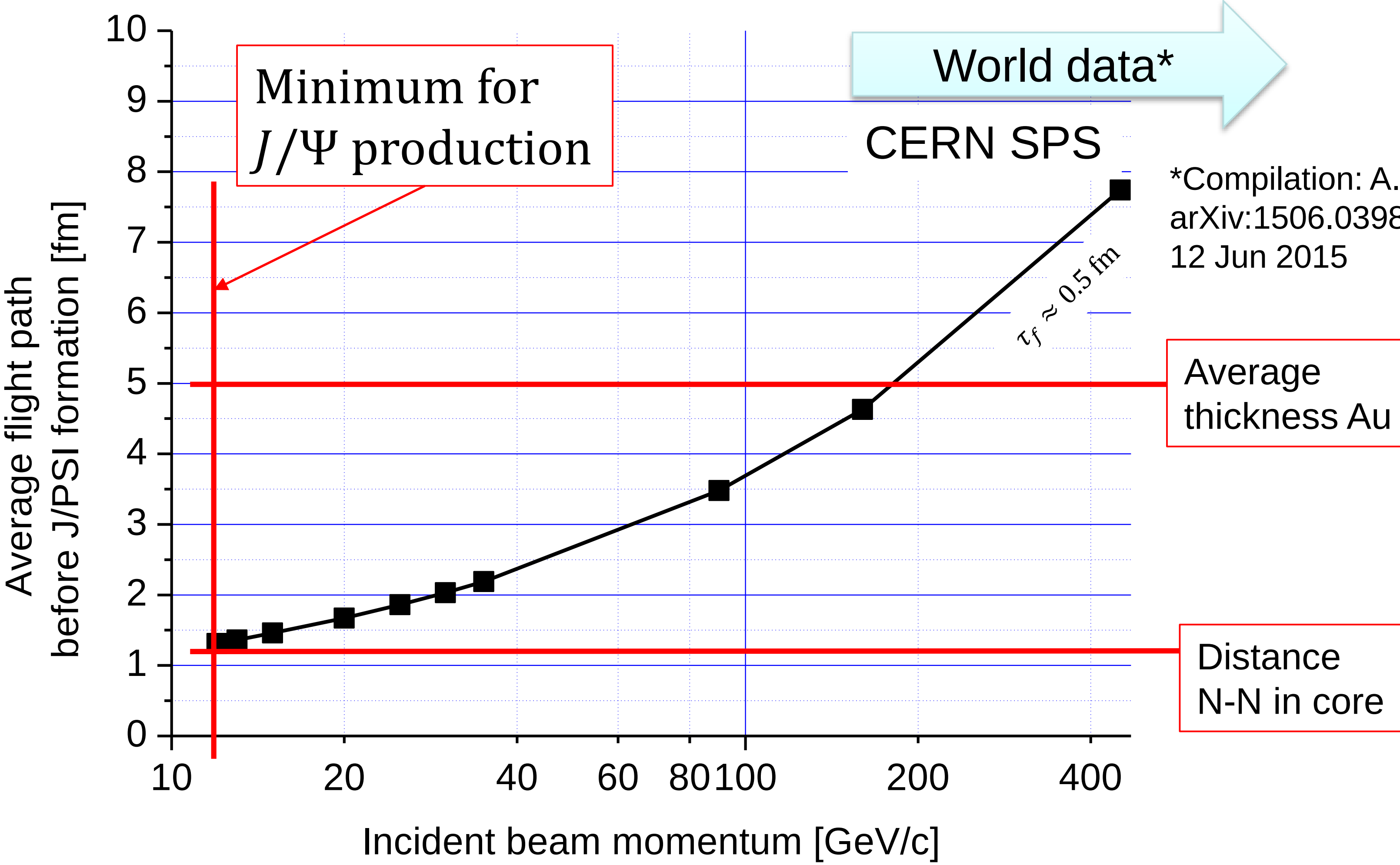
Phase 3: J/Ψ travel through nuclear matter.

Finally: Possible J/Ψ dissociation.

Measurement uncertainties?



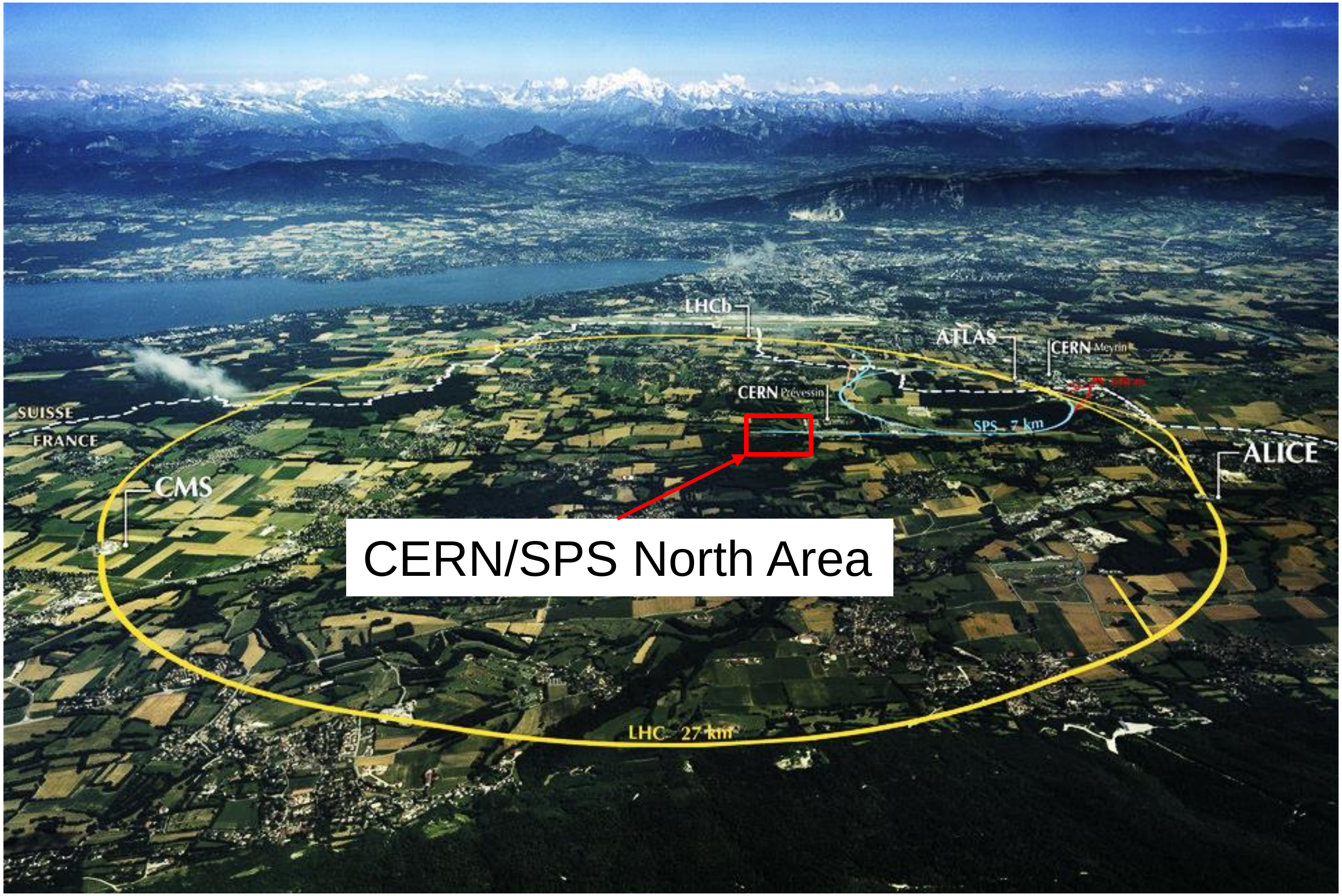
Formation length



*Compilation: A. Andronic et al., arXiv:1506.03981v1 [nucl-ex] 12 Jun 2015

Known since late 1980s:
Word data measures $c-\bar{c}$, not J/Ψ interaction in nucl. matter
Additional measuremens are needed…

Experimental proposal for SPS (1990s)



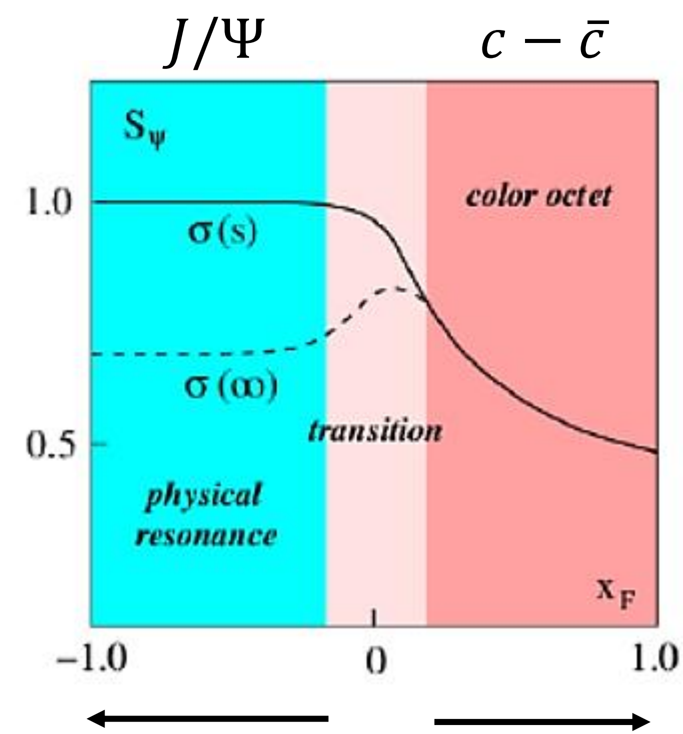
Measurements, initial proposal

D. Kharzeev, H. Satz, PLB 1995,
H. Satz – HICforFAIR Workshop: Heavy flavor physics with CBM, FIAS, May 2014

Idea:

- Shoot Au on p-target at SPS.
- Collect J/Ψ, which are emmitted in beam direction.

=> Select J/Ψ moving slowly in nuclear core.



slower faster

than center of mass

Problem (1990s):
Existing experiments not suited for doing the job (acceptance).

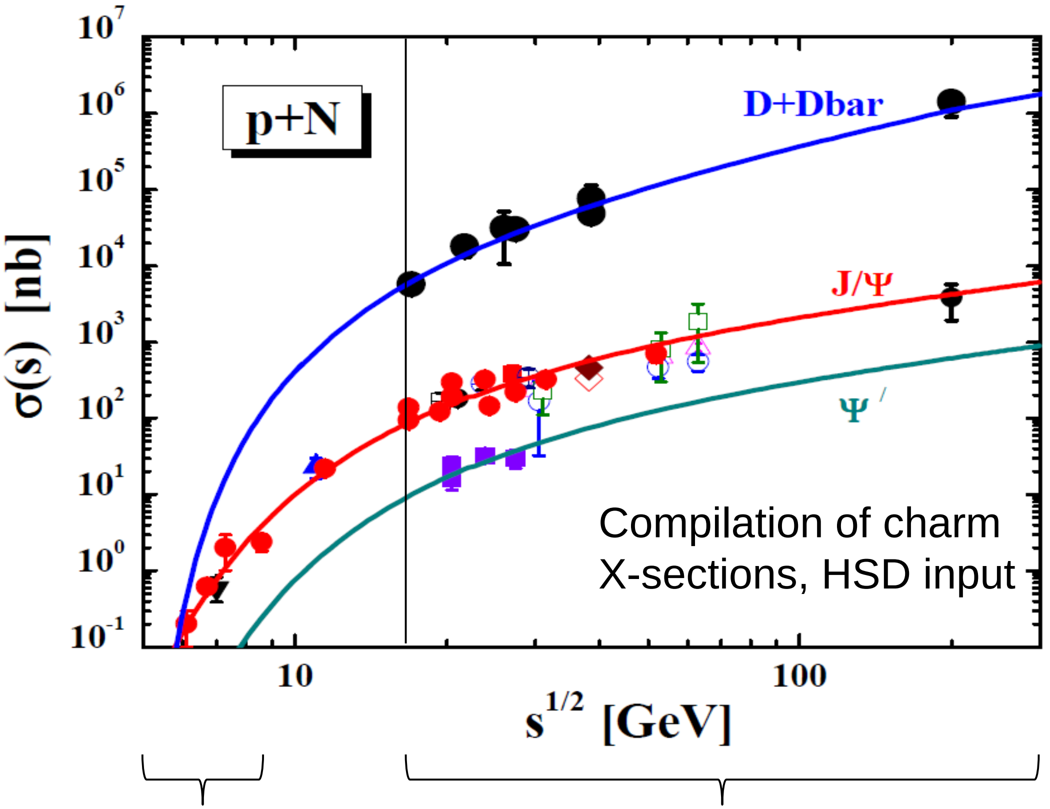
Today: No J/Ψ sensitive experiment @ SPS.

Consequence: Issue remained open from ~1990 until today.

Direct measurements – the challenge

Need to perform precision measurements with very low charm X-sections.
⇒ High collision rate

Need to measure open charm and J/Ψ.
=> Next generation instrument.



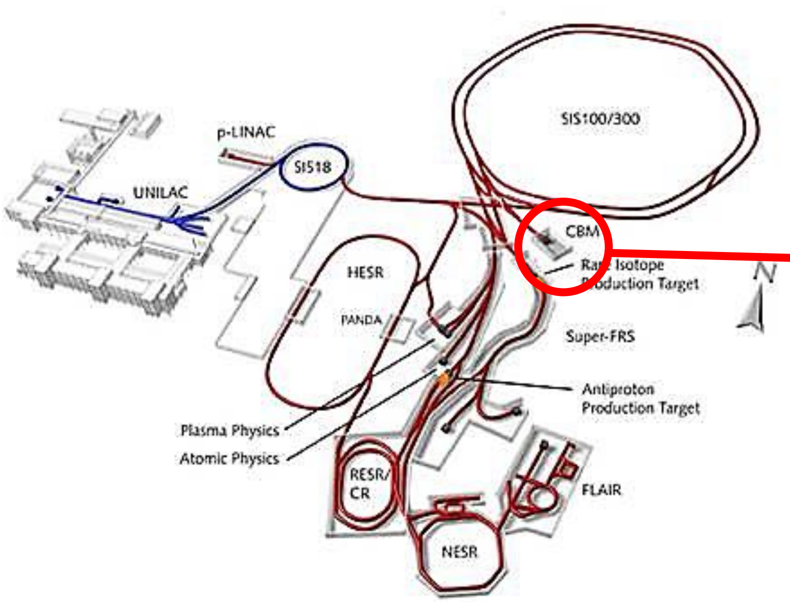
Region of interest

Robust data available

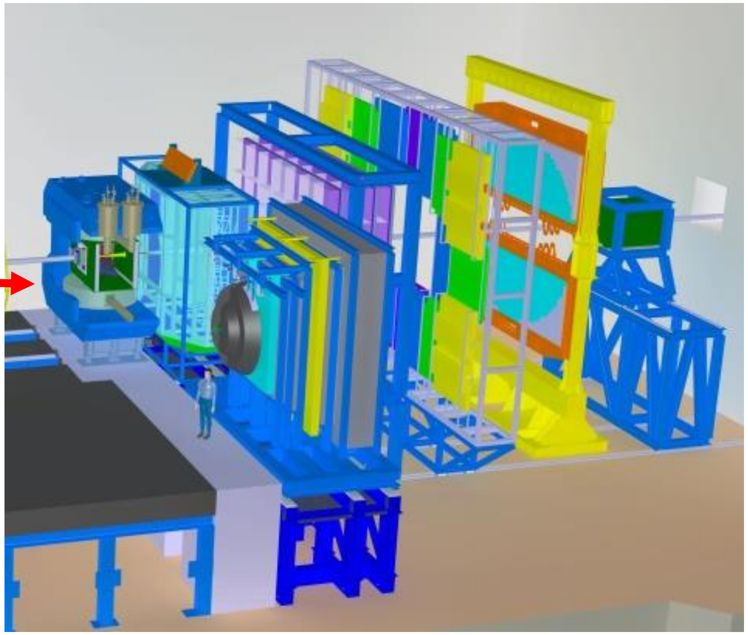
Required: A unique set of accelerator and detector

A possible technology

FAIR @ Darmstadt/Germany



The CBM - Experiment



Beam energy:

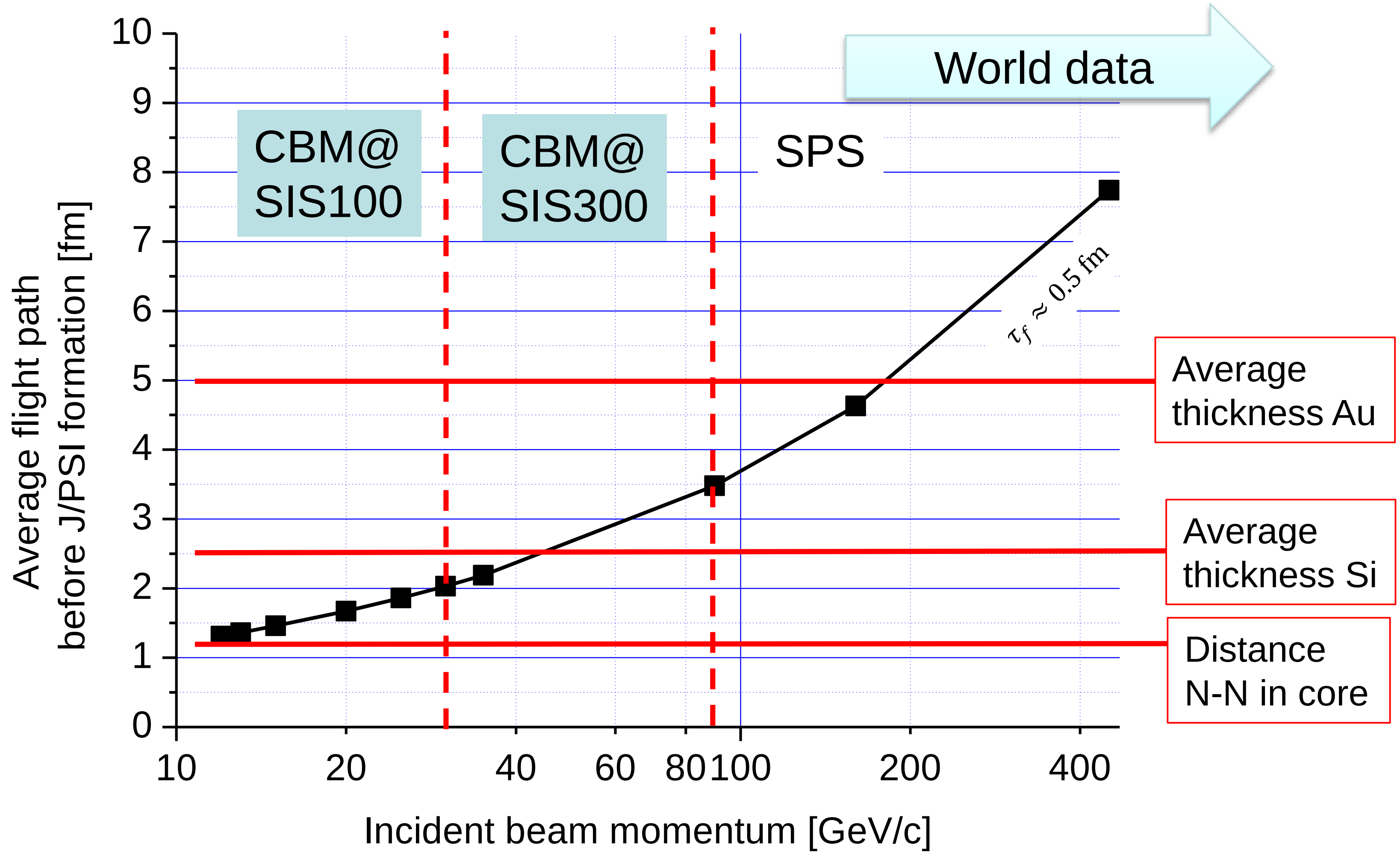
	Au+Au	p+A
SIS100	~12 AGeV	~30 GeV
SIS300	~35 AGeV	~90 GeV

Detector (design performance):

	Au+Au	p+A
J/Ψ	10^7 coll/s	>>10^7 coll/s
$D^{+,-,0}$	10^5 coll/s	10^7 coll/s

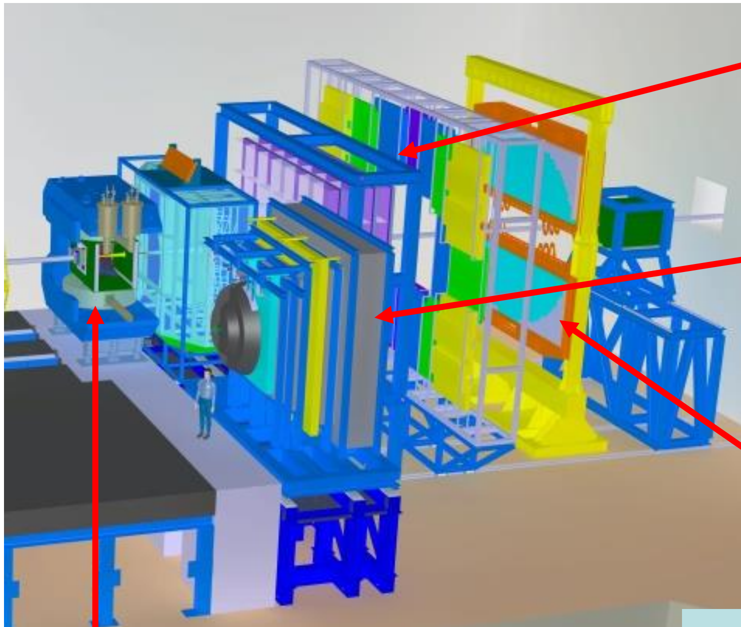
CBM@SIS100 will be available in 2021

Formation length



CBM@SIS100 covers the most interesting energy range for measuring J/Ψ dissociation.

CBM design features



Electron spectrometer:

$$J/\Psi \rightarrow e^{+} + e^{-}$$

Muon spectrometer:

$$J/\Psi \rightarrow \mu^{+} + \mu^{-}$$

EM – calorimeter:

$$J/\Psi \rightarrow \gamma + \gamma$$

Systematic errors can be controlled.
=> Suited for precision J/Ψ measurements.

High precision, high rate vertex detector + Time of flight detector:

$D^{\pm} \rightarrow K + \pi + \pi$

$D^{0} \rightarrow K + \pi$

$D^{0} \rightarrow K + \pi + \pi + \pi$

Open charm can be measured.
Suited to extract $c - \bar{c}$ cross sections.

Measurement uncertainties?

Low beam energy (e.g. 15 GeV)
$\Rightarrow$ fast formation of J/Ψ
$\Rightarrow$ $c-\bar{c}$ path small w.r.t. J/Ψ path

May be measured
Measure J/Ψ and D

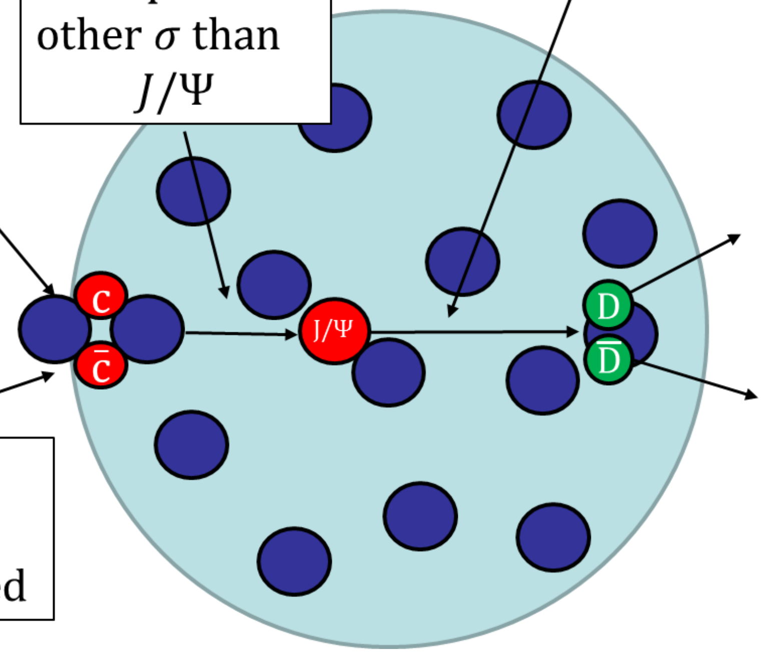
Close to $c-\bar{c}$ threshold.
Protons unlike to produce J/Ψ in second interaction.
=> J/Ψ production in first collision.

Modified $c-\bar{c}$ cross section?

$c-\bar{c}$ pair has other σ than J/Ψ

Interaction path too short?

Position of $c-\bar{c}$ formation to be determined

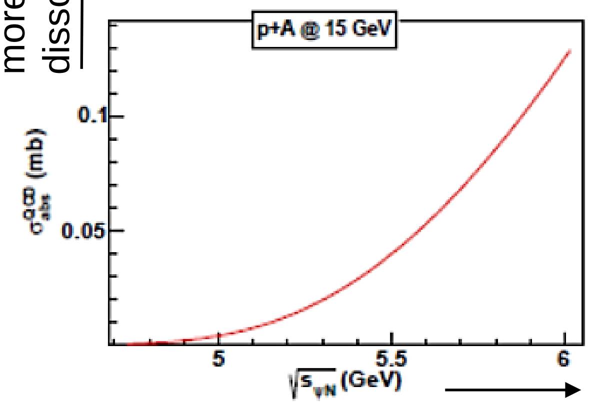


CBM seems particularly well suited to answer these questions.

Different models

more J/Ψ dissociation

D. Kharzeev, H. Satz
PLB 1995



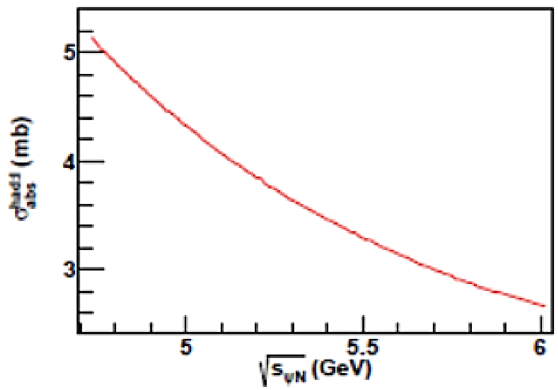
faster J/Ψ

Assumptions:

Gluonic dissociation
Hadronic dissociation negligible

=> Mostly no J/Ψ dissociation

K. Haglin et al.
PRC 2000

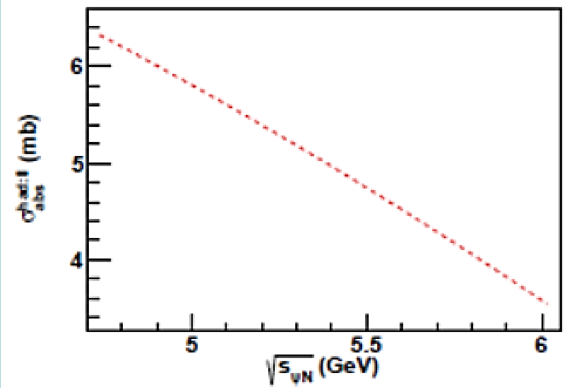


Assumptions:

Substantial hadronic dissociation:
$J/\Psi + \mathrm{N} \rightarrow \Lambda_C + \bar{D}$

=> Sizable J/Ψ dissociation.

R. Molina et al.
PRC 2012



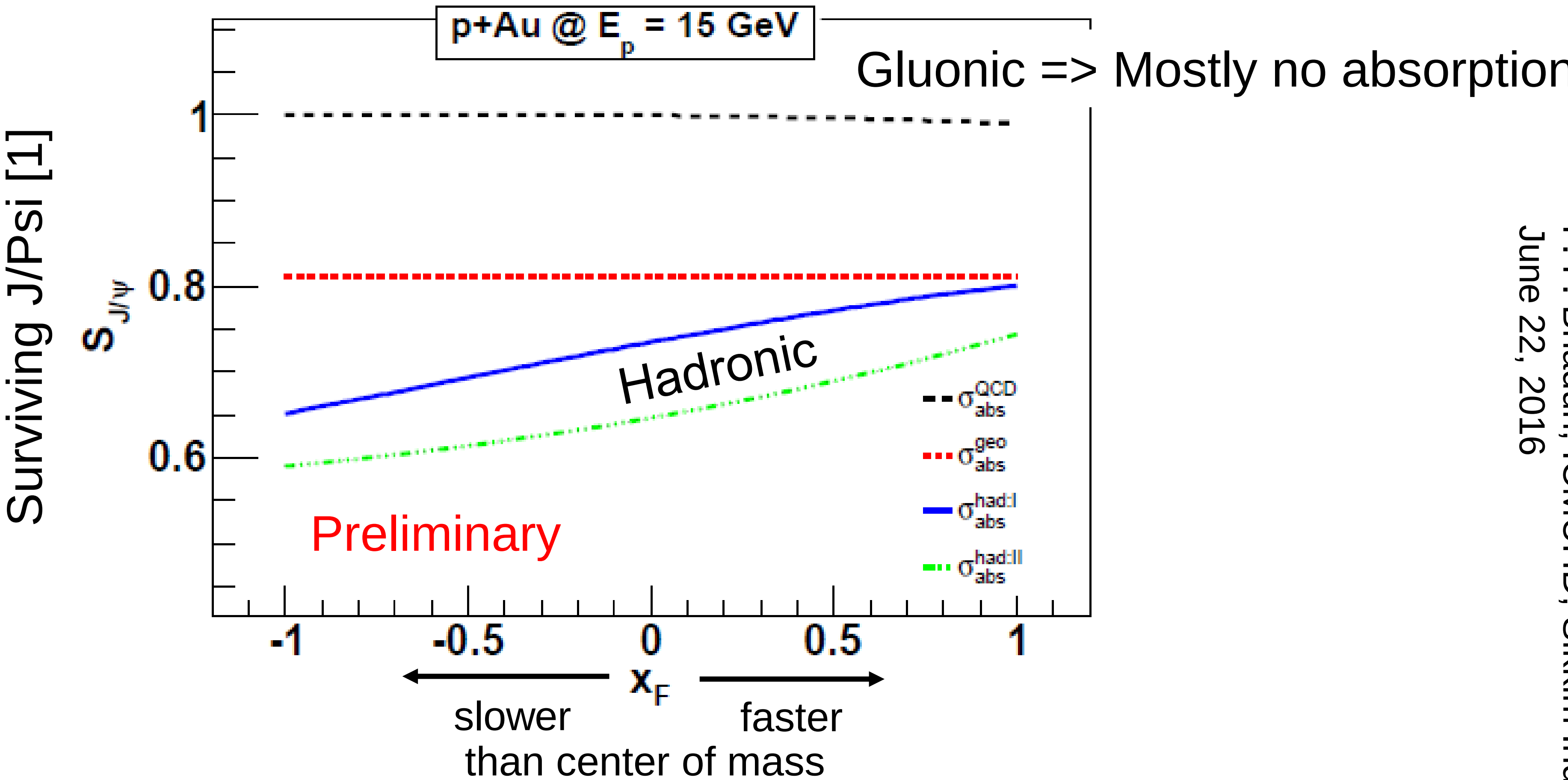
Assumptions:

Hadronic dissociation
Multiple channels
Fermi motion.

=> Sizable J/Ψ dissociation.

P. P. Bhaduri, ICMUHD, Sikkim India, June 22, 2016

Model separation



P. P. Bhaduri, ICMUHD, Sikkim India,
June 22, 2016

CBM should be able to distinguish different dissociation mechanisms (to be confirmed)

Summary and conclusion

J/Ψ suppression forms a classic probe for a phase transition from hadronic matter to QGP

Interpretation of known J/Ψ suppression is hampered by unknown X-section for hadronic J/Ψ dissociation.

Measurement so far impossible: $c - \bar{c}$ is boosted out of nuclear core before forming J/Ψ.

Measurements with CBM with p-A at SIS100 beam energies may

- provide necessary knowledge on hadronic J/Ψ dissociation
- allow for understanding J/Ψ dissociation process
- help to interpret existing data on J/Ψ suppression

Excluding hadronic J/Ψ suppression would support QGP as origin of the known J/Ψ.

Dedicated feasibility studies started. Stay tuned.