Quark Matter 2018 summary

Or: what I take home from the conference…
A biased summary

Marco van Leeuwen, Nikhef and CERN
Small systems
Small system flow: fine print!

Ansatz: soft production + jets, resonances, etc 'non-flow'

CMS, ALICE: high-multiplicity minus low-mult

ATLAS: template fit

Background scaling in $v_2$ determination matters!
New techniques: multi-particle subevent cumulants

Effectively suppress non-flow with moderate multiplicity/smaller eta gap
Checking geometry; $v_2 + v_3$

Elegant idea: vary geometry by changing shape of colliding nuclei

On top of this: fluctuations, orientation
Checking geometry; $v_2 + v_3$

Elegant idea: vary geometry by changing shape of colliding nuclei

On top of this: fluctuations, orientation

PHENIX, arXiv:1805.02973
New results on small system flow: LHC

Light flavours show ‘mass ordering’

D mesons and J/ψ also follow flow

Light and heavy flavour particles show large azimuthal anisotropy

Note also: effect seems to persist to high $p_T \sim 8 \text{ GeV}$ — details subject to ‘fine print’?
Flow without a liquid

Can you have flow with a few scatterings? ‘anisotropic escape’ mechanism

Initially isotropic momentum distribution

More particles moving in ±x-direction

Scattering randomises directions; more scatterings to ‘out-of-plane’

Anisotropic density converted into anisotropic momentum distribution by few scatterings

Kurkela, Wiedemann, Wu, arXiv:1805.04031

Kurkela, Wiedemann, Wu, arXiv:1803.02072
Flow without a liquid

Can you have flow with a few scatterings?
‘anisotropic escape’ mechanism

Initially isotropic momentum distribution

More particles moving in ±x-direction

Scattering randomises directions; more scatterings to ‘out-of-plane’
Anisotropic density converted into anisotropic momentum distribution by few scatterings

Kurkela, Wiedemann, Wu, arXiv:1803.02072

Transverse size: $\gamma = R / l_{\text{mfp}}$

Small systems: ‘single hit’ kinetic transport equal to full hydro

Kurkela, Wiedemann, Wu, arXiv:1805.04031
Flow without a liquid

Can you have flow with a few scatterings? ‘anisotropic escape’

More particles moving in ±x-direction

Kurkela, Wiedemann, Wu, arXiv:1803.02072

Two parallel strings

Formation time is important

Two-particle correlations

Shows a clear signal in a transport calculation

Other mechanisms/pictures being discussed: string shoving, CGC
⇒ more field-based; to some extent just a different language?

Review in M Strickland’s talk
Connecting small and large systems

Hydro (behavior) is everywhere

Large flow in small systems

Fast thermalisation/hydrodynamisation

IP Glasma fields

Hydrodynamics

Originally proposed by Heller and Spalinski, PRL (2015)

Review: Florkowski, Heller, Spalinski, 2017

M. Strickland, JN, G. Denicol, PRD 2018

See B. Meiring's talk
See I. Yan's talk
See M. Martinez' talk
See C. Chattopadhyay's talk
See U. Heinz' talk
See R. Critell's poster
See J. C. Solana's poster
See N. C. Cruz' poster
See G. Denicol's poster
See E. Maksymiuk's poster
Connecting small and large systems

Hydro (behavior) is everywhere

Downside of focusing on energy/momentum flow?

Fast thermalisation/hydrodynamisation

Large flow in small systems

---

Slide from J Noronha

See also: A Mazeliauskas

---

IP Glasma fields

Hydrodynamics

---

Originally proposed by Heller and Spalinski, PRL (2015)
Review: Florkowski, Heller, Spalinski, 2017

M. Strickland, JN, G. Denicol, PRD 2018

---

See B. Meiring's talk
See L. Yan's talk
See M. Martinez' talk
See C. Chattopadhyay's talk
See U. Heinz' talk
See R. Critelli's poster
See J. C-Solana's poster
See N. C. Cruz' poster
See G. Denicol's poster
See E. Maksymiuk's poster
Deriving proton substructure

Flow-like effects in pp require substructure 'constituents', strings, etc

J.S. Moreland, et al
Deriving proton substructure

Flow-like effects in pp require substructure
‘constituents’, strings, etc

Bayesian fit + gaussian emulator: probe large parameter space
Output: full covariance matrix 15 parameters

input: multiplicity, mean $p_T$, $v_n$ in PbPb and p-Pb

J.S. Moreland, et al
Deriving proton substructure

Flow-like effects in pp require substructure: ‘constituents’, strings, etc.

- Sampling radius
- Constituent width
- Constituent number

- 1 fm
- 0.8 fm
- 0.6 fm
- 0.4 fm

Bayesian fit + gaussian emulator: probe large parameter space
Output: full covariance matrix 15 parameters

Number of constituents

Constituent width, radius

input: multiplicity, mean $p_T$, $v_n$ in PbPb and p-Pb

No strong preference for a specific constituent number

width > radius
Deriving proton substructure

Flow-like effects in pp require substructure
‘constituents’, strings, etc

Bayesian fit + gaussian emulator: probe large parameter space
Output: full covariance matrix 15 parameters

Constituent width, radius

input: multiplicity, mean \( p_T \), \( v_n \) in PbPb and p-Pb

No strong preference for a specific constituent number

Number of constituents

Shows that we are sensitive to nucleon substructure
‘configuration space picture of the proton’
Proton substructure from UPCs

Coherent and incoherent exclusive $J/\psi$ in ep

$\gamma p \rightarrow J/\psi p, Q^2 = 0 \text{GeV}^2$

**UPC at the LHC**

**ALICE: 1406.7819**

**Talk:** H Mantysaari  
**Overview:** A Angerami

Coherent: average

\[
\frac{d\sigma}{d|t|} \propto \langle |A| |p\rightarrow Vp| \rangle^2
\]

Incoherent: RMS

\[
\frac{d\sigma}{d|t|} \propto \langle |A| |p\rightarrow Vp| \rangle^2 - \langle |A| |p\rightarrow Vp| \rangle^2
\]

Dissociative increase more slowly than elastic consistent with HERA data

Different angle: Spatial size, fluctuations measured by coherent/incoherent interactions

Should compare and contrast conclusions from flow/final state and EM interactions
Switching off the flow: $e^+e^-$

Talk: J-Y Lee

High-multiplicity events

Low T; ‘multi-jet’

High T; ‘di-jet’

No evidence of long-range correlations beyond Pythia expectation
Familiar behaviour: non-flow dominates at small multiplicity and without eta-gap

No flow-like signal seen in high-multiplicity, large eta gap for $c_2$, $c_3$, $c_4$
Familiar behaviour: non-flow dominates at small multiplicity and without eta-gap

No flow-like signal seen in high-multiplicity, large eta gap for $c_2$, $c_3$, $c_4$

No flow with ‘single string’ ⇒ Need multiple interactions to set up initial geometry
Flow without energy loss?

Open charm mesons

ALICE Preliminary \( p\bar{p}, \sqrt{s_{NN}} = 5.02 \text{ TeV} \)
Prompt D mesons, \(-0.96 < y_{cm} < 0.04\)

\[
R_{ppb} = 1
\]

Non-prompt J/\(\psi\) from B

\[
ATLAS-CONF-2018-013
\]

\[
R_{ppb} = 1
\]
Flow without energy loss?

Open charm mesons

ALICE Preliminary  p–Pb, √s_{NN} = 5.02 TeV
Prompt D mesons, -0.96 < y_{cm} < 0.04

Average D^0, D^+, D^- measured pp reference at √s = 5.02 TeV

Average D^0, D^+, D^- measured pp reference at √s = 5.02 TeV

Non-prompt J/ψ from B

Flow from transport: need only few (elastic) scatterings to generate v_2
energy loss can be small
What about peripheral AA?

Why is $R_{AA} \sim 0.8$ for peripheral events? $N_{\text{part}} \sim 5-10 \sim p$-Pb

Observation: $R_{AA}$ does not increase for centrality $> 80\%$
It decreases?
Peripheral events described by HG-Pythia
increase of pp impact parameter + multiplicity
What about peripheral AA?

Why is $R_{AA} \sim 0.8$ for peripheral events?

$N_{\text{part}} \sim 5-10 \sim p$-Pb

Observation: $R_{AA}$ does not increase for centrality $> 80$
It decreases?

Peripheral events described by HG-Pythia
increase of pp impact parameter + multiplicity

ALICE, Pb-Pb, $\sqrt{s_{NN}} = 5.02$ TeV, charged particles, $|\eta| < 0.8$

$R_{AA}$ for peripheral events

QM2017: D Perepelitsa

ALICE, arXiv:1805.05212
Flavour production in small systems

(Multi-)strange baryon production

T. Sjostrand @ QM

- Conventional pp generators successful, with MPI + CR generating some collectivity, but now cracks.
- Need new framework for baryon production.
- String close-packing likely to influence hadronization, before (shoving), during (ropes) and after (rescattering).

Increase of strange baryon production already starts in pp
Flavour production in small systems

T. Sjostrand @ QM

- Conventional pp generators successful, with MPI + CR generating some collectivity, but now cracks.
- Need new framework for baryon production.
- String close-packing likely to influence hadronization, before (shoving), during (ropes) and after (rescattering).

(Multi-)strange baryon production

Increase of strange baryon production already starts in pp

Heavy quark baryon/meson ratio similar to $\Lambda/K$

Much larger than e.g. Pythia
Flavour production in small systems

(Multi-)strange baryon production

- Conventional pp generators successful, with MPI + CR generating some collectivity, but now cracks.
- Need new framework for baryon production.
- String close-packing likely to influence hadronization, before (shoving), during (ropes) and after (rescattering).

T. Sjostrand @ QM

Increase of strange baryon production already starts in pp

Heavy quark baryon/meson ratio similar to $\Lambda/K$

Much larger than e.g. Pythia

Changing the system size: Xe-Xe

1-day run in Oct 2017
Many new results from ALICE, ATLAS and CMS
Multiplicity production

Multiplicity/N_{part} ‘scales’ (approximately) between XeXe and PbPb
Multiplicity production

Multiplicity/\(N_{\text{part}}\) ‘scales’ (approximately) between XeXe and PbPb

![Graph showing multiplicity production](image)

CMS

Preliminary

CMS-PAS-HIN-17-006

CMS

XeXe \(\sqrt{s_{NN}} = 5.44\) TeV

\(\langle dN_{\text{ch}}/d\eta \rangle \bigg|_{|\eta|<0.5} / \langle N_{\text{part}} \rangle\)

ALICE, \(|\eta|<0.5\)

Xe-Xe \(\sqrt{s_{NN}} = 5.44\) TeV

Pb-Pb \(\sqrt{s_{NN}} = 5.02\) TeV

<table>
<thead>
<tr>
<th>(N_{\text{part}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(N_p=3, \mu=3.5)</td>
</tr>
<tr>
<td>(N_p=3)</td>
</tr>
<tr>
<td>(N_p=5, \mu=4.3)</td>
</tr>
<tr>
<td>(N_p=5)</td>
</tr>
</tbody>
</table>

Sharper increase for central collisions

Origin not fully understood?
Flow in Xe-Xe

Zeroth order:
Centrality dependence of average $v_n$ very similar
Driven by centrality, $\epsilon_n$, not volume/multiplicity!

Next order: increase of $v_2$ in central collisions
- Fluctuations
- Deformed Xe

Described by Trento+Hydro

ATLAS Preliminary
Centrality (%)

CMS Preliminary
$0.3 < p_t < 3$ GeV/c

CMS-PAS-HIN-18-001

ALICE, arXiv:1805.01832

ATLAS-CONF-2018-011
Closer look at $v_2$ and $v_3$ scaling

Explore initial state models:

$\varepsilon_n = f(\text{cent, A})$

$S = g(\text{cent, A})$

Trento $p=0$ gives a good description of the initial state

$\rho \propto \sqrt{T_A T_B}$

As does const quark glauber, with $q=5,7$

$\frac{v_n}{\varepsilon_n} = \text{hydro conversion efficiency}$

$1/S \frac{dN_{\text{ch}}}{d\eta} \text{ (fm}^{-2}) = \text{energy density}$
Closer look at $v_2$ and $v_3$ scaling

Explore initial state models:

$\varepsilon_n = f(\text{cent}, A)$
$S = g(\text{cent}, A)$

Trento $p=0$ gives a good description of the initial state

$$\rho \propto \sqrt{T_A T_B}$$

As does const quark glauber, with $q=5,7$

Also being explored at RHIC
Nuclear modification factor: centrality dependence

Approximate scaling with $N_{\text{part}}$, or $dN/d\eta$

New scaling proposal:

\[ R_{L}^{XePb} \equiv \frac{1 - R_{XeXe}}{1 - R_{PbPb}} \approx \frac{\xi T^{a} L^{b}_{Xe}}{\xi T^{a} L^{b}_{Pb}} \approx \left( \frac{A_{Xe}}{A_{Pb}} \right)^{b/3} \]

Djordjevic, arXiv:1805.04030

T-dependence drops out when $T$ similar for equal centralities

ALICE, arXiv:1805.04399
Nuclear modification factor: centrality dependence

**Approximate scaling with \( N_{\text{part}} \), or \( dN/d\eta \)**

Theory/phenomenology task:
Explore constraints on density, path length dependence

New scaling proposal:
Djordjevic, arXiv:1805.04030

\[
R_{L}^{XePb} \equiv \frac{1 - R_{XeXe}}{1 - R_{PbPb}} \approx \frac{\xi T^{a} L_{Xe}^{b}}{\xi T^{a} L_{Pb}^{b}} \approx \left( \frac{A_{Xe}}{A_{Pb}} \right)^{b/3}
\]

T-dependence drops out when T similar for equal centralities

ATLAS-PRELIMINARY

ALICE, arXiv:1805.04399
System size check list

Leveraging the system size as an free parameter:

• Multiplicity production: quasi-understood

• Azimuthal anisotropies: understood

• Nuclear modification factors: some homework to do, no surprises
System size check list

Leveraging the system size as an free parameter:

- Multiplicity production: *quasi-understood*
- Azimuthal anisotropies: *understood*
- Nuclear modification factors: some homework to do, no surprises

...we understand the dominant dynamics
Magnetic fields and angular momentum

Anomalous *chiral* effects
(e.g., CME)

**Vortical effects**
(e.g., Polarization)

Time evolution of magnetic fields depends on conductivity
Probing the magnetic field: Charge dependence of directed flow

Classical effects: Lorentz

Hall effect

ALICE: charged particles

STAR: D mesons

Talk: S Singha

Hint of charge dependence of $v_1$

D meson $v_1$ might be large; quark charge dependence
Probing the magnetic field: Charge dependence of directed flow

Classical effects:
- Lorentz
- Hall effect

ALICE: charged particles

Directed flow ($v_1$)

<table>
<thead>
<tr>
<th>Theory update: vorticity reduces signal</th>
</tr>
</thead>
</table>

D meson $v_1$ might be large; quark charge dependence

Sketch: J Margutti
Probing the magnetic field: Charge dependence of directed flow

Classical effects: Lorentz

\[ F = q v \times B \]

Hall effect

\[ \nabla \times E = -\frac{\partial B}{\partial t} \]

ALICE: charged particles

\[ v_1 = \frac{\langle p_x \rangle}{p_T} \]

Preliminary signals are small, but may be in reach.

Theory update: vorticity reduces signal

Hint of charge dependence of \( v_1 \)

D meson \( v_1 \) might be large; quark charge dependence

Resulting signals are small, but may be in reach
Chiral Magnetic effect

Observable: charge separation perpendicular to event plane

\[ J_5 \propto \mu_y B \]

Conditions:

1) Chiral imbalance:
   e.g. more left than right handed
2) Magnetic field

Caveat: large backgrounds from \( v_2 \)
Chiral Magnetic effect

Observables: charge separation perpendicular to event plane

\[ J_5 \propto \mu_5 B \]

Conditions:
1) Chiral imbalance: e.g. more left than right handed
2) Magnetic field

Caveat: large backgrounds from \( v_2 \)

ALICE, CMS: use event-shape engineering to dial background

ALICE, PLB 777, 151

CMS, PRC 97 (2018) 044912
Chiral Magnetic effect

Conditions:
1) Chiral imbalance: e.g. more left than right handed
2) Magnetic field

Observable: charge separation perpendicular to event plane

\[ \mathbf{J}_5 \propto \mu_y \mathbf{B} \]

ALICE, CMS: use event-shape engineering to dial background

STAR: mass dependence + ESE

Caveat: large backgrounds from \( v_2 \)
Chiral Magnetic effect: limits

Observable: charge separation perpendicular to event plane

\[ J_5 \propto \mu_B \mathcal{B} \]

Conditions:
1) Chiral imbalance: e.g. more left than right handed
2) Magnetic field

ALICE, PLB 777, 151

Several groups are modeling hydro + magnetic fields
Overview talk: F. Becattini
Chiral Magnetic effect: limits

Observable: charge separation perpendicular to event plane

\[ J_5 \propto \mu_y B \]

Conditions:
1) Chiral imbalance:
   e.g. more left than right handed
2) Magnetic field

Current consensus:
- Backgrounds are large
- Signal fraction may be < 10% at RHIC + LHC

Current consensus:
- Backgrounds are large
- Signal fraction may be < 10% at RHIC + LHC

Several groups are modeling hydro + magnetic fields
Overview talk: F. Becattini
Chiral Magnetic effect: limits

Observable: charge separation perpendicular to event plane

\[ J_5 \propto \mu_y B \]

Conditions:
1) Chiral imbalance:
   e.g. more left than right handed
2) Magnetic field

Current consensus:
- Backgrounds are large
- Signal fraction may be < 10% at RHIC + LHC

RHIC isobar run dedicated to this topic

Conditions:
1) Chiral imbalance:
   e.g. more left than right handed
2) Magnetic field

Current consensus:
- Backgrounds are large
- Signal fraction may be < 10% at RHIC + LHC

RHIC isobar run dedicated to this topic

Several groups are modeling hydro + magnetic fields
Overview talk: F. Becattini
Vorticity

Clear effect seen: modulation of longitudinal spin alignment with angle to event plane

However: sign is opposite of expected!
High $p_T$ and Jets
The basics: Charged particle $R_{AA}$

Nuclear modification factor results continue to improve uncertainties and extend $p_T$ range
The basics: Charged particle $R_{AA}$

Nuclear modification factor results continue to improve uncertainties and extend $p_T$ range

Challenge for models + field
How accurate do we expect models to be?
Relating jets and hadrons: fragment distributions

Reminder: jets are also suppressed

jet $R_{AA} <$ hadron $R_{AA}$ (at fixed $p_T$)
Relating jets and hadrons: fragment distributions

Reminder: jets are also suppressed
jet $R_{AA} <$ hadron $R_{AA}$ (at fixed $p_T$)

Link: fragment distributions
‘fragmentation functions’

NB: While not ‘fragmentation functions’ in the QCD/vacuum sense, fragment distributions also evolve slowly with jet $p_T$
Relating jets and hadrons: fragment distributions

Reminder: jets are also suppressed
jet $R_{AA} < \text{hadron } R_{AA}$ (at fixed $p_T$)

Link: fragment distributions
‘fragmentation functions’

NB: While not ‘fragmentation functions’ in the QCD/vacuum sense, fragment distributions also evolve slowly with jet $p_T$

Need high-$z$ enhancement to connect the dots

Talk: D Pablos
Relating jets and hadrons: fragment distributions

Reminder: jets are also suppressed
jet $R_{AA} <$ hadron $R_{AA}$ (at fixed $p_T$)

Link: fragment distributions
‘fragmentation functions’

NB: While not ‘fragmentation functions’ in the QCD/vacuum sense, fragment distributions also evolve slowly with jet pt

Need high-$z$ enhancement to connect the dots

Next step: jets as multi-parton states; do the partons lose energy independently?
Medium-induced and vacuum splittings; coherence

Formation time set by angle, momenta

Caucal, Iancu et al, arXiv:1801.09703

\[ t_{\text{vac}} \ll t_{\text{med}} \equiv \sqrt{\frac{\omega}{q}} \iff \omega \gg \left( \frac{q}{\theta_0} \right)^{\frac{1}{3}} \]

Expect radiation outside medium

Qualitatively has the right behavior:
Large angle radiation is formed outside the medium?
High-$p_T$ jets vs hadrons

**Charged particle $R_{AA}$**

- CMS 5.02 TeV
- ALICE 2.76 TeV
- CMS 2.76 TeV
- ATLAS 2.76 TeV

**Jet $R_{AA}$**

- ATLAS Preliminary
- anti-$k_T$, $R = 0.4$ jets

**$p_T$-dependence:**

- Single particles: consistent with expected constant ($\log E$) dependence
- Jets: suggest increase of $\Delta E$ vs $E$

**Tentative interpretation:** in jets, multiple partons lose energy; more partons in high-E jets $\Rightarrow$ more E-loss
High-$p_T$ jets vs hadrons

$p_T$-dependence:

Single particles: consistent with expected constant (log $E$) dependence

Jets: suggest increase of $\Delta E$ vs $E$

Tentative interpretation: in jets, multiple partons lose energy; more partons in high-$E$ jets $\Rightarrow$ more $E$-loss

First glimpse of jets as scale-dependent probes

Opens up a field of study: $p_T$-dependence of jet modifications
Jet sub-structure: measuring partons

Declustering: ‘peel apart’ the shower

Increase in asymmetric splittings

Normalisation: probability distribution per jet that passes the cut

Reduction in (rare) symmetric splittings

CMS, PRL 120 (2018) 142302

Zapp and Milhano, PLB 779 (2018) 409

Without recoil: energy loss suppress symmetric splittings

With recoil: soft fragments/medium enhancement at small z

What drives the change?
Jet sub-structure: measuring partons

- Suppression at large z (symmetric splittings)
- increase of unselected jets ($z_g < 0.1$; or $\Delta R < 0.2$ for right panel)

Consistent with independent energy loss of large angle splittings
Direct photons: ‘fixing’ the jet energy and color charge

\( \gamma \)-jet momentum balance pp

\( p_T^\gamma = 100-158 \) GeV

Centrality dependence; \( p_T^\gamma = 100-158 \) GeV

\( p_T^\gamma = 63.1-79.6 \) GeV

Even in pp balance not perfect
Described well by Pythia, Herwig, and NLO

Clear increase in asymmetry: energy loss
NB: some recoil jets may fall below the cut

Shape depends on \( p_T^\gamma \)
Low \( p_T \) more asymmetric

See also: CMS, HIN-16-002

ATLAS-CONF-2018-009
Recoil fragment distributions

Recoil fragment distributions $p_{T,\gamma} > 60$ GeV

Recoil fragment distributions: $\gamma$-jet and di-jet

$\gamma$-jet, $p_{T,\gamma} > 60$ GeV

$\gamma$-jet: suppression at high $z$

Di-jet: enhancement at large $z$

Different bias/selection

quark vs gluon jets

Models capture trends

Need mechanism

for soft fragments

Enhancement of soft fragments; reduction of hard fragments

$\xi_{jet} = \ln \left( \frac{p_{T,jet}}{p_{T,h}} \right)$

$\xi_{\gamma} = \ln \left( \frac{p_{T,\gamma}}{p_{T,h}} \right)$

$\xi = 0.7 \sim z = 0.5$
Electromagnetic hard probes: muon pairs

UPC process:
\[ gg \rightarrow m \rightarrow m \]

Heavy flavour background subtracted with DCA, momentum balance

\[ \alpha = 1 - \frac{|\phi^+ - \phi^-|}{\pi} \]
Electromagnetic hard probes: muon pairs

UPC process:
$gg \rightarrow m \ m$

Acoplanarity

$\langle k_T^2 \rangle \approx 70$ MeV
Electromagnetic hard probes: muon pairs

UPC process:
\[ gg \rightarrow m m \]

Induced \( \langle k_T^2 \rangle \approx 70 \text{ MeV} \)

Is this EM tomography of the QGP?

Small effect, but measurable with di-muons
Heavy Flavor
Open charm at RHIC energies

New D meson RAA

Updated results: $R_{AA} < 1$ at all $p_T$

$D_s/D^0$ ratio

$\Lambda/D^0$ ratio

$D_s$ and $\Lambda_c$ production larger than pp

Charm redistributed over hadronic channels?
Heavy flavor flow

Heavy flavor participates in the collective dynamics at RHIC and LHC energies.
Flow strength similar to light hadrons.
Heavy flavor modeling

Challenge for theory: understand modelling landscape; what features are essential? What further experimental input can be generated?

Model strategies

Benchmarking the theories ‘apples-to-apples’

End game: determine $D_s(T)$

... and compare to related quantities

References:
- R Rapp et al, arXiv:1803.03824
Heavier flavor: B mesons

STAR: D⁰ from B mesons
Qualitatively consistent with expectations:
B less suppressed than D

CMS: D⁰ from B mesons

Beauty production and flow being explored

Further test of heavy flavor transport
HF production dynamics: direct pairs vs gluon jets

Use di-muon angle distributions to differentiate pair creation: back-to-back pairs

gluon splitting: near side pairs

electron-positron mass distribution depends on angular distributions

Future direction:

single vs double b-tag jets

+ several new results on D mesons in jets from ALICE+CMS

Exciting prospects: use heavy flavors to tag shower prongs and follow energy loss

Multi-parton energy loss
**J/ψ at high p_{T}**

**Low p_{T}: coalescence/recombination important**

**High p_{T}: open and hidden charm R_{AA} similar**

**J/ψ suppression at high p_{T} driven by parton energy loss?**

**Talk: I Vitev**
Production mechanism: J/ψ in jets

Initial expectation: color-singlet J/ψ could be produced without accompanying fragments
New insight: high-\(p_T\) J/ψ produced in jets

Near-side peak: hadrons accompany the J/ψ
Bottomonia melting

Clear hierarchy of suppression, but no sudden turn-on
- T does not change rapidly with centrality
- Average over system
- Melting sets in for $T < T_m$

Y(1S)     Y(2S)     Y(3S)
T_{\text{diss}} (MeV)  500   240   190

Y(1S)     Y(2S)     Y(3S)
T_{\text{diss}} (MeV)  600   230   170

Overviews: R Ma and E Ferreiro

ALICE, arXiv:1805.04387
A very productive conference: many new results

... more than fits in this talk
A very productive conference: many new results

... more than fits in this talk

Improving our understanding of the parton nature of the QGP
A very productive conference: many new results

... more than fits in this talk

Improving our understanding of the parton nature of the QGP

... of small systems
A very productive conference: many new results

... more than fits in this talk

Improving our understanding of the parton nature of the QGP

... of small systems

... and of energetic probes of the plasma
A very productive conference: many new results

... more than fits in this talk

Improving our understanding of the parton nature of the QGP

... of small systems

... and of energetic probes of the plasma

Thank you for your attention

And to all who provided input