ATLAS Heavy Ion Physics Outline
Draft 0.1
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Prepared as input to the US ATLAS Heavy Ion "project plan"

1) Minimum bias physics
   a) Physics issues
      i) Particle multiplicities – consistent w/ extrapolations of RHIC data or CGC?
      ii) Crude estimates for initial entropy/energy densities
      iii) Elliptic flow strength – "strongly coupled" matter or not?
   b) Measurements
      i) Multiplicity and E_T distributions
      ii) $dN_{chg}/d\eta$, $dE_T/d\eta$ (minimum bias)
      iii) $v_2(\eta)$ using reaction plane (minimum bias)
   c) Questions/required information/issues
      i) What is total Pb+Pb cross-section?
      ii) Can we run a "crossing" trigger at low luminosity?
      iii) Assuming we can, what fraction of cross-section will pass offline collision selection cuts?
      iv) What will ZDC response be for peripheral collisions?
      v) What are background/beam-gas rates?
      vi) Can we use ZDC to reject beam gas (if relevant) without compromising efficiency for peripheral collisions?
2) Event properties w/ centrality selection
   a) Physics issues
      i) Multiplicity/transverse energy increases proportional to N_{part}, N_{coll}, in-between?
      ii) Central $dN_{chg}/d\eta$, $dE_T/d\eta$, v_2 consistent with trends established at RHIC?
      iii) Multiplicity and transverse energy variation w/ centrality consistent with CGC or not?
      iv) Does v2 @ LHC exceed "hydrodynamic limit"?
      v) Are some events "different" (DCC/"centauro"/??)
   b) Measurements
      i) $dN_{chg}/d\eta$, $dE_T/d\eta$
      ii) $v_2(\eta)$ using reaction plane
      iii) Fluctuations (neutral/charged, ?) **Need help here – this is not my area of expertise!!**
   c) Questions/required information/issues
      i) Best method for centrality determination? (existing studies by Krakow group)
      ii) "Minimum bias" trigger efficiency vs centrality (depends on trigger)
      iii) Adapt existing Glauber Monte-Carlo codes (which)?
      iv) What if multiplicity or ET is not proportional to N_{part}? How to bootstrap centrality selection?

3) Low-pT particle production
   a) Physics issues
      i) Inverse slope consistent with RHIC trends?
      ii) Chemical/kinetic freeze-out conditions
      iii) $v_2(p_T)$ consistent with hydrodynamics?
      iv) Final-state phase space (over)population
      v) Thermal abundance of charm
   b) Measurements
      i) d^2n_{chg}/dp_T^2 vs η in centrality bins
      ii) $v_2(p_T)$
      iii) Multiplicity fluctuation in $\Delta\eta\Delta\phi$ bins
   c) Questions/required information/issues
      i) How low is low (at what pT does hard production dominate) ?
      ii) Bias on v2(pT) measurement from jets
      iii) Can we measure weak decays (Λ, K_s, …) ?
      iv) Do we have any handle on thermal charm production?
4) Single High-p_T particle (including prompt photon) production
   a) Physics issues
      i) Medium-induced parton energy loss
         (1) Dependence on collision geometry (centrality, reaction plane)
         (2) Dependence on η, consistent w/ expectations from CGC + energy loss calculations?
         (3) Parton/energy density of medium
      ii) Test accuracy of hard scattering rate calculations (direct photons)
      iii) Saturation effects at "intermediate" p_T
      iv) Jet conversion photon production (QGP signature)
   b) Measurements
      i) d^2n_{chg}/dp_T^2 vs η in centrality bins
      ii) High-p_T isolated prompt photons, d^2n_{chg}/dp_T^2 vs η, $\Delta\phi_{RP}$
         (1) $\Delta\phi$ dependence a "control" test – shouldn't be any
      iii) $R_{AA}(p_T, \eta, \Delta\phi)$ in centrality bins
      iv) Hadron/photon ratio
         (1) i.e. use detectable isolated photons as benchmark for high-pT hadron production – different from RAA (see question 2 below).
      v) $v_2(p_T, \eta)$ in centrality bins
   c) Questions/required information/issues
      i) Systematic errors in T_{AB} estimates @ LHC
      ii) p-p charged p_T distribution baseline? Extrapolated from full energy? How?
      iii) Photon isolation cut efficiency vs p_T
      iv) Charged particle reconstruction efficiency, background vs p_T
      v) Can we measure weak decays @ high p_T?
      vi) Can we measure prompt photons in pT range where jet conversion mechanism contributes?
      vii) Can we reject π^0/η decays in measuring prompt photons?
5) Single jet production and Fragmentation
   a) Physics issues

i) Medium-induced parton energy loss
   (1) Dependence on geometry (centrality, angle of jet wrt reaction plan) consistent with energy loss calculations?
   (2) Dependence on η
   (3) Parton/energy density of medium
ii) Energy, kT distribution of emitted gluons (measureable?)
iii) Interaction of gluon radiation with medium
iv) Medium-regulated parton shower
v) Quark/gluon vs bottom quark energy loss
vi) High-p_T propagation in medium (Mach cone/Cherenkov cone)
vii) Photon bremsstrahlung from jets

b) Measurements
i) dn/dE_T for jets vs cone size
   (1) dependence on η
   (2) dependence on centrality, $\Delta\phi_{RP}$
ii) Charged particle fragmentation function
   (1) Dependence on E_T, η, centrality, $\Delta\phi_{RP}$
   (2) J_T distribution
iii) Jet energy distribution vs $\Delta\phi$, $\Delta\eta$, R ($R \equiv \sqrt{\Delta\eta^2 + \Delta\phi^2}$)
   (1) dependence on E_T, η, centrality, $\Delta\phi_{RP}$
iv) Sub-jet z, E_T and k_T distribution
   (1) dependence on E_T, η, centrality, $\Delta\phi_{RP}$
v) All of above for b-tagged jets
vi) Jet -> Photon fragmentation function vs z, k_T

c) Questions/required information/issues
i) Jet reconstruction efficiency/background vs E_T
   (1) dependence on centrality and η (same for all below)
   (2) Sensitivity to elliptic flow-modulated background
ii) Jet energy, angular orientation resolution in presence of soft background
iii) Sensitivity of i, ii to strong modifications of jet shape
iv) Charged particle reconstruction efficiency/background in jet
v) B-tagging efficiency and background
vi) Optimal observables for jet energy loss (e.g. "core" E_T)
vii) Can we measure hard photons in a jet?
viii) How to do sub-jet analysis in soft background ?
ix) Sensitivity of jet energy distribution analysis to soft background

6) Di-jet, isolated photon-jet, multi-jet events
a) Physics issues
i) Test understanding of "energy loss" process
   (1) Dependence on orientation of di-jet axis wrt reaction plane
   (2) Asymmetric energy loss due to geometry and "trigger bias"
ii) Better constraint on medium properties
iii) Di-jet acoplanarity and p_T broadening by medium
   (1) Consistency of p_T broadening with jet quenching in energy loss calculations

(2) Modification of vacuum radiation pattern by medium?

iv) All physics in 5) but with photon "control" or di-jet tag

v) Saturation effects on di-jet acoplanarity, mono-jets

b) Measurements

i) dn/dN_{jet} vs centrality

ii) All single jet observables but correlated with energy of "tag" jet/photon

iii) Di-jet $dn/d\phi_{12}$, $d^2n/dx_E d\phi_{12}$ ($x_E \equiv E_{T1} / E_{T2}$)

(1) vs centrality, η, $\Delta\phi_{RP}$, E_{T1}

iv) $d^2n/dE_{T1}dE_{T2}$ for different di-jet orientation (same information as in i but with different emphasis)

v) dn/dp_{out}

vi) Same as ii, iii for photon-jet

vii) Above but with one or both jets w/ b tag

c) Questions/required information/issues

i) Efficiency/background of photon isolation vs photon energy, η

ii) Jet angular resolution (see above)

iii) Efficiency/background for pure di-jet pairs

iv) Effect of missing jets in multi-jet events

v) Confusion due to multiple jet pair production

7) Quarkonia/Vector mesons/di-leptons (**need input from Laurent**)

a) Physics issues

i) Debye screening of quarkonia in medium

ii) Quarkonia formation via recombination

iii) Modification of vector meson properties in medium

iv) Virtual photon emission from medium

v) Virtual photon bremsstrahlung from jets

b) Measurements

i) J/ψ, ψ' and Y (states) production

ii) Low-mass di-muon production at moderate to high p_T

iii) i and ii with jet tag, jet rejection

iv) di-electron measurements (any hope here?)

c) Questions/required information/issues

i) J/ψ, ψ' and Y acceptance/rates into muon spectrometer vs η (Laurent)

ii) di-muon acceptance at low mass (< 1 GeV) vs p_T

iii) di-muon mass resolution vs true pair mass, p_T, η

iv) "Direct"/bottom feeddown/jet fragmentation rates for J/ψ, ψ'

v) Baseline for J/ψ, ψ' and Y rates

8) "Exotica"

a) Physics issues

b) Measurements

c) Questions/required information/issues