Good morning,

I come back to you with a bunch of 16 questions (sorry for that...) related to Rivet.
If this is less annoying for you and if you feel it is needed, one can organise a vidyo/skype meeting to discuss those points.

Marc and I are currently trying to rivetise some ALICE analyses, the ones related to inclusive J/ψ in pp 7 TeV.
(I also add Sarah, since she is interested in J/ψ production in MC generators. Same for Michael.)

It deals with two papers :
- inclusive J/ψ cross-section = f(p_T, y) = http://inspirehep.net/record/897764
- J/ψ production = f(multiplicity, y) = http://inspirehep.net/record/1088833

Part A - projections

- Queston A.1/ inclusive J/ψ measurement

From the experimental point of view, the inclusive measurement should include the various components of the J/ψ production :

- ✔ direct J/ψ
- ✔ χ_{C0}, χ_{C1}, χ_{C2}
- ✔ ψ(2S)
- ✔ B^0
- ✔ $B^{\pm}$
- ✔ B_S

I wondered if this is obvious that any of those particles stays within the UnstableFinaleState projection. (According to include/Rivet/include/Projections/UnstableFinaleState.hh, it seems the user can define and set which particles have to be decayed, which ones have not to.)

- Question A.2/ definition of stability

Has the Rivet user to define the set of stable/non-stable particles ?
If yes, how can one do that ?

- Question A.3/ default set of stable particles

Is there any default choice, common to Pythia 8, Herwig++, Sherpa, for the projection of UnstableFinaleState ?
For instance, do π^0 enter this projection ? also $\pi^{\pm}$? Σ^0 ? $\mu^{\pm}$? …

- Question A.4/ UnstableFinalState : mothers and daughters

In this « unstable » projection, I actually wonder what particles in the decay chain are retained : the mother particle only (say Ω^-) or the mother but also the full decay-chain products (Ω^- but also Λ + K^- and further p + π^- and finally the respective decay products of K^- and π^-) ?
- From what I have noticed here and there in the Rivet source codes of analyses, it seems it goes along the line of the latter option (mother + daughters). But I wanted to have a confirmation of this.

Part B - decay chain

- Question B.1/ information on the mother particles

Imagine one wants to study the parent of a given particle.
In Rivet analyses, I have found two ways to do that so far.

In in src/Analyses/ALICE_2011_S8909580, one can read the following lines to identify the possible ancestor of $\Xi^\pm$:

```
...
    switch(p.pdgId()) {
    case 3312:
    case -3312:
      if ( !( p.hasAncestor(3334) || p.hasAncestor(-3334) ) ) {
      _histPtXi->fill(pT, weight);
      }
      break;
...
```

In Rivet 2.0.0b1, in src/Analyses, I found the J/ψ analysis by ATLAS, ATLAS_2011_I9035664. There, one can find the following lines, to define the non-prompt component of the signal :

```
...
foreach (const Particle& p, ufs.particles()) {
    if (abs(p.pdgId()) != 443) continue;
    HepMC::GenVertex* gv = p.genParticle()->production_vertex();
    bool nonPrompt = false;
    if (gv) {
      foreach (const GenParticle* pi, Rivet::particles(gv, HepMC::ancestors)) {
        const PdgId pid2 = pi->pdg_id();
        if (PID::isHadron(pid2) && PID::hasBottom(pid2)) {
          nonPrompt = true;
          break;
        }
      }
    }
...
```

I wonder if you would recommend one option over the other. I mean, if one wants to check and sort out particles according to their mother particle, should we just test individual PID hypotheses, one by one, by hand or loop over any possible ancestors ?

- Question B.2/ Rivet::particles(gv, HepMC::ancestors)

In the second case exposed above, it is not clear for me which lineage we trace with Rivet::particles(gv, HepMC::ancestors).
Do we loop over the parent particles only (level n-1) or do we also go up to grand-parents and beyond (level n-1, level n-2, n-3 ...) ?

To take examples, what should I do if I want to trace chains like :

- ✔ $B^* \to B + X \to J/\psi$
- ✔ $\Omega^- \to \Xi^0 + X \to \Lambda + X \to$ proton +X

Part C - normalisation

- Question C.1/ Normalisation by $\Delta y \Delta p_T$

Imagine one considers results like $d^2N/dp_T dy = f(p_T)$ in a certain rapidity range.
I was wondering about the division by the p_T bin width and rapidity interval.
I had a look into various analyses and the source code of the method Rivet/Analysis::scale(), do you confirm that :

- ✔ the division by Δy has to be performed by the user in the finalize() method,
- ✔ the division by Δp_T is applied automatically, within the method scale()

?

- Question C.2/ event:weight()

In most of the analyses which I looked at, I found that histograms are filled with event::weight and finalize with a division by sumOfWeight().
It is really not clear for me what is actually hidden behind those weights.
Can you explain me or point me to a place where it is explained ?

- Question C.3/ getting results in terms of cross-sections

We would like to produce results as cross-sections and not only dN/dy, say, in pp collisions at $\sqrt{s} = 7$ TeV. I guess, for that, one has to use the method Rivet/Run::crossSection().
However, I am not sure whether the method returns the total *inelastic* cross-section.

Does the cross-section returned by this method corresponds to a fraction of the total cross-section, the fraction associated with the projection used for the given analysis (chargedFinaleState, unstableFinalState, …) ?
If indeed the case, what if the analysis calls several projections ?

is the cross-section() then taking into the different FinalStates in place ?
I mean, imagine one calls chargedFinalState and unstableFinaleState, will crossSection() take into account charged + all the *neutral* unstable particles ?

- Question C.4/ definition of non-single diffractive interactions

In the same spirit, I wonder how to get the value of the non-single diffractive (NSD) cross-section of the pp interactions.
Do I understand correctly that it is up to the user to define what NSD could mean ?
(I had a look at a STAR analysis ; to my knowledge, STAR results on identified particles are done for NSD events. Here I found STAR_2006_S6500200.
It seems they start the Rivet analysis by checking if there is 0 charged particle in certain pseudo-rapidity regions, close the beam pipe, in the acceptance of their beam-beam-counters. If the case, the event is discarded.)

Part D - multiplicity

- Question D.1/ what enters into the multiplicity definition

For J/ψ production = f(multiplicity, y), we will need to study the charged particle density dNch/dy.
I have found, in Analyses/EXAMPLE.cc, some lines showing how to use the multiplicity estimator.
But I am not 100 % sure to get how it works though.

```
    const FinalState cnfs( -4, 4, 2*GeV );
    const ChargedFinalState cfs( -4, 4, 2*GeV );
...
    addProjection( Multiplicity(cnfs), "CNMult");
    addProjection( Multiplicity(cfs), "CMult");
...
    const Multiplicity& cnm = applyProjection<Multiplicity> (event, "CNMult");
    _histTot->fill( cnm.totalMultiplicity(), weight);
    _histHadrTot->fill( cnm.hadronMultiplicity(), weight);
...
    const Multiplicity& cm = applyProjection<Multiplicity> (event, "CMult");
    _histChTot->fill( cm.totalMultiplicity(), weight);
    _histHadrChTot->fill( cm.hadronMultiplicity(), weight);
```

Do I understand properly that a multiplicity estimator is in fact associated with a given projection ? and will then return only the number of particles present in this specific projection ?
(and to be more precise, in a certain η range and above a certain p_T threshold.)

- Question D.2/ an artificial pp event and projection contents

Let's take an artificial example.
(I did not think much, if any, about quantum numbers to be conserved...)
Imagine a pp event which has as direct production of particles of the following types :

- ✔ π^0,

- ✔ π^- ,
- ✔ K^0s,
- ✔ n,
- ✔ p^+,
- ✔ Λ,
- ✔ Ξ^+,
- ✔ $\Xi(1530)^0$,
- ✔ J/ψ,
- ✔ e^-,
- ✔ μ^+,
- ✔ γ,
- ✔ υ

If indeed the multiplicity estimation is function of the projection considered, then let me check with you what should happen for different particles for various projections, if they will induce a +1 in the particle counter or not.

<u>Hypothesis 1 :</u> *FinalState projection*

- ✔ In such general projection, everyhting including photons and neutrinos will be accounted for ?

<u>Hypothesis 2 :</u> *ChargedFinalState projection*

- ✔ In such projection, the direct Ξ^+ will also make a +1 to Nch ?
- ✔ What is about the $\Xi^\pm$ stemming from the decay of the resonance $\Xi(1530)^0$?
- ✔ Dalitz decay daughters of π^0 ?
- ✔ products from dilepton decay of (neutral) J/ψ ?
- ✔ What is about K^0s daughters, when the kaon decay soon after the primary vertex into π^- and π^+ ? or same question for Λ decaying quickly into p + π^-? (this is typically the contamination I have in mind from an experimental point of view, if one goes for a measurement of Nch based on primary tracks. As far as I know, experiments usually assess such effects and correct their results for this.)

<u>Hypothesis 3 :</u> *UnstableFinalState projection*

No question for the moment (Héhé...).
It depends on the answers to questions A.3 and A.4 above.

Part E – Practical questions

- <u>Question E.1/</u> large number of event in simulation

How to simulate a large number of events ?
Is there any way to launch several simulations of the same type but with different random seeds on different machines and then merge the outcome in the end ?
(e.g. imagine I want to study with very good accuracy the outcome MC generators for Ω^- up to

10-15 GeV/c).

- Question E.2/ enhanced or biased MC production

As a complement, is there a possibility to tell the generator to simulate something else than Min Bias events, something like focusing on some specific particle or physics processes ?

Example :
I am interested in generating complete events that have at least one « inclusive » J/ψ or alternatively something like events which have at least one pair of quarks $c+\bar{c}$, and correspondingly quarks $b+\bar{b}$, in proportion that make sense physically (ratio beauty/charm is senseful) to have prompt and non-prompt D, J/ψ, etc in the final state.

I guess there the key may be in the parameter file provided to the generator (?).

(I had a look on the MCplots web page.
I was looking for generation of events with rare processes
There, for instance, one can find analyses from :
- ✔ ATLAS (ATLAS_2011_S9128077)
- ✔ CMS (CMS_2011_S9086218)

about $d^2\sigma/dp_T dy$(jet) = f(jet p_T), where jet p_T goes up to ~1 TeV/c.
I was surprised by the low number of events needed to get such plots.
- ✔ >2 ×10^6 for ATLAS,
- ✔ >2.7 ×10^6 for CMS.

And in the code, I found nothing particular going in the direction of an enhancement of the jet signal.)

- Question E.3/ internal bremsstrahlung of J/ψ

In the future, we may be interested of having a look of the angular correlations between $J/\psi \rightarrow e^+e^-$ and the charged tracks in the event.
For this, a feasibility study performed by Michael in his master thesis in Heidelberg showed that experimentally it might be important to cut rather tightly around J/ψ PDG mass, on the invariant mass distribution of the di-electron candidates, say $2.92 < m_{ee} < 3.16$ GeV/c².
This is done to remove biases from the radiative tails, on the azimuthal angle of the reconstructed J/ψ.
In MC studies, I think this cut will have to be reproduced, since on top of bremsstrahlung in the detector, the « internal bremsstralung » (decay $J/\psi \rightarrow e^+e^-\gamma$) is an important effect, with B.R.($J/\psi \rightarrow e^+e^-\gamma$) ≈ 1/6 · B.R.($J/\psi \rightarrow e^+e^-$).

I wonder if the decay $J/\psi \rightarrow e^+e^-\gamma$ is handled and implemented in the decayers of Pythia, Sherpa, Herwig...
(I think it is not the case for instance in Pythia 6 or 8.)

- Question E.4/ Rivet with non-Fortran generators

Very naïve question from my side, but I actually do not know how to run a new Rivet analysis with C++ generators (Herwig++, Pyhtia8, Sherpa...).
What is the command line to be launched to do so ?
- Tutorials usually show examples with fortran generators, like Pythia6, making use of AGILe.