Intro / Disclaimer

- I have attempted here to “air” ideas and concerns over PC
  - **What it is for**
  - **How we should present/defend/justify it**
- Some of the points raised here are based on concerns and comments from others
  - **I have attempted to play both sides of the arguments to understand the issues**
- My focus (here) is not on the technical challenges of PC
  - **Where the interfaces and technical constraints are is an engineering issue (and challenge)**
  - **I have focused more on the conceptual need for PC and its role in the project phases**
  - **The required effort/resource to achieve PC will eventually be judged/justified by the above**
- The discussions touch in many places on ‘governance/mass-production models’ (perhaps inevitable so?)
  - **I do not consider myself an expert in these fields, so treat all my comments with due caution**
  - **It may (in retrospect) but unadvisable to mix these things too much (as is the tendency)**
    - Making PC a ‘corner stone’ of our mass-production models may be a mistake at this stage, but alluding to the benefits is OK.
- All of the following is provided for <u>our</u> discussion and review
  - **Perhaps we can focus on some of the points raised here while discarding others**
  - **Clearly there are more issues that could be added that I have not considered.**

- Provided for your input – but again, I do not consider myself qualified to make good judgement on these issues, given my vanishingly small experience.

Nick (01.10.08)

What we (PMs) must achieve

- Clear and unambiguous explanation of the rationale for Plug Compatibility (PC)
  - **A. During current TD Phase R&D**
  - **B. During Project Construction Phase**
  - **C. During “transition” between A and B**
  - **D. During operations (and subsequent upgrades)**

- Rationale must justify the TD Phase resources required to achieve interface document
  - **Engineering effort required**
  - **Global consensus on specifications**
  - **Agreement by all to follow specifications during regional cryomodule development**
    - This is the hardest part of all: a specification document is worthless unless it is accepted and adhered to.

A: TD Phase R&D (1)

- Three important goals for TD Phase:
  - **Development to a mature state SCRF "know-how" in all three regions**
    - Including regional industry
  - **Cost reduction**
    - In this context of a cryomodule ("cost per MeV") – if possible!
  - **A new updated cost-estimate for the ILC**
    - Similar to RDR estimate, but based on more sophisticated mass-production (and governance) models
      - RDR was effectively based on a single world-wide bid for tender.

- Original (RDR) concept:
  - **Single baseline solution**
  - **Supported alternative designs (so-called ACD)**
  - **Concept for "down-select" for TDR**
    - Actually more like an "up-select" as there was a baseline defined.

- Concept of "baseline", "down-select" worrying to some
  - **Not conducive to technology innovation (possibly leading to cost-reduction) The need to learn how to do something inevitably leads to evolving designs**
    - Just copying an existing solution is not intellectually satisfying
    - The desire to "make it better" (or just different) is very strong
  - **ACD → BCD acceptance difficult to define, especially with unknown time frame for construction**
    - A strong motivator for PC in period (A)

  - **(Note that U.S. and Europeans were content to focus on so-called Type-IV cryomodule as defined at Snowmass '05)**

A: TD Phase R&D (2)

- PC is a formal way of supporting quasi-independent R&D efforts, while still maintaining some focused global goal for the TD Phase
  - **i.e. we are working together towards a 'common' cryomodule design (even if that design is based on a set of interface definitions allowing flexible solutions).**

- Parallel R&D efforts, innovation and different design approaches now appears to be considered acceptable, but does this <u>mandate</u> or <u>require</u> PC?
  - **Strictly no if you accept a loose (intellectual) collaboration between the regional efforts (close to current reality)**
  - **PC was effectively invented (by Akira) to bring some structure/focus to this loose collaboration (not to allow it to diverge too significantly, which is the tendency if left unchecked).**

- Question: how does PC help the three TD goals stated on previous slide?

A: TD Phase R&D (3)

- **Development to a mature state SCRF "know-how" in all three regions (including industry)**
  - Allowing freedom/flexibility to develop in-house SCRF technology (and therein expertise) may be the only realistic way to achieve this goal (certainly seems to be the case at KEK).
  - Taking ownership of a technology (via change?) is a strong intellectual motivator
  - If we accept that the regional development will be the primary driver for the local industrial involvement, then we must also accept that allowing freedom/flexibility of that development is mandatory in achieving a strong local industrial expertise.
    - Assumes (local) leadership via the regional (local) laboratory R&D.
    - Counter arguments exist (cross-regional developments – eg XFEL klystron)
- **(Cryomodule) cost reduction**
  - Allowing innovative design is the only way to achieve better cost-performance, but
  - Design variants should be cost-driven, or at least demonstrate the potential for better cost/performance (cavity shapes are good examples)
  - Just "being different" does not mean "being better" (or cheaper).
- **A new updated cost-estimate for the ILC**
  - Requires cost-models to justify (beyond simplistic RDR concept)
  - Note it is mandatory that we show PC to be a 'cost-reducing' concept (fears of the opposite are often voiced).
  - Note that innovation itself does not specifically require PC: if one region's R&D pays off and a significant cost reduction is achieved, it is likely that these innovations will be adopted by all.
    - A natural 'down-select'
    - Notwithstanding industrial intellectual property rights

- **None of the above strictly requires or mandates PC**
  - the rationale of PC must go beyond the basic (current) R&D effort to address points B, C and D in a seamless fashion

B: Construction Phase

- Understanding the role of PC during construction phase is at the root of most current criticism
  - **Cf Olivier Napoly's comments wrt to mass production – and in particular – assembly line tooling.**
- We need to develop (as far as necessary) mass-production models which show the need for PC
  - **Why PC is beneficial during the construction phase**
  - **Why PC is a 'cost-reduction' policy (aid to maintaining global competition), or at least explain why it will not lead to a cost increase.**
- We must indicate technically what we mean by PC in the construction phase
  - **Basically the 'unit' of PC, and how it factors into the mass-production models**
- Impact on supply-lines, risk mitigation and time-scales should be considered
  - **We will want to move as fast as possible after approval – are some models faster than others?**
- As necessary, the relevant aspects of the possible governance models should be considered
  - **International financing and "in-kind" contribution models**
  - **Models for risk management.**

- Important to quote "case studies" to justify our arguments

B: Construction Phase
Two possible models for (our) discussion

- CERN-like (LHC)
  - **A Central Lab (CL) is set-up which is given an international budget.**
  - **CL then controls the budget/project**
  - **CL accepts the 'risk' and responsibility for budget/schedule (and making the project work)**
  - **Mass production can still be distributed, but completely controlled by CL.**

- Regional Centre (RC) model (ITER-like?)
  - **Regional financial contributions to CL are predominantly via 'in-kind' (e.g. cryomodules)**
  - **RCs are set-up to develop and mass-produce cryomodules**
  - **RCs have their own (regional) budgets and control**
  - **RCs assume risk of producing on-spec/on-time/on-schedule delivery of in-kind contribution to CL.**
  - **Role of CL? As integrator and overall PM, CL must assume some of the risk/responsibility and maintain some control over the RCs.**

- How is PC relevant to either of these models?

B: Construction Phase

- Risk mitigation:
  - **Require at least 2 vendors (per component?)**
  - **Require at least 2 CM assembly and testing plants**
    - One per region (i.e. 3) would require a production rate of ~1 CM per day.

- PC would allow the technical innovation during the R&D phase to be directly applicable to the construction phase
  - **Multiple vendors can compete on the open-market with their developed and mature 'variant' designs**
  - **Competition will push further cost-reduction development**
  - **Note: only really works if all variants are more or less same performance/cost**
    - Large cost differential between two plug-compatible design variants should automatically favour the cheaper variant!

- PC specifications must also consider assembly and tooling
  - **Must look beyond CM component interface specs. to cost effective ways to assemble the CM.**
  - **Only this will guarantee true PC in the construction phase.**
    - This is not an insignificant engineering effort, which would ultimately require prototyping variants to make sure they really fit together.
    - Automotive industry (amongst) others have perfected this over decades of incremental engineering and experience: driven by profit/cost, but these industries have a long-term sustainable market.

B: Construction Phase

- Previous comments on PC seem applicable to either of the two finance models proposed

- Superficially there seems no specific reason why arguments apply more or less to RC or CL models
  - **They only differ in how the money flows, and who accepts the risk.**

- CL model *may* result in more monolithic (i.e. uniform construction) by favouring less overall vendors
  - **But vendor solutions could still be PC orientated.**

- Conversely RC approach may promote more vendors
  - **Individual RCs may have slightly different approaches to risk mitigation, and have somewhat different (regional) constraints.**

- Important to maintain global competition between vendors to guarantee lowest market price
  - **there must be no suggestion of regional protectionism,**
  - **unless governments agree to support this model directly, and live with the potentially higher costs (varying region to region).**

Devil's Advocacy (1)

- An important lesson learnt from LHC was the need for CERN to accept all the risk for mass-production to significantly reduce the cost
  - **A shift from 'build to spec' to 'build to print – build to process'**
  - **LHC cold-masses were produced by industry but under strict control of CERN**
    - From component / material procurement, through Q&A to final magnet assembly and acceptance testing.
  - **Reported as being critical for cost-reduction**
  - **Is PC a factor here? CERN only allowed minimum variation in the magnet design to accommodate individual industrial preference.**
- Note that LHC approval occurred when magnet design was relatively immature.
  - **Quoted 10 year R&D effort together with industry to be in a position to even tender the mass production!**
  - **CM design – especially in Europe via XFEL – is arguably already much further advanced than this.**

Devil's Advocacy (2)

- In principle CERN/LHC model can be moved to the 3 RC model without loss
  - **Think of the European centric LHC dipole mass-production scheme as one RC of our model**
  - **Each RC can equally play the role of CERN for that region.**
    - Same risk acceptance,
    - Same cradle-to-grave control of the (regional) mass-production.
  - **But it must all come together in one place in the end**
    - IMO the CL management will (must) have final authority to make the project work
    - Understanding the relationship with RC is critical
    - Does PC play a role here?

Devil's Advocacy (3)

- The alternative to PC in the construction phase:
  - **A true down-select to a single cryomodule design**
  - **B (Construction Phase) discussions and comments still valid**
    - Open global market for production (everybody bids on the same coupler, or tuner, or cavity etc.)
    - Build-to-print/process (LHC concept - risk acceptance)
    - Reduced number of variants/spares etc.
- What is lost is the seamless integration between A (R&D) and B (Construction)
  - **Loose time in having RC/Industries pick-up on selected baselined component.**

C: Waiting for approval

- Perhaps the strongest motivator for tight PC
- If we get it right, it allows innovating R&D to continue but,
- Allowing us to ‘react quickly’ to approval
  - **Shifting gears to a construction project**
  - **Note comment on previous slide concerning construction models and time-scales**
- PC can play the role of “moderator” during this extended R&D phase
  - **Preventing too much divergence in the R&D and**
  - **More importantly in the industrial set-ups**

D: Operations (Upgrades)

- In the context of upgrades, PC could be of critical benefit
  - **Better performance / cost “units” could replace original technology as cryomodules are repaired (for example)**
  - **PC does not mean having to maintain multiple spares**
    - If all tuners fit, then any tuner can be used to replace a broken one.
    - Does require “true and complete PC”
    - When ordering new spare components (?) can make use of multiple vendor quotes etc
      - i.e. not being stuck with original vendor
      - Note this is of course also true if select one single baseline-design which is then mass-produced on the open market.
- As with B (Construction Phase) some models need to be developed
  - **Do CMs get repaired locally in local CL infrastructure or**
  - **Shipped back to RC for repair**
  - **?**