PIP-II Component Yield

- **Achieved Yield vs. Design Specs**: What were the final yield rates for your project's cavities, high-power couplers, and cryomodule components, and how did the achieved performance compare to the original design specifications?
- The project is still in the early stages of production component (e.g., cavities, couplers, tuners…) qualification efforts, so final yield #'s are not available.
- Experience from prototyping has informed potential production component yield
  - 12 SSR1 cavities
  - 9 SSR2 cavities
  - 6 HB cavities
  - 6 LB cavities
  - 8 HB/LB tuners, 9 SSR tuners (mechanical, motors, piezos)
  - 11 HB couplers
    - None of these components experienced any "fatal" issues (except cavity re-processing for FE mitigation)
- Based on this experience we have contracted for the following production quantities :
  - SSR1 cavities : 9 (8 required)
  - SSR2 cavities : 33 (30 required)
  - HB cavities : 20 (18 required)
  - LB cavities : 38 (36 required)
  - 650 couplers : 66 (58 required)
  - 650 tuners : 66 (58 required)
  - SSR couplers: 51 (46 required)
  - SSR tuners : 48 (46 required)

PIP-II Component Yield

- At present we have tested 8 HB production cavities, without “fatal” rejects
  - All cavities met the required specifications
  - Though it is possible one (yet untested) cavity might be rejected due to contact with HPR wand
- At present we have tested 2 SSR1 production cavities and 1 SSR2 production cavities, with 0 rejects
  - All cavities met the required specification
- At present we have tested 20 650 MHz and 3 325 MHz couplers, with 1 reject
  - All couplers meet the required specifications
- All tuner motors and piezos were checked out, without any rejects.

- Based on current performance, we do not expect > 5-10% “reject rate” for components (not counting cavity re-processing, typically “budgeted” at 25-40%).

- Keys to “success” :
  - Use proven vendors, along with significant vendor oversight, coupled with comprehensive QA/QC protocols both at the vendor and the project (e.g., couplers from experienced vendor)
  - Leverage previous development and production activities, minimizing new development, taking advantage of established tooling, processes, procedures (e.g., tuner motors and piezos from LCLS-II experience/vendor)

PIP-II Performance Transfer

- **Performance Transfer & Margins**: What was the observed performance degradation from the Vertical Test (VT) to the final cryomodule (CM) operation, and what rationale was used to define the design margins necessary to account for this "VT-to-CM" transfer?
- We currently have limited information regarding VT to CM performance degradation.
  - HB650 prototype CM
    - In general quench/gradient performance was maintained
    - FE was a more prevalent source of performance degradation
      - This was attributable to poor coupler installation procedure/tooling – resolved using improved tooling at UKRI, Cobot at CEA
    - Q values were sometimes maintained, sometimes lower, based on .e.g., trapped flux from quenches during MP conditioning
  - SSR1 prototype CM
    - All 8 cavities achieved nominal Phase I and II gradients
    - Q values were initially systematically lower than in STC testing, but attributed to trapped flux due to magnetization of nearby CM components resulting from solenoid operations
      - DeGaussing procedure developed, Q improved by ~ 50%, better matching STC

- A better indicator is STC (horizontal cryostat) test of jacketed cavities after vertical testing
  - Low power coupler swapped for high power coupler after VTS test
  - No change in quench limit or Q from Vertical Test if cavity remains FE–free
    - Requires “good” coupler installation tooling and procedure
  - Processes nearly identical to string assembly → STC result should be transferable to CM environment

PIP-II Performance Transfer

- Cavity performance margins
  - 650 Acceptance/Admin limits
    - In CM : Nominal + 15%
    - In Horizontal test : Nominal + 15%
    - Vertical test (jacketed) : Nominal + 15%
    - Vertical test (bare) : Nominal + 20%

    - Degradation in Q_0 or quench limit between bare & jacketed rarely observed, but additional 5% margin applied

  - SSR Acceptance/Admin limits
    - In CM : Nominal + 15%
    - In Horizontal test : Nominal + 15%
    - Vertical test (jacketed, at IJCLab only) : Nominal + 15%

    - SSR cavities are not tested bare.

  - Due to the nature of the Linac (H^-), larger acceptance limits (margins) above nominal in CM operation do not yield usable extra gradient.

PIP-II Logistics & Transport

Logistics & Transportation: What were the primary technical difficulties encountered during the transportation of finished cryomodule components, and what specific monitoring criteria (e.g., vacuum, shocks, alignment) were used to validate the hardware's integrity upon arrival?

- We have successfully transported a completed CM from FNAL to UK and back.
  - No performance degradation was observed – CM was tested at 2K after return to FNAL
    - This was preceded by "dummy load" tests (fully instrumented) and "local" CM transport, fully instrumented.
    - Instrumentation includes accelerometers, active monitoring of BL vacuum (NEG pump)
    - CM is put into "transport" state – removal of coupler air side components, installation of "transport restraints"

Transport of bare, jacketed, and dressed (with high power coupler) cavities is routine

  - Both under vacuum and at atm.
    - No instances of leaks (not leak checked, in order to preserve cavity surface condition – no evidence of leaks during 2K testing)
  - Typically include accelerometer
  - Comprehensive incoming inspections

- Transport of tested/qualified couplers is routine.
  - One coupler's crate showed signs of damage, coupler was OK.

- Tariffs and customs clearance are uncertain obstacles. This leads to schedule undertainty.