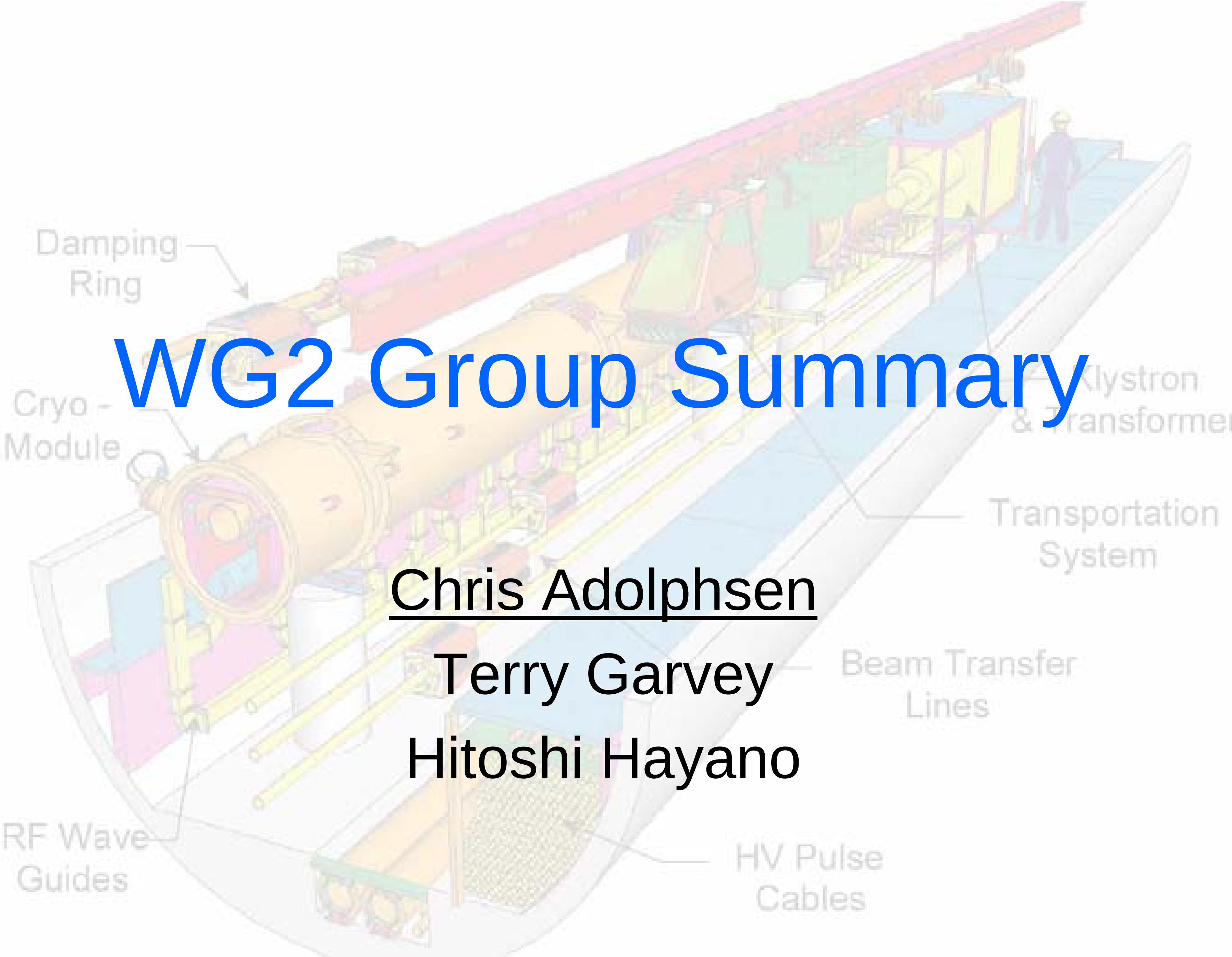
WG2 Group Summary

Chris Adolphsen

Terry Garvey

Hitoshi Hayano



Linac Options Fest

On Thursday afternoon, various experts summarized the linac baseline options. Although hard choices have yet to be made, have better defined the possibilities and their implications.

Topic	**Speaker**	**Institution**
Modulator	Ray Larsen	SLAC
Klystron	Stefan Choroba	DESY
RF Distribution	Brian Rusnak	LLNL
LLRF	Stefan Simrock	DESY
Cryomodule Design	Carlo Pagani	INFN
Cryogenic System	Tom Peterson	FNAL
Linac Lattice and Quad/BPM Layout	Nikolay Solyak	FNAL
Linac Tunnel Options	Tom Himel	SLAC
Linac Gradient - Global View	Chris Adolphsen	SLAC

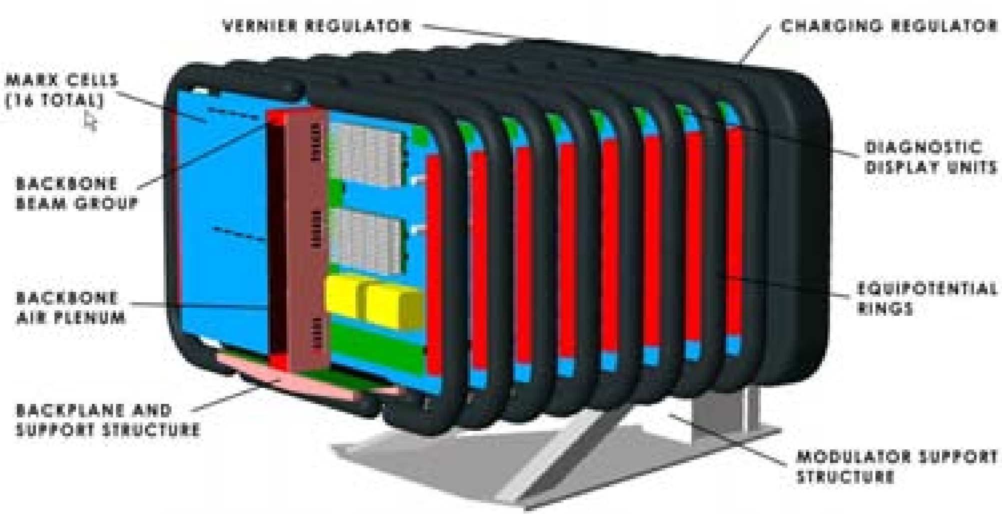
Modulators

- Choice based on experience: Pulse Transformer
  - 10 units have been built over 10 years, 3 by FNAL and 7 by industry.
  - 8 modulators in operation – no major reliability problems (DESY continuing to work with industry on improvements).
  - FNAL working on a more cost efficient and compact design, SLAC building new dual IGBT switch.
- Choice based on potential cost savings and improved performance: Marx Generator
  - Solid state, 1/n redundant modular design for inherent high availability, reliability,
  - Highly repetitive IGBT modules (90,000) cheap to manufacture.
  - Eliminating transformer saves size, weight and cost, improves energy efficiency.

Ray Larsen

Modulators (115 kV, 135 A, 1.5 ms, 5 Hz)

Pulse Transformer Style

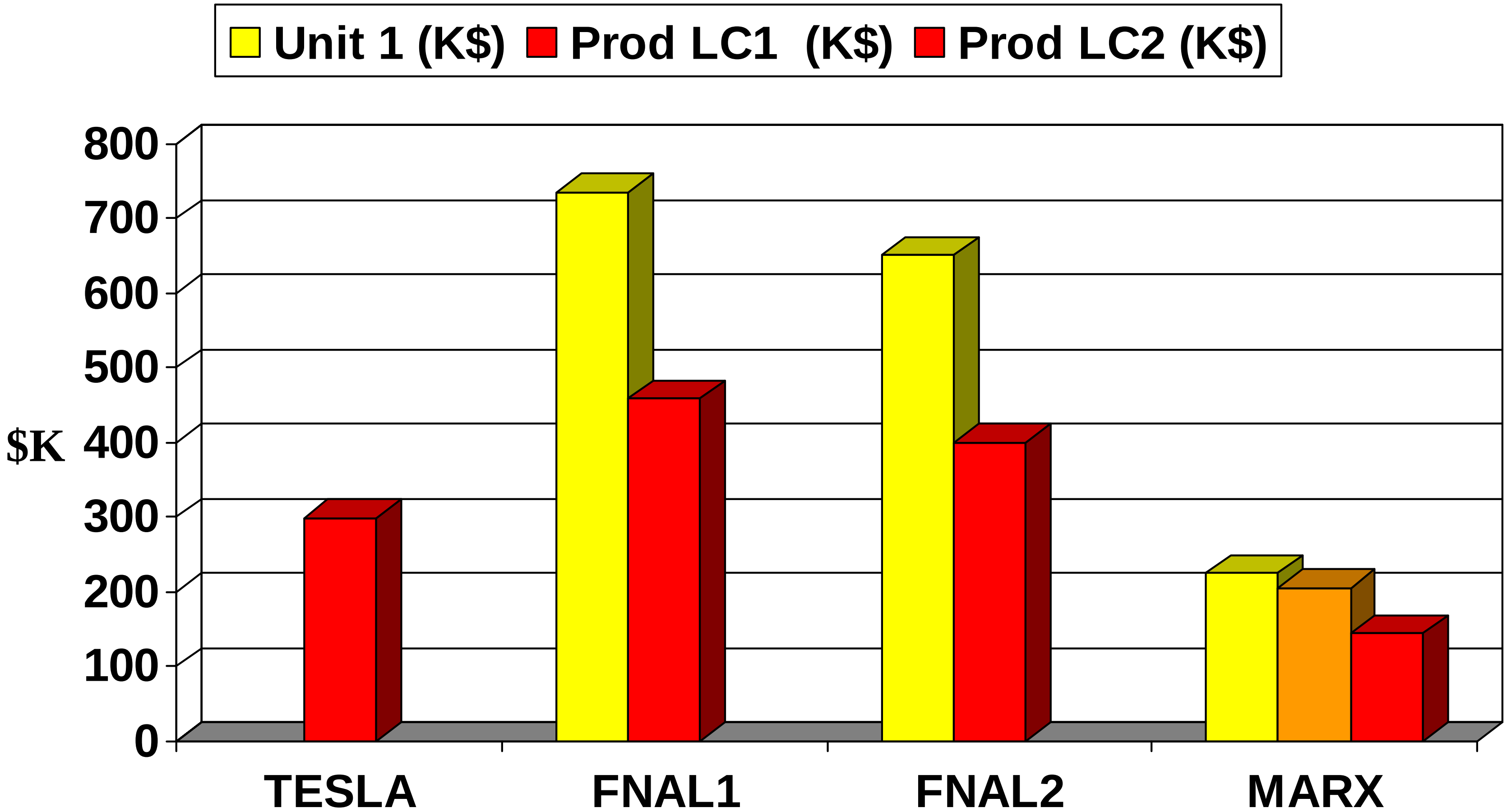


(~ 2m Long)

Operation: an array of capacitors is charged in parallel, discharged in series.

Will test full prototype in 2006

Modulator Unit 1 vs. 572 Unit Avg. Production Cost Estimates



Other Modulator R&D

- R&D needed on 120 kV single cable distribution, klystron protection scheme.
- Three Marx SBIR Phase I proposals awarded.
- DTI Direct Switch due at end of 2006 for evaluation at SLAC.
- SNS HVCM being staged, optimized, evaluated at SLAC L-Band Test Facility.

Klystrons

Available today: 10 MW Multi-Beam Klystrons (MBKs) that operate at up to 10 Hz

Thales

CPI

Toshiba

Stefan Choroba

Status of the 10 MW MBKs

- Thales: 4 Tubes produced, arcing problem seems to be solved, more tubes are in production. Two now run at full spec.
- CPI: Prototype factory tested, now for acceptance test at DESY.
- Toshiba: Prototype reached 10MW, 1ms, 10Hz.
- Horizontal 10MW MBK soon – required for the XFEL and for ILC with klystrons in the tunnel.

Alternatives to be Considered

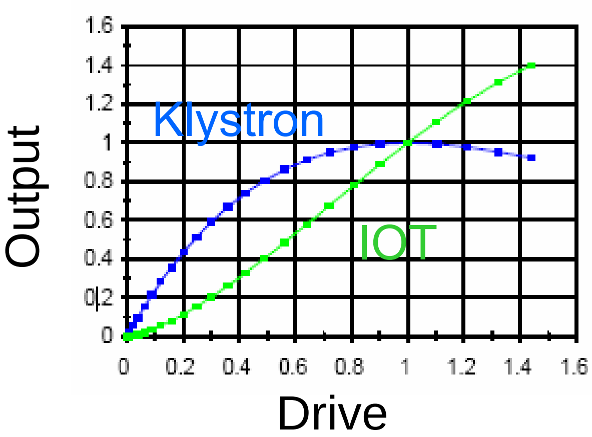
10 MW Sheet Beam Klystron (SBK)

Parameters similar to 10 MW MBK

SLAC

5 MW Inductive Output Tube (IOT)

Peak Output Power	5	MW (min)
Average Output Power	75	kW (min)
Beam Voltage	115	kV (nom)
Beam Current	62	A (nom)
Current per Beam	5.17	A (nom)
Number of Beams	12	---
Frequency	1300	MHz
1dB Bandwidth	4	MHz (min)
Gain	22	dB (min)
Efficiency	70	% (nom)



CPI

Low Voltage 10 MW MBK

Voltage e.g. 65 kV
Current 238A
More beams

Perhaps use a Direct Switch Modulator

KEK

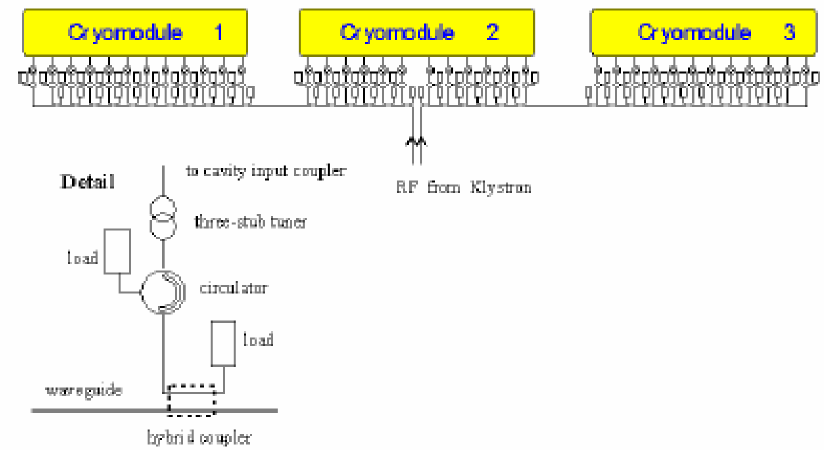
Klystron Summary

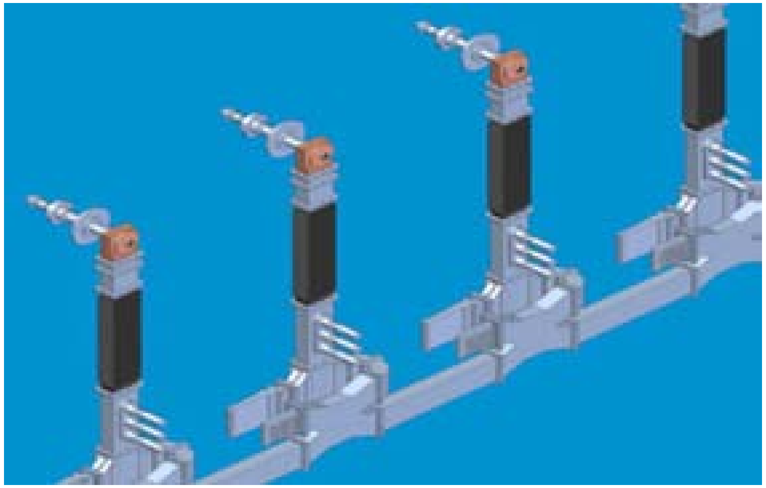
- 10 MW MBKs should be chosen as sources for baseline, alternatives could be developed if enough resources are available to make the 10 MW MBKs cheap, reliable, high efficient etc.

- The development of a new type of high power RF source always requires several years.

RF Distribution

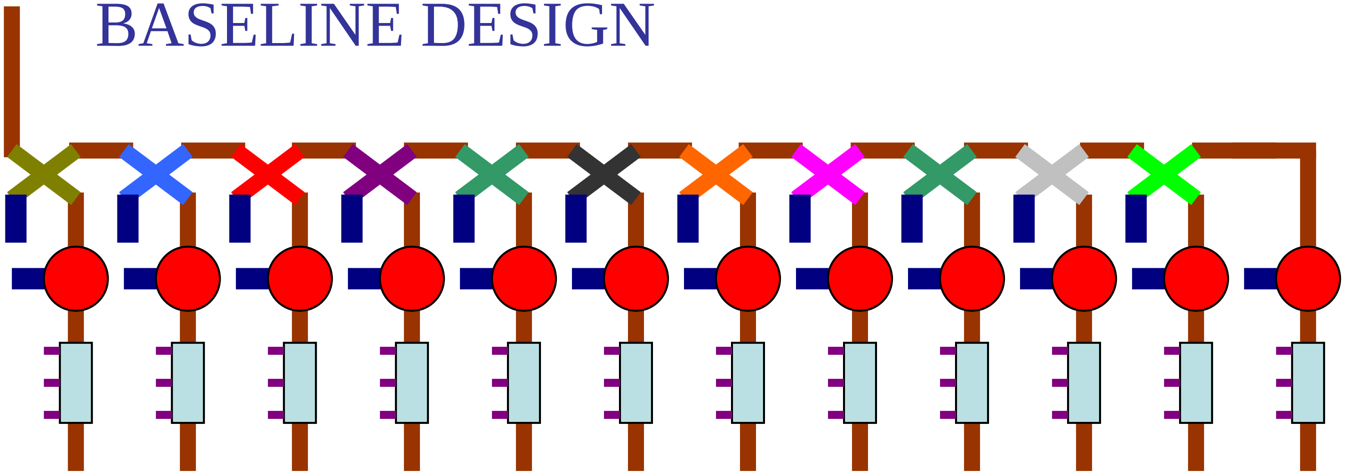
- **XFEL / TDR RF distribution concept should be used for the Baseline**
  - it is a mature design
  - it does not need significant R&D to work
  - it is possible to cost with contingency
  - there is a clear path forward to validate design ==> XFEL
- **Cons (costly)**
  - A few too many knobs, e.g. 3 stub tuner AND adjustable coupler
  - A large number of expensive components: circulators, stub tuners, high power loads. Total of 220,000 parts.





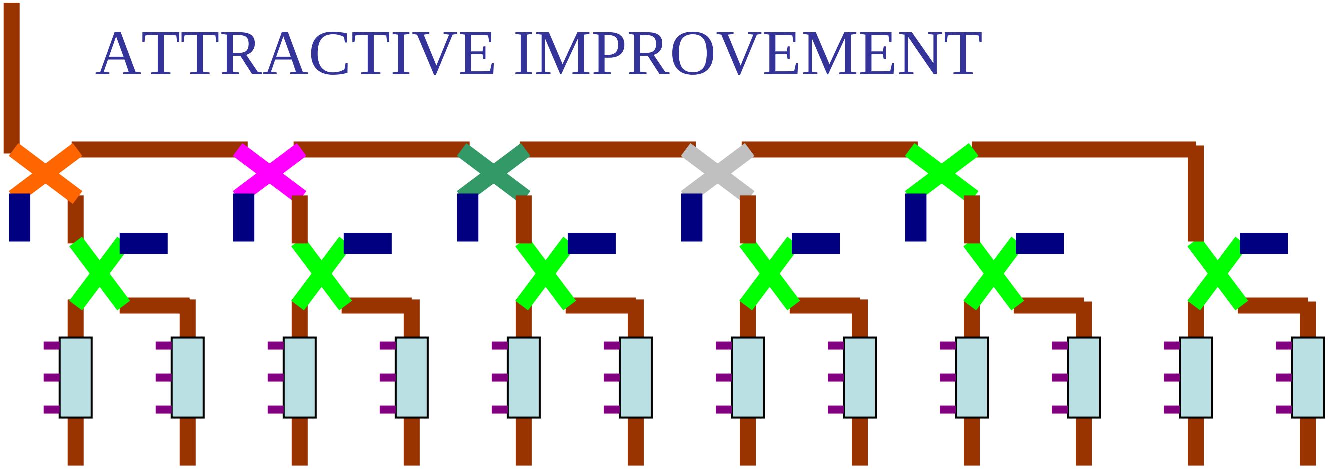
Brian Rusnak

BASELINE DESIGN



Similar to TDR and XFEL scheme.

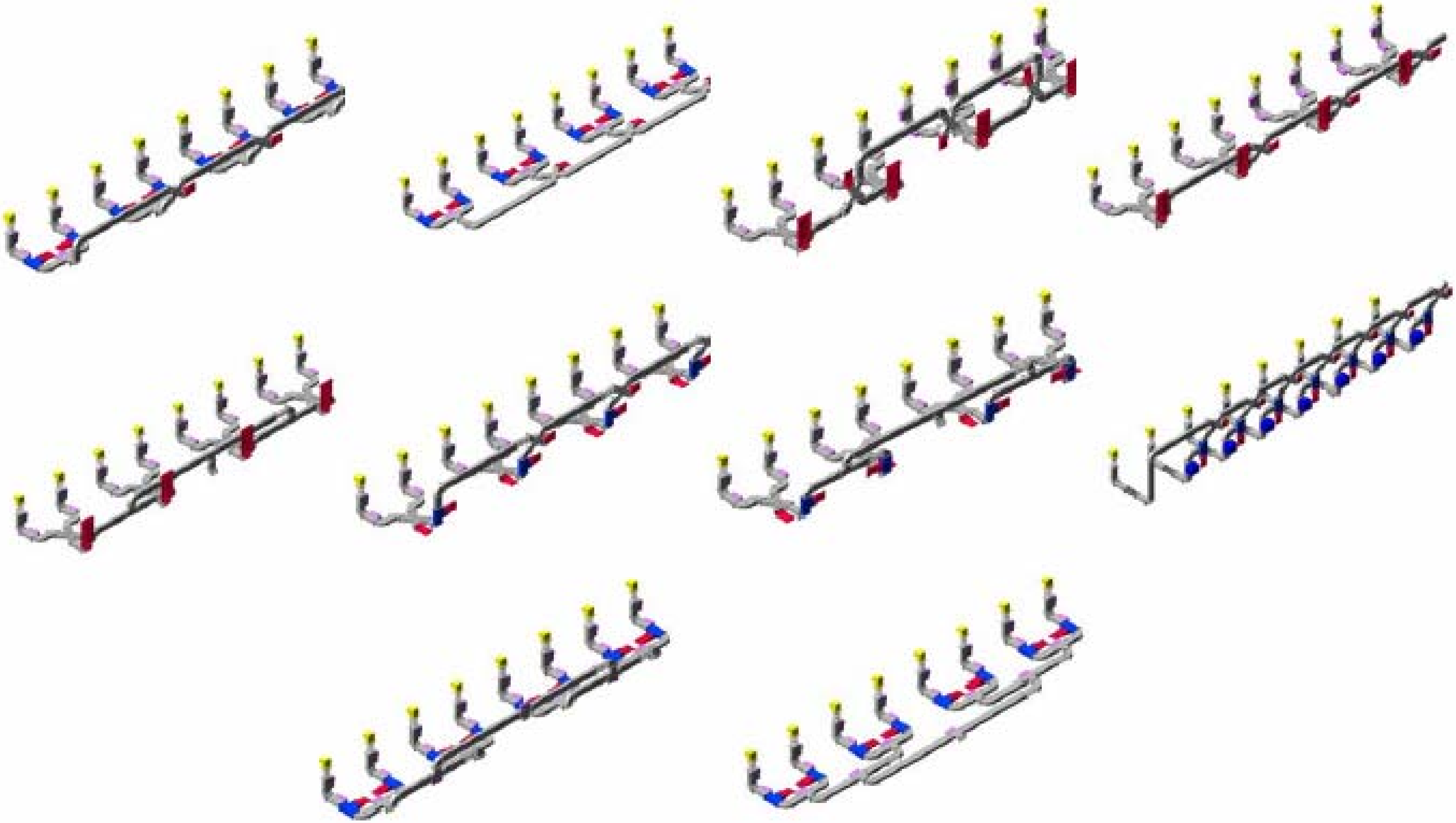
ATTRACTIVE IMPROVEMENT



With two-level power division and proper phase lengths, expensive circulators can be eliminated. Reflections from pairs of cavities are directed to loads. Also, fewer types of hybrid couplers are needed in this scheme. There is a small increased risk to klystrons. (Total reflection from a pair of cavities sends < 0.7% of klystron power back to the klystron.)

C. Nantista, SLAC

Alternative Waveguide Distribution Schemes Being Considered by DESY



RF Distribution Conclusions

- **Baseline**
  - The TDR / XFEL RF distribution scheme is a reasonable choice for the BCD.
  - It is a technically workable approach that will be expensive.
  - R&D on the BCD is mainly on reducing cost and part count.
- **Alternative**
  - Alternative splitting schemes need to be evaluated further for reducing cost.
  - Additional technology evaluations to increase system efficiency and fault agility need to be done.

Low Level RF

Proposal for Baseline Design

- LLRF systems for VUV-FEL and X-FEL should serve as baseline for LLRF for ILC. Same architecture is used as SNS, J-PARC, Cornell and others with smaller number of channels.

- Performance (Luminosity !) of ILC is strongly coupled to performance (field stab. and availability) of LLRF
  - Need high degree of automation
  - Beam based feedbacks
  - Build-in diagnostics
  - Extensive exception handling

  Most of the work just started

- Requires assembly of several strong teams from regions

R&D Issues

- Hardware technology is rapidly advancing and should be picked at the last possible moment.
- Need to evaluate and redefine software architecture
  - Modularity and standardisation to facilitate collaboration
- Need to continue algorithm development and demon-strate with beam
  - will have test facilities in all regions
  - need prototypes of hardware
- Need to work on availability

Cryomodules

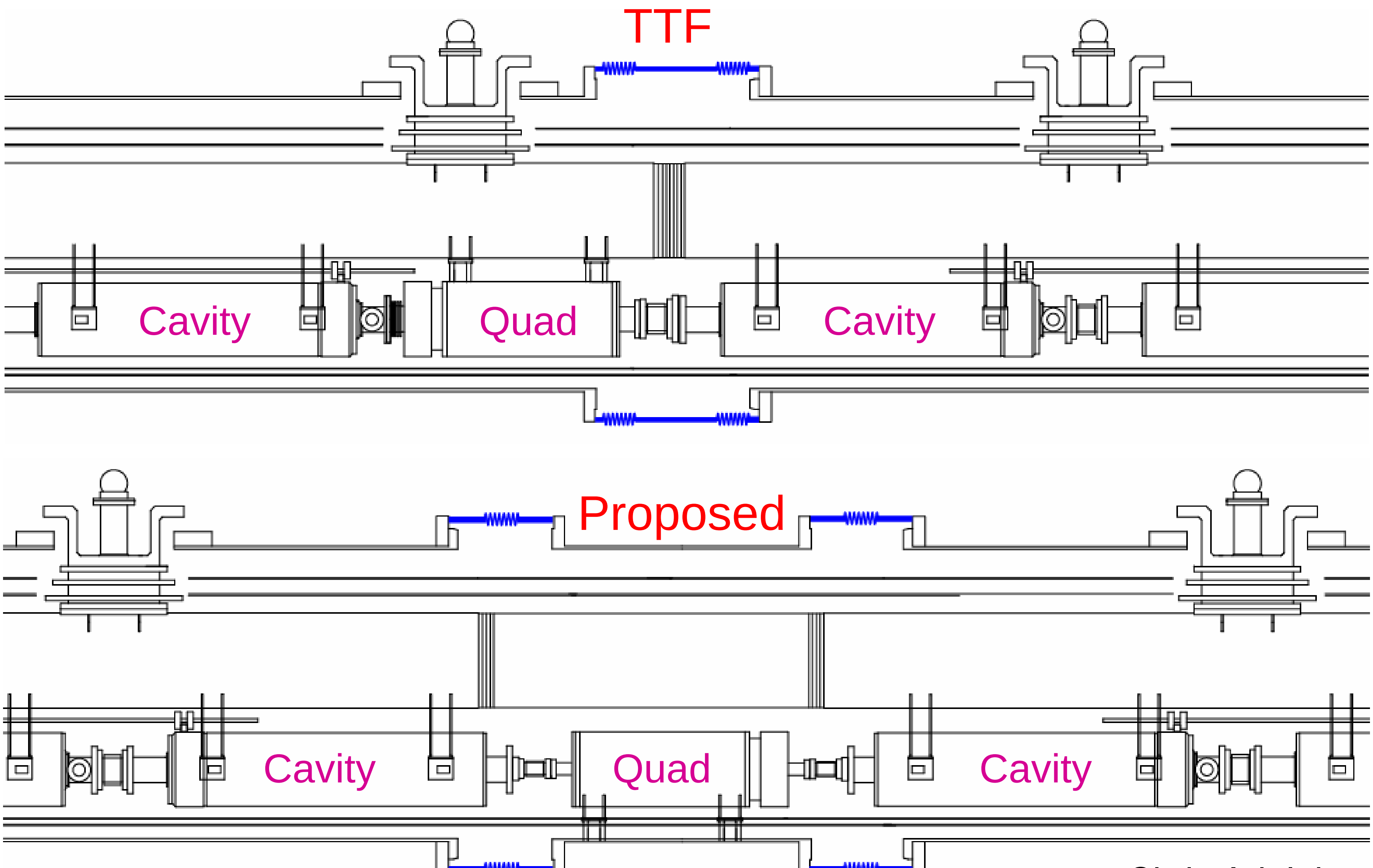
Module	Installation date	Cold time [months]
CryoCap	Oct 96	50
M1	Mar 97	5
M1 rep.	Jan 98	12
M2	Sep 98	44
M3	Jun 99	35
M1* MSS	Jun 02	30 8
M3* M4 M5	Apr 03	19 19 19
M2*	Feb 04	16

Carlo Pagani

From Cryomodule Type III to ILC

- Take TTF Type III as reference conceptual design
- Introduce layout modifications required to fit ILC requirements:
  - Quadrupole / BPM package at the center (symmetry and stability)
  - Consider/include movers (warm) at the center post for x,y quadrupole beam based alignment
  - Consider/include movers to optimize the module centering according to HOM data
  - Review suspension system (post, etc.) for stability and transport
  - Review pipe sizes/positions according to gradient and cryo-distribution
- Review all the subcomponent design for production cost and MTBF
  - Materials, welds, subcomponent engineering, LMI blankets, feed-through, diagnostics and cables, etc.
- Reduce the waste space between cavities for real estate gradient
  - Flange interconnection, tuners, etc.
- XFEL, SMTF and STF should move as much as possible in a parallel and synergic way.

Quad/BPM Layout



Chris Adolphsen

Cryogenic System

Surface cryogenic plant here
with major tunnel access

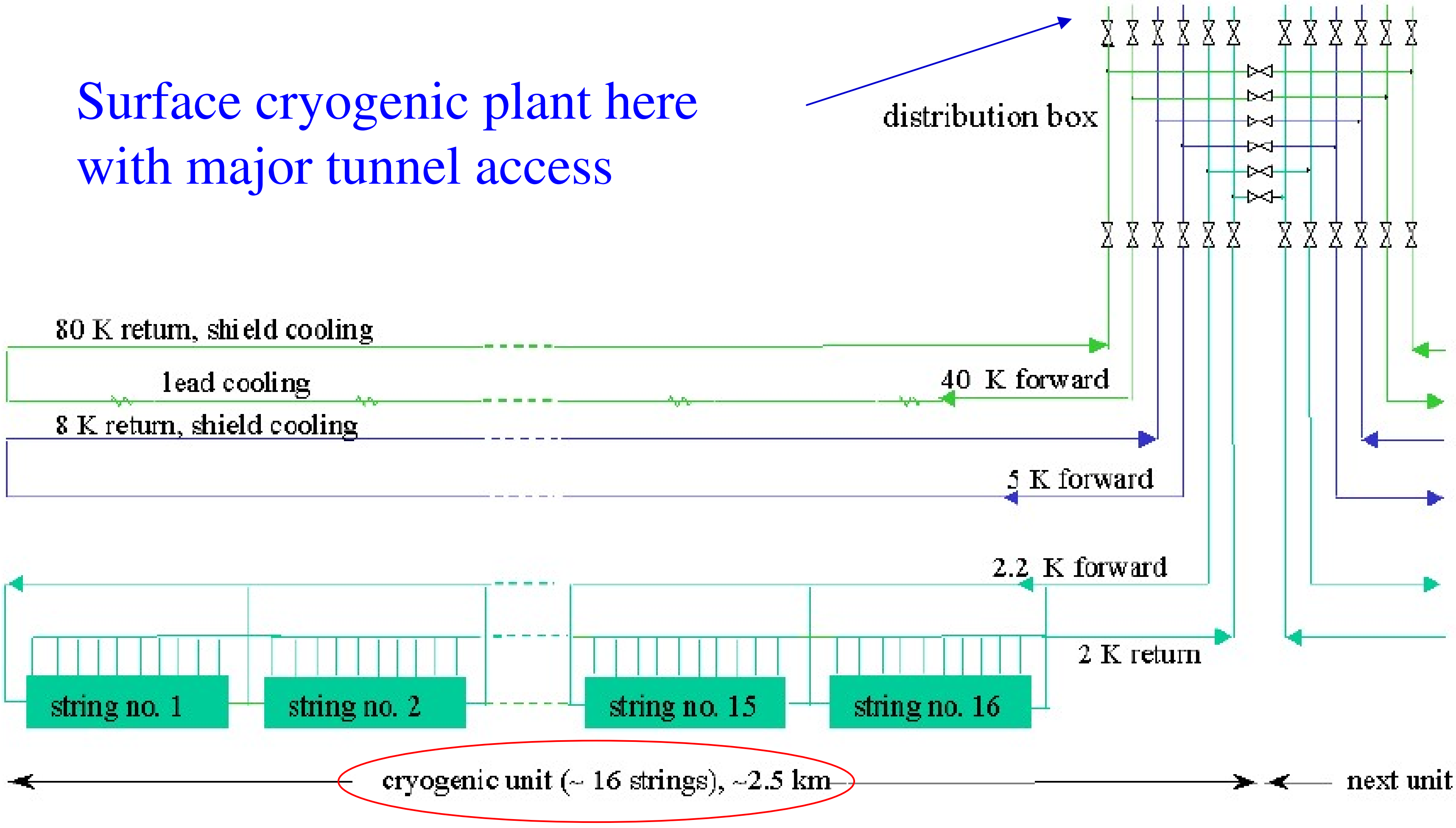


Figure 8.7.2: *Cryogenic unit.*

Tom Peterson

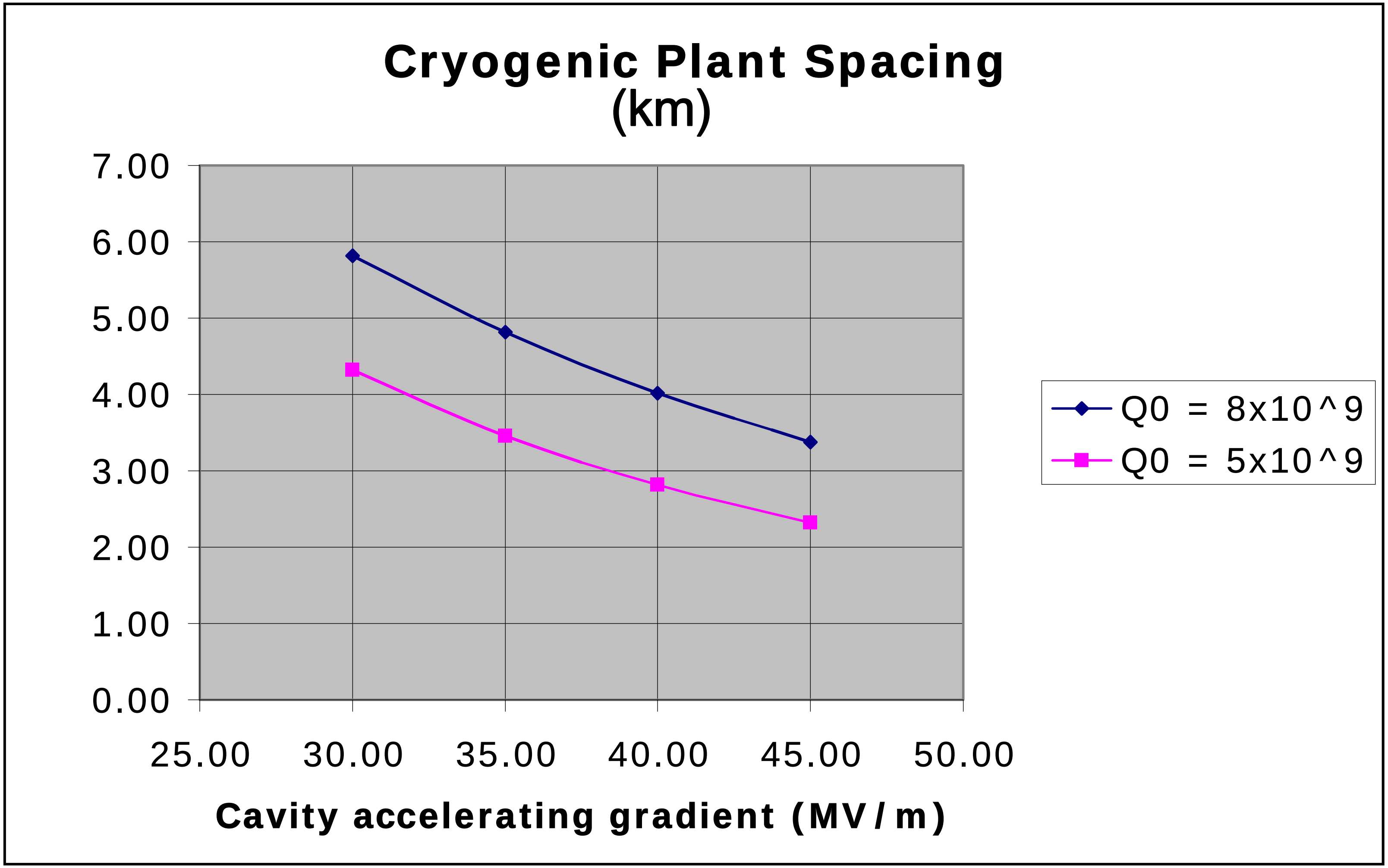
Some Cost Considerations

- For a tunnel depth greater than 30 m, one should consider placing some portion of the cryogenic refrigeration system in a cavern at tunnel level.

- At 35 MV/m, Qo = 8x10^9, 5 Hz and 5 km cryoplant spacing, we are at the 24 kW, 4.5 K equivalent load limit for large helium cryoplants.

- As we increase cooling power, we are adding more cryoplants and adjusting plant spacing, so scaling is not with the 0.6 power of the load, but may be more nearly linear with total cooling required.

Cryogenic plant spacing as set by the practical limit of total capacity for a single plant equivalent to 24 kW at 4.5 K.



Linac Lattice Configuration

- Choice based on experience and multiple cross-checked calculations
  - TESLA TDR like lattice with continuously curved or segmented linac:
    - One quad per two, 12-cavity cryomodules or three, 8-cavity cryomodules.
    - Most of Installation tolerances for cavity, Quad / BPM are achievable and was demonstrated at TTF cryomodules.
    - BPM resolution ~ few μm routinely achieved.
    - One-to-one and DFS tuning algorithm was demonstrated, need more understanding of possible limitation.
    - XFEL will serve as a benchmark.

- Choice based on potential cost savings (need R&D)
  - Lattice with larger quad spacing:
    - High energy part of the Linac is more robust (smaller emittance dilution). Larger quad spacing here is cost saving
    - Using beam position information from cavities for BBA will allow reduce number of BPMs.

Nikolay Solyak

Layout Issues

- Main Linac Bending Options (site dependant):
  - Straight line linac, no bends.
  - Continuously vertically curved linac with bending magnets between modules: requires extra magnets, extra length
  - Discrete vertical bends:
    - 1 bend per linac for 500GeV
    - 2 bends per linac for 1 TeV
    - 200 m extra length per bend
- Quad and Cavity apertures
  - Linac will likely tolerate the increasing of the wakefield due to:
    - New shape HG cavities with smaller radius ~ 30 mm
    - New Quad design with smaller radius ~ 18 mm

Tunnel Options

- Consider two main options:
  1. TESLA style: **1** tunnel with modulators in sparse support buildings.
  2. Or **2** full tunnels with virtually all active equipment in the support tunnel.

- Each option could be
  a. In a **deep** tunnel
  b. Near the **surface** (with support equipment on the surface)

Pros/cons of 1 vs 2

- Cost: favors 1. USTOS estimates 1 is 5% cheaper (about $400M), then add 3% for availability improvements for a net 2%.
- Availability risk: favors 2. With same MTBFs, 1 tunnel is down 30.5% versus 17% for 2. Can make better MTBFs, but higher cost/risk.
- Commissioning: favors 2. Subtle problems that require hands on with a scope and beam to understand will be very slow to solve.
- Pulse transformers disturb damping rings: favors 2. only if pulse transformers are used.
- Commissioning/upgrade: favors 2. Installation in support tunnel can go on while commissioning/running occurs in accelerator.
- Unless one wants to improve the cost estimate, no further work is needed to decide on BCD.
- My conclusion: 2

Pros/cons of deep vs surface

- Cost: favors surface. Cut and cover construction is cheaper. I think civil group has numbers. Get them and put them here.
- Ease of finding site: favors deep. Sites with right topology and bareness are few are far between. Eased somewhat if can have vertical bends in the linac.
- My conclusion: Carry both options until site is selected.

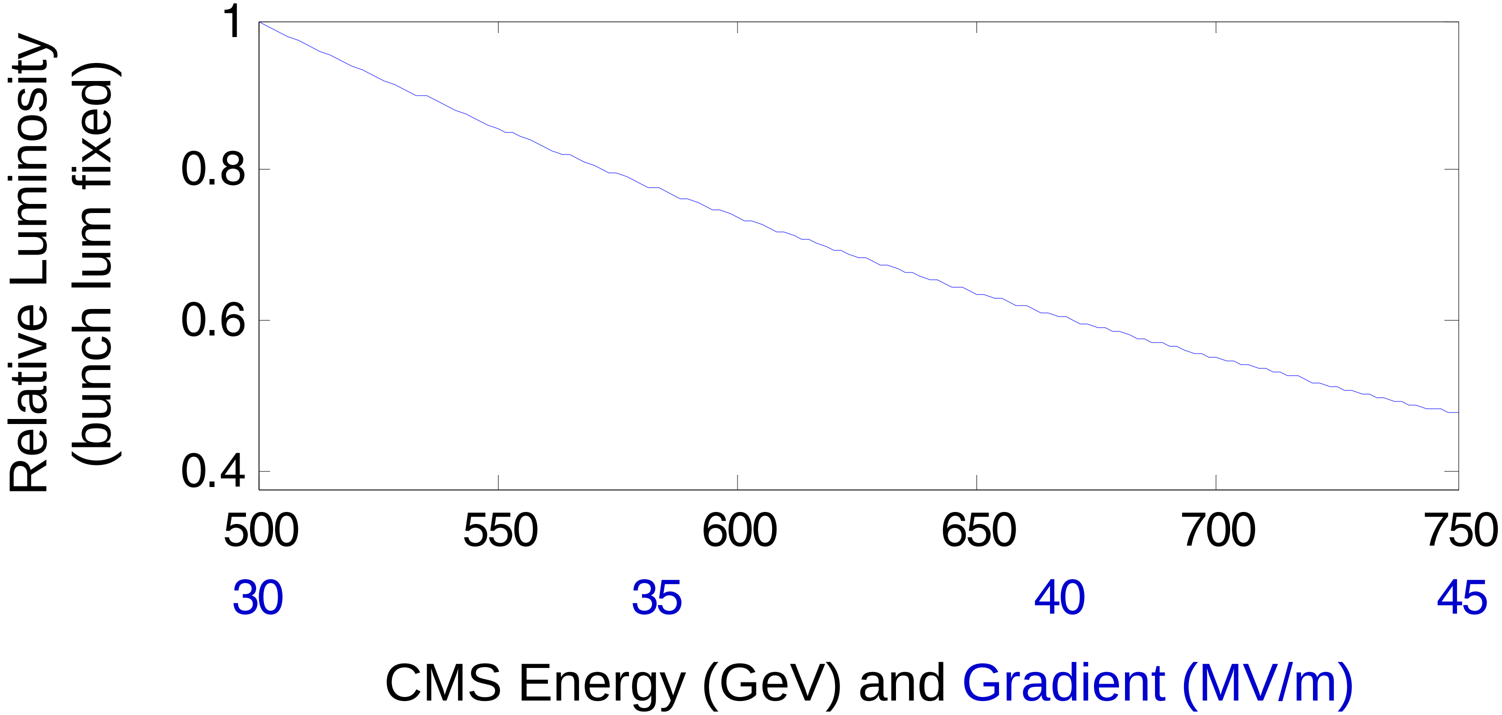
Gradient – Global View

- Minimize Cost
  - Minimum capital cost about 40 MV/m
    - 1 % TPC increase at 35 and 45 MV/m
    - 4 % TPC increase at 30 MV/m
  - However, AC-to-Beam efficiency decreases from 17.0% at 28 MV/m to 15.3% at 35 MV/m.
- Provide Extended Physics Reach
  - Choose gradient somewhat lower than thought achievable so higher energies are reachable at lower beam current (~ luminosity).
  - Use highest gradient cavities available at time of machine construction.

Chris Adolphsen

Practical Choice

- Design for 30 MV/m.
- If decrease current by reducing number of bunches, achieve the following energy reach assuming ~ 50% cooling overhead used and no Q variation with gradient (could lower rep rate if needed).



Comments on WG2 Options

- Lack of comparative cost and risk data makes it hard to reach definitive conclusions.
  - Little done since US Options Study.
- Personal and regional interests compound the problem.
- In near term, should concentrate on major cost drivers – other decisions can wait.