Introduction, 9mA program goals, schedule, constraints

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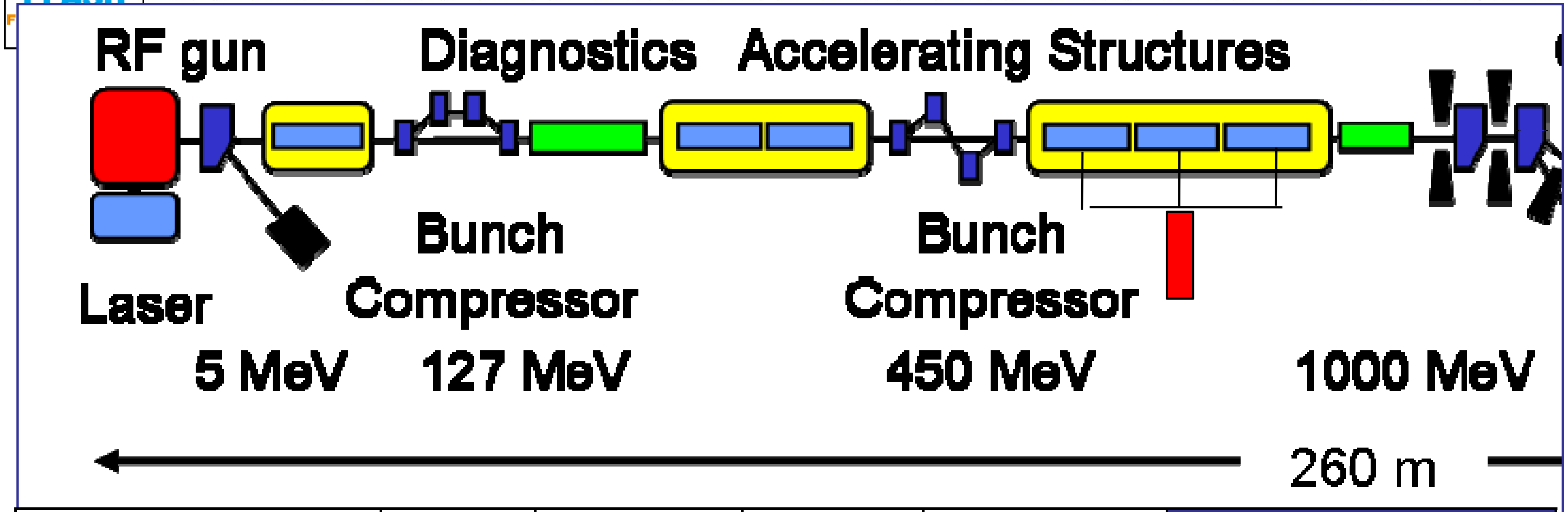
9mA Experiment Mini-Workshop
16.01.2009

9mA Experiments in TTF/FLASH



		XFEL X-Ray Free-Electron Laser	ilc	FLASH design	FLASH experiment
Bunch charge	nC	1	3.2	1	3
# bunches		3250*	2625	7200*	2400
Pulse length	μs	650	970	800	800
Current	mA	5	9	9	9

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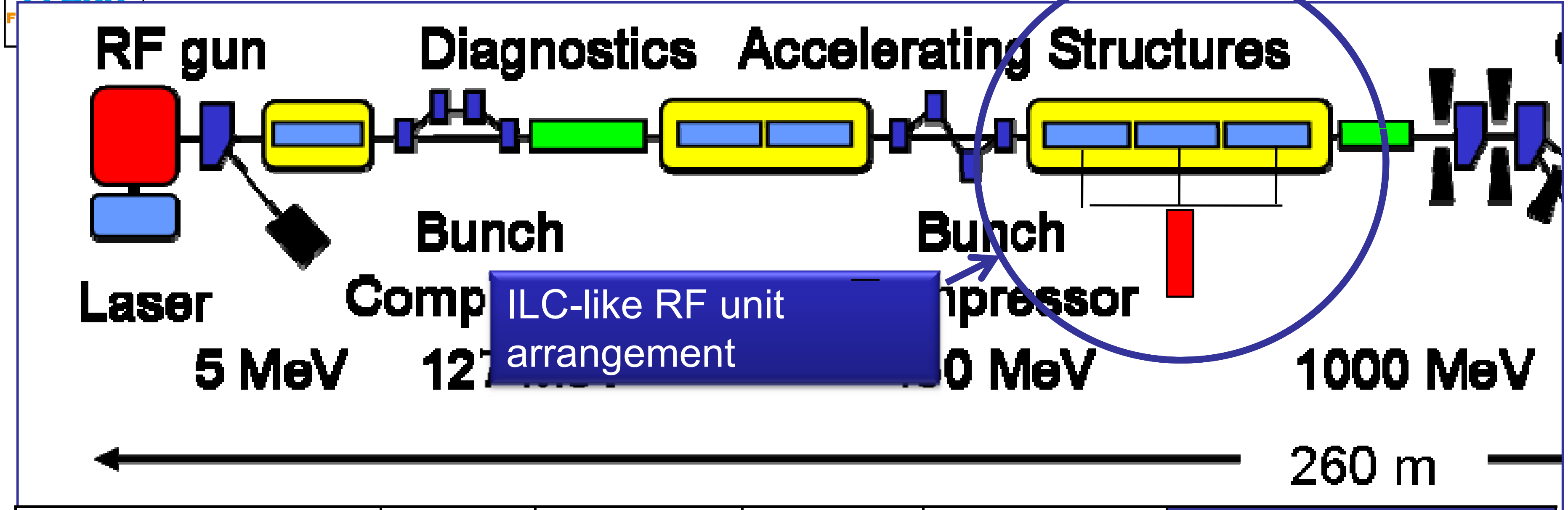

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Primary Objectives

- **Long-pulse high beam-loading (9mA) demonstration**
  - 800μs pulse with 2400 bunches (3MHz)
  - 3nC per bunch
  - Beam energy 700 MeV ≤ E_{beam} ≤ 1 GeV
- **Primary goals**
  - Demonstration of beam energy stability
    - Over extended period
  - Characterisation of energy stability limitations
    - Operations close to gradient limits
  - Quantification of control overhead
    - Minimum required klystron overhead for LLRF control
  - HOM absorber studies (cryo-load)
  - …

Primarily a LLRF experiment

- **Major challenge for FLASH !**
  - Pushes many current operational limits
  - Planning and preparation:

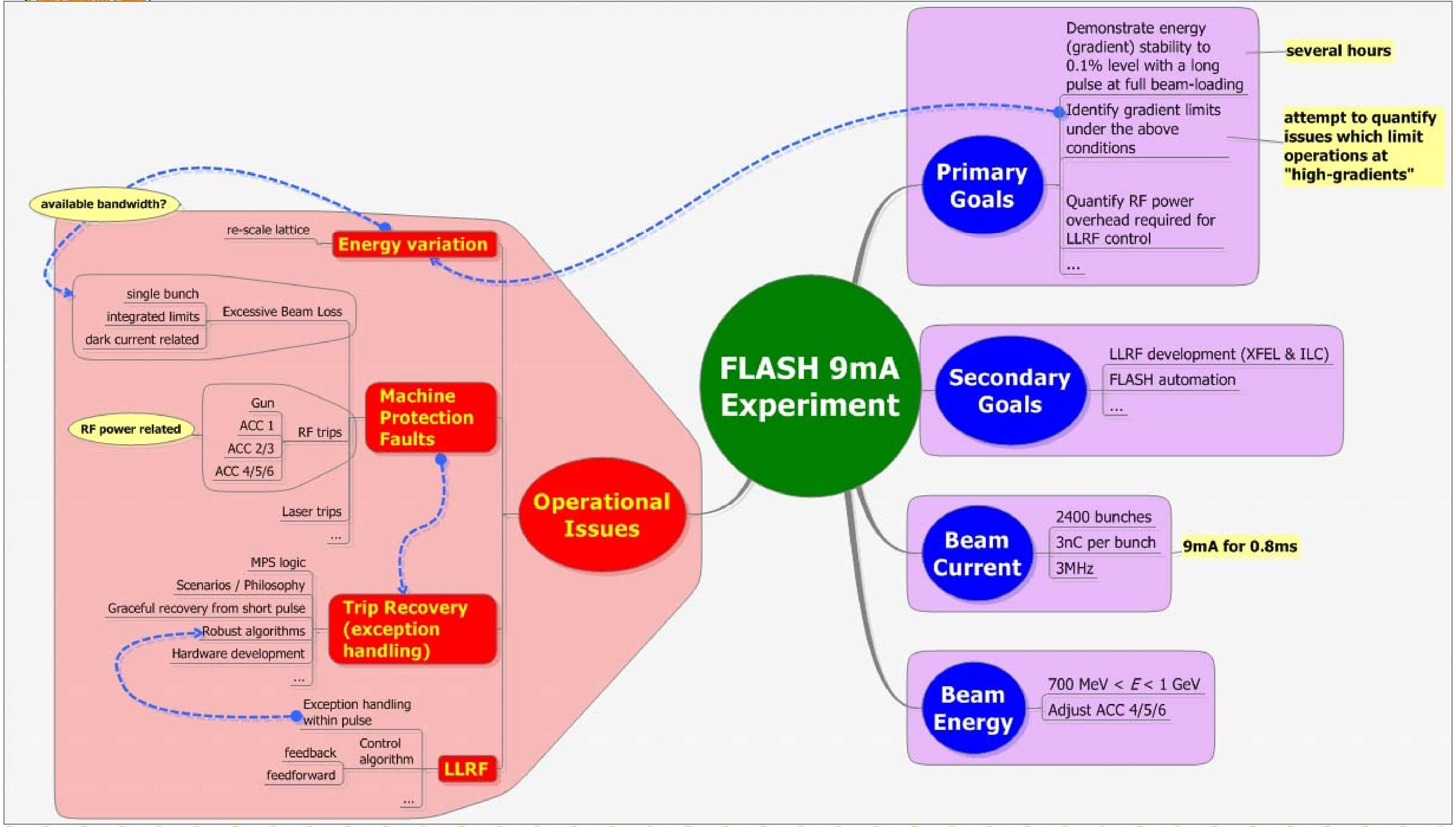
Context

- **Experiment addresses needs of ILC, XFEL and FLASH**
  - ILC: International GDE stated milestone
    - primary driver: important and visible deliverable for international effort
  - XFEL: Close collaboration with world-wide LLRF groups
    - Focus (potentially accelerate) development and planning for XFEL
    - "Operation at limits" experience provides important Input for future XFEL development
      - Important demonstration also for XFEL
  - FLASH: Addresses many operational issues
    - Automated exception handling and recovery
    - Better characterisation of machine
    - Towards routine high-power long-pulse operation for users.

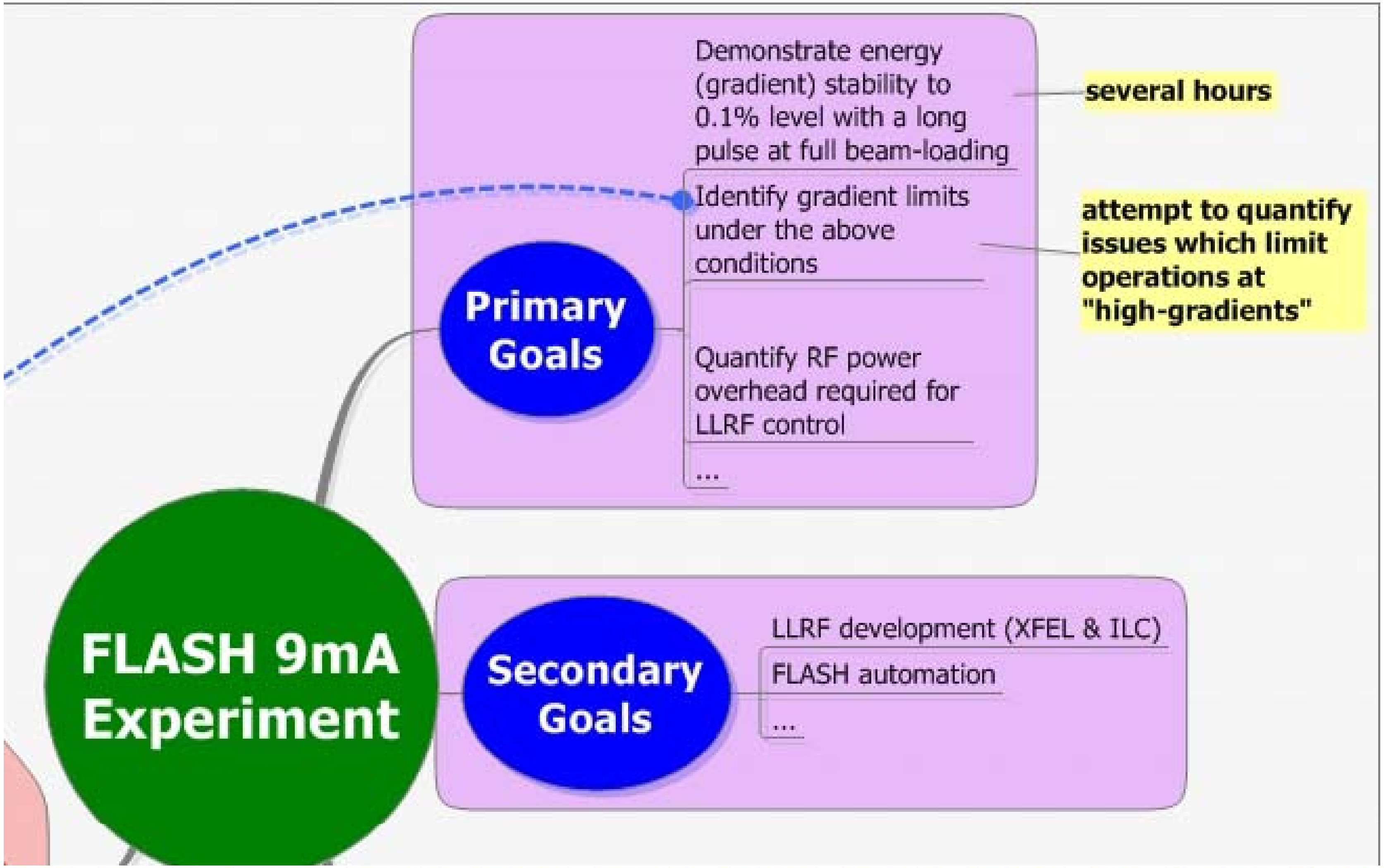
H. Weise

- **TTF2/FLASH remains a unique facility world-wide**

Achieving the Goals



Achieving the Goals



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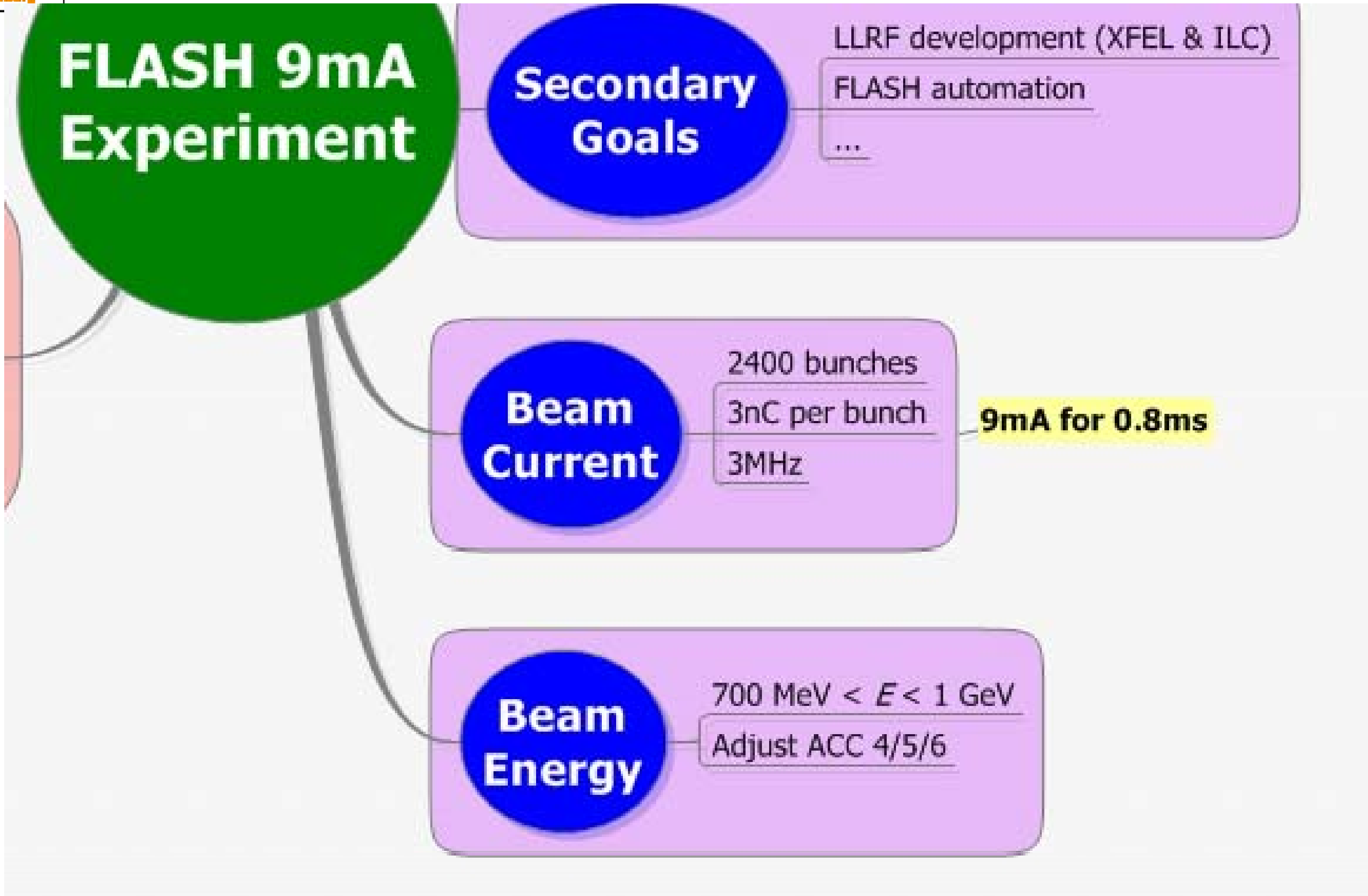
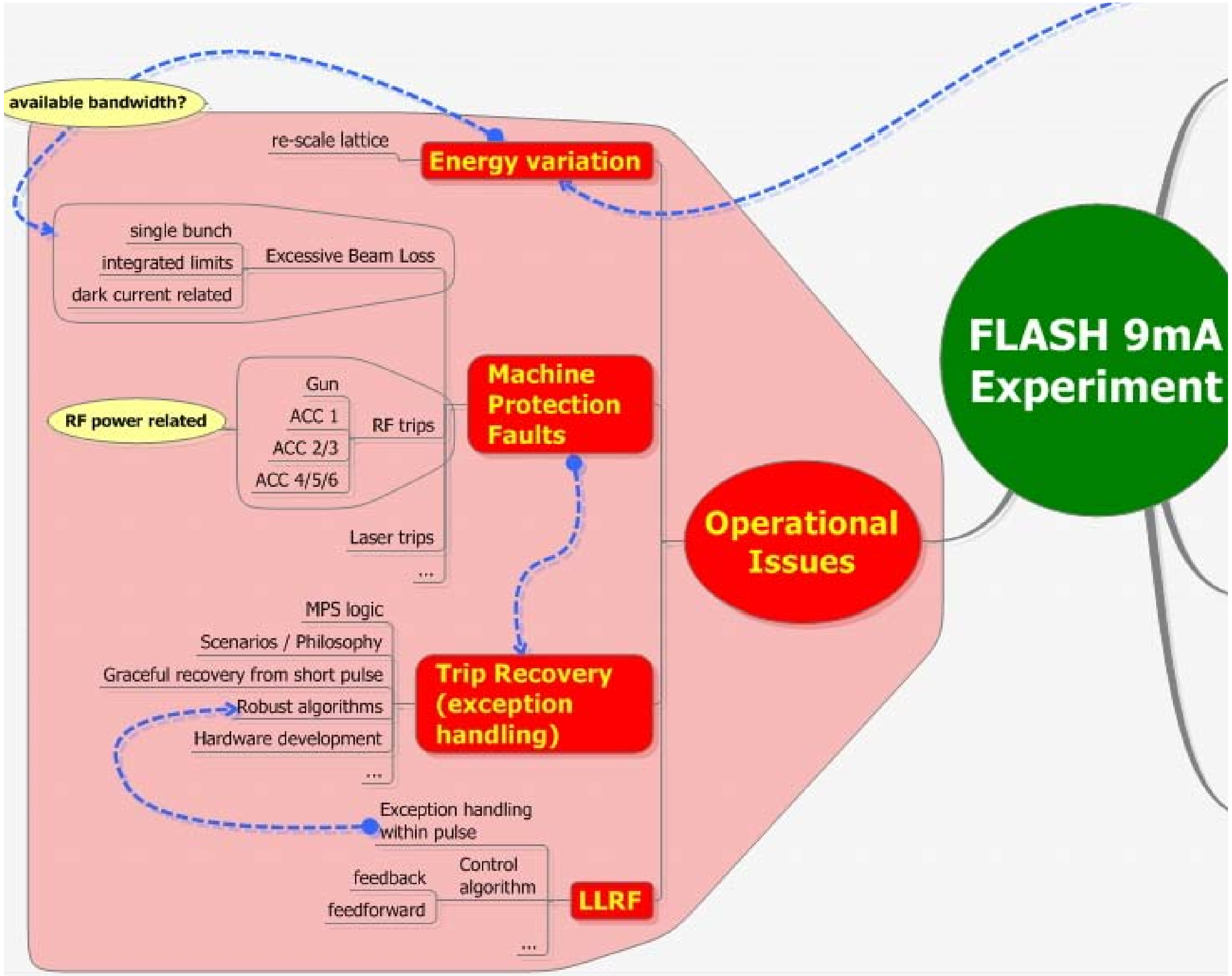


Achieving the Goals



Goals of 9mA test (summary)

- **Demonstrate energy stability <0.1% (LLRF) with high beam-loading**
  - Bunch to bunch
  - Pulse to pulse
  - Over many hours (~ shift)
- **Evaluate operation close to cavity limits**
  - Quench limits
  - Impact of LFD, microphonics etc.
- **Evaluate LLRF performance**
  - Required klystron overhead
  - Optimum feedback / feedforward parameters
  - Exception handling (development)
  - Piezo-tuner performance *etc.*
- **Evaluate HOM absorber (cryoload)**
- **Controls/LLRF development**
  - Software & algorithm development for ATCA (XFEL) LLRF system

Original Proposed Schedule

- **19/05-01/06/08: 1st machine study peri**
  - 3nC optics via by-pass (good transmission)

complete

- **08-28/09/08: 2nd machine study peri**
  - By-pass TPS (6 shifts)
  - Longer bunch trains

Complete / Aborted!

- **05-18/01/09: 3rd machine study peric**
  - ~~"dress rehearsal"~~ (est. ~~6~~ 4 shifts)
  - LLRF development / quench limits / beam loss

De-scoped Complete

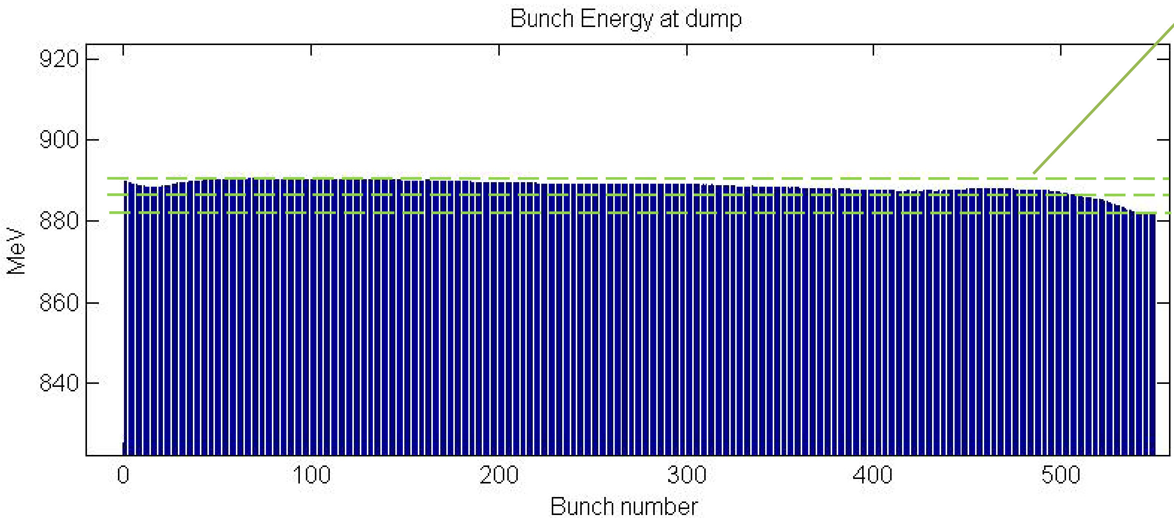
- **Before shutdown 09: Dedicated 9mA experiment**
  - 2 week (tbc) run dedicated to 9mA studies
  - Detailed experimental programme in planning

LLRF development & planning for

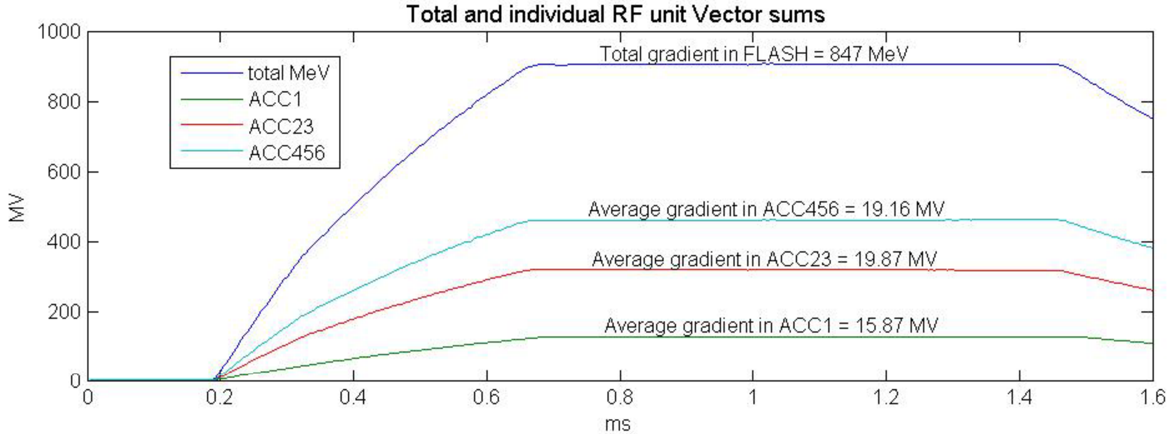
XFEL ✓
FLASH ✓
ILC ✓

almost 100% synergy

High Beam-Loading Long Pulse Operation



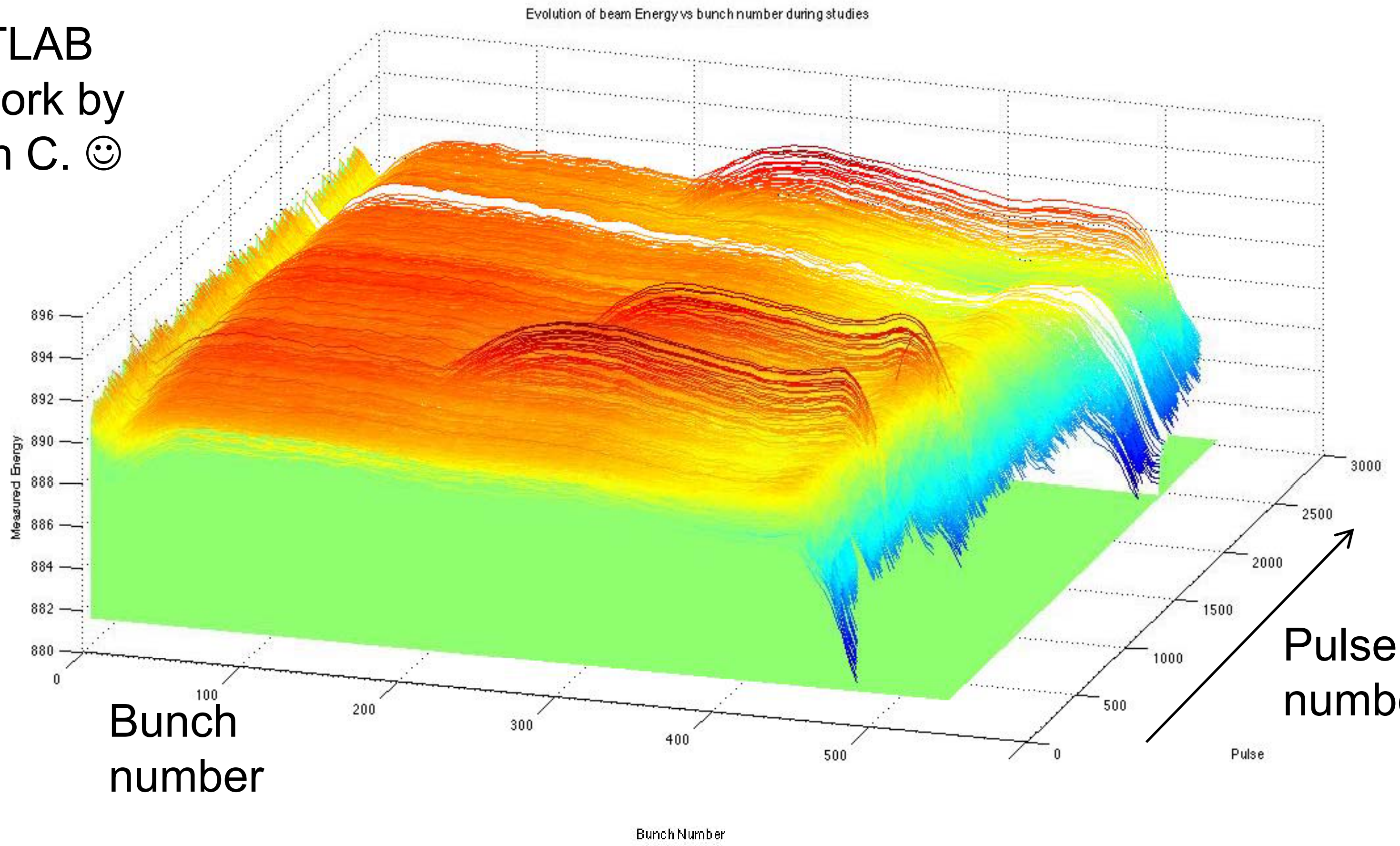
10 MeV over 550 bunches (~1%)
(~4 MeV over 1st 500)



- **450 bunches achieved with stable operation**
  - Few hours of archived data
  - Currently under analysis
  - (vacuum OK)
- **Long bunch trains with ~2.5 nC per bunch:**
  - 550 bunches at 1MHz
  - 300 bunches at 500KHz
  - 890 MeV linac energy
- **All modules (RF) running with 800us flat-top and 1GeV total gradient**
- **Increase from 450 to 550 bunches eventually caused vacuum incident**
  - The “straw that broke the camels back!”

Beam energy at the dump

MATLAB
artwork by
John C. ☺



Bunch
number

Pulse
number

LLRF Observations & Comments 1

- **In general, system works relatively well**
- **3mA beam loading (new regime) required <u>manual adjustment</u> of LLRF beam-loading parameters**
  - As we increased the number of bunches (learning curve)
  - Understanding path to automation ($\rightarrow$ XFEL/ILC)
  - Program termination (vacuum incident) did not allow enough time to *optimise* LLRF parameters
- **Existing data indicates stability issues which we will need to address by increasing regulator gain**
  - Likely to get more prominent as we increase beam-loading and gradient

LLRF Observations & Comments 2

- ***Adaptive Feed-Forward* system is being used to compensate inadequacies in control system**
  - No *a priori* knowledge of beam pulse structure sent to LLRF
  - AAF used to deal with (user driven) changes
  - Beam pulse termination (MPS) influences AFF causing errors (next pulses)

- **Different AFF systems in FLASH**
  - Hardware implementations
  - Move towards common platforms/algorithms (SIMCON-DSP)

- **LLRF feedback gain in general too low (20)**
  - Will cause problems for high beam-loading at high-gradients
  - Microphonics, LFD, etc…

LLRF Observations & Comments 3

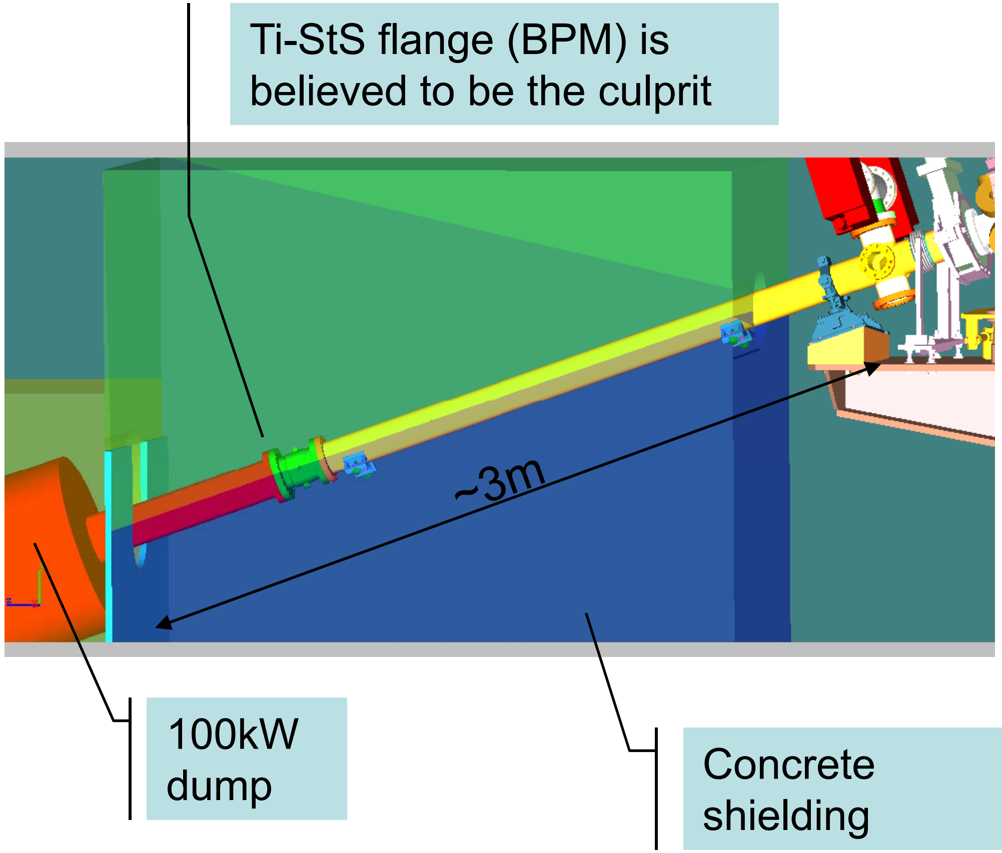
- **Existing data analysis needs to be augmented**
  - Still questions concerning interpretation
  - Further (refined) experiments being planned
  - Continued analysis of existing data

- **DAQ system invaluable but needs tool development (on-going)**

- **Extrapolation to 9mA**
  - What additional problems can we predict from existing data
  - What measures must we take to alleviate them
  - List of improvements to LLRF systems
    - Subject of a seminar in their own right

Vacuum repair & instrumentation

- **FLASH operation currently limited to ~30x1nC bunches**
  - Cu window
- **Dump line (see right) will be replaced by 3m contiguous Ti pipe**
  - No BPM
- **Addition (MPS) diagnostics foreseen**
  - Thermometry
  - Loss-monitoring
  - ..
- **No magic fix – will still require 'experience' to understand new diagnostics**



→ Presentation by M. Schmitz

Challenges & Preparation (Review)

	Item	Problem	Responsible	Due date / test
Long RF Pulse	Gun thermal stability	Trip recovery? (see LLRF)	Floettmann (Krebs)	??
	Klystron/Modulator Issues (ACC1?)	Stability at long pulse (trip rate)	Choroba	?? (ASA[illegible]
3MHz operation	Laser Pockels cells	FPGA/controls (pulse length constraint?)	Schreiber Fröhlich	Test before [illegible]
		Spare cells	Schreiber (Wills)	Pu[illegible]e before 10/08
	TPC / MPS system 3MHz controls issues		Rehlich Fröhlich	Before 5/08 [illegible]udies)
High bunch charge	High-transmission optics through by-pass		Golubeva Balandin	3 shifts during May Accelerator Studies to test
	RF gun parameters		Krasilnikov	?? (Before May, set-up in optics shifts)

OK? Run Lower Gradient

Resolved? Status?

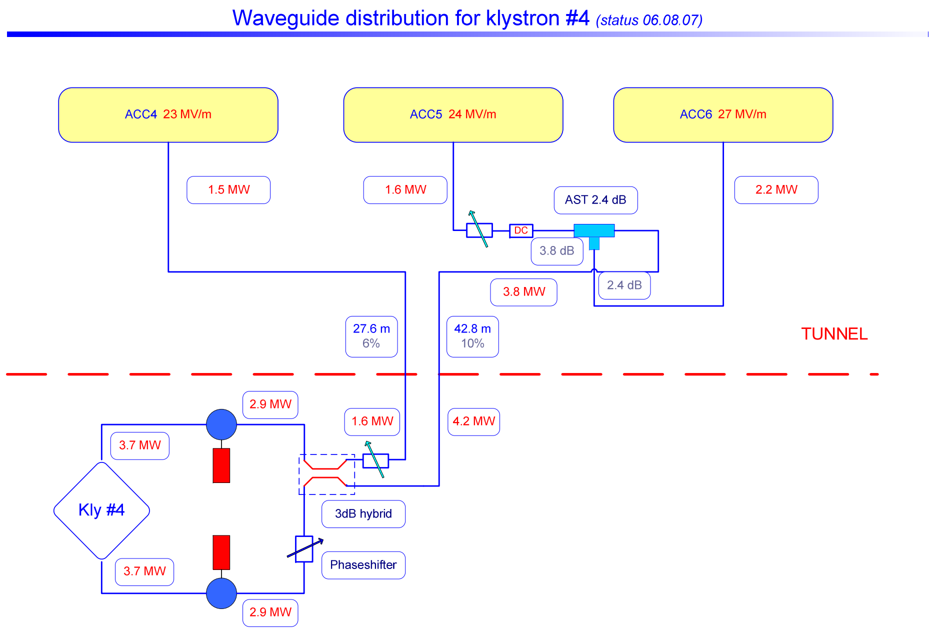
No test with beam until main run

Need status

Challenges & Preparation (Review)

	Item	Problem	Responsible	Due date / tested by
High charge (cont.)	BPM saturation	Install attenuators (if necessary)	Nölle	1 day to inst… …stall First n… …or optics set-… May 08 Not needed?
MPS	TPS in by-pass	Installation and commissioning	Napoly/Hamdi (Saclay)	1 shift/day for 3 days of 300 1 nC bunches (Sep08 Accelerator Studies)
	BML in by-pass	Check / test	Fröhlich	1 shift to test. (Can overlap with TPS testing in Sep. 08)
Other issues:	Beam dump constraints		Schmitz	Input needed for optics work May 08.
	Cryogenics	Any issues?	Lange / Petersen	Heads-up for high gradient running.
	By-pass “energy spectrometer” resolution	Would like to measure <10^{-3} relative bunch-bunch energy deviation.	Kammerling / Nölle	Answer by 15/0… …08 In theory OK (look at data)

ILC RF Unit (ACC456)



- **From ILC perspective, ACC456 is the most interesting**
- **Strong links to ILC "S2" Goals**
  - String test with beam
- **What can we achieve with this test with respect to S2?**

ILC S2 context of 9mA studies

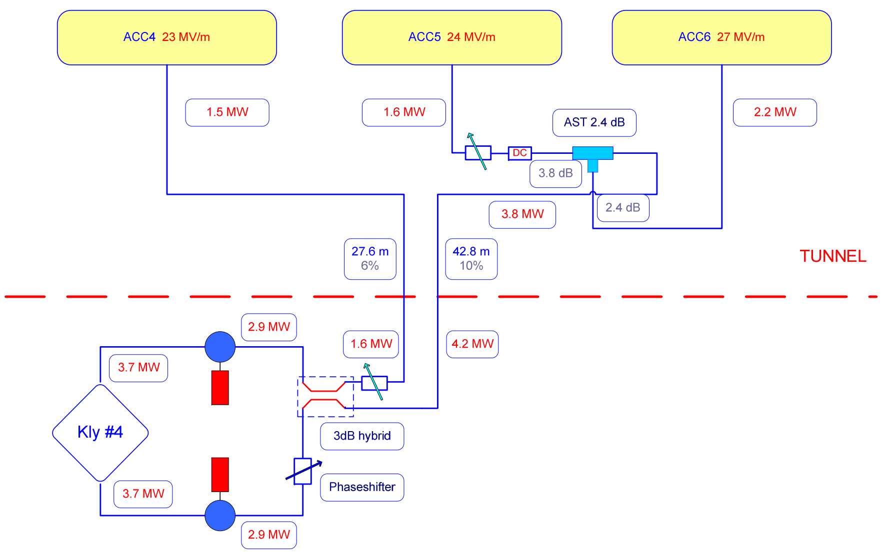
S2: Test of ILC RF unit (1 klystron – 26 cavities) operating at an average gradient of 31.5 MV/m with full beam loading at 9mA

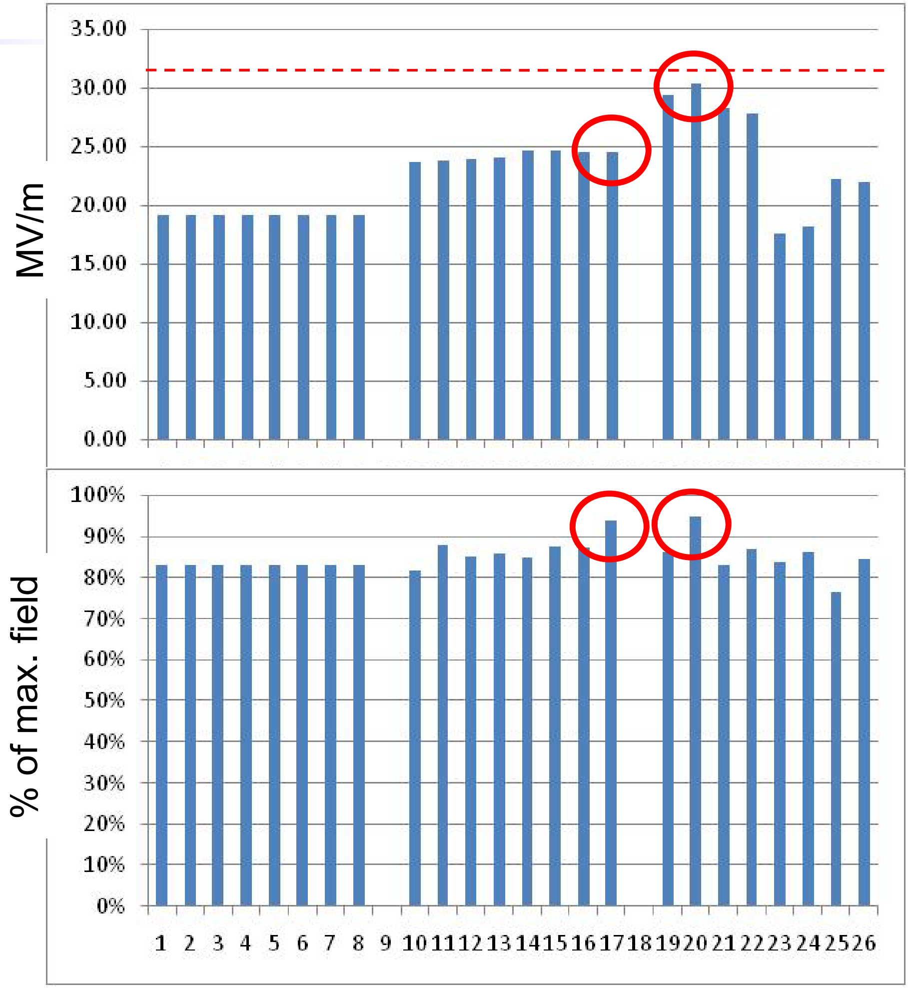
Item #	S2 Goals
2	Beam-based feedback and controls
4	RF 'fault-recognition' software
5	Quench rates and recovery times
7	Gradient spread
9	HOM heating
12	Produce a 'spec RF Unit'
10	Check beam phase and energy stability

9mA Goals
Operation close to gradient limits
Demonstration of beam energy stability over extended period
Characterisation of energy stability limitations
HOM absorber studies (cryoload)
Long-pulse operation with full beam loading
Quantification of control overhead

9mA Experiment: limits

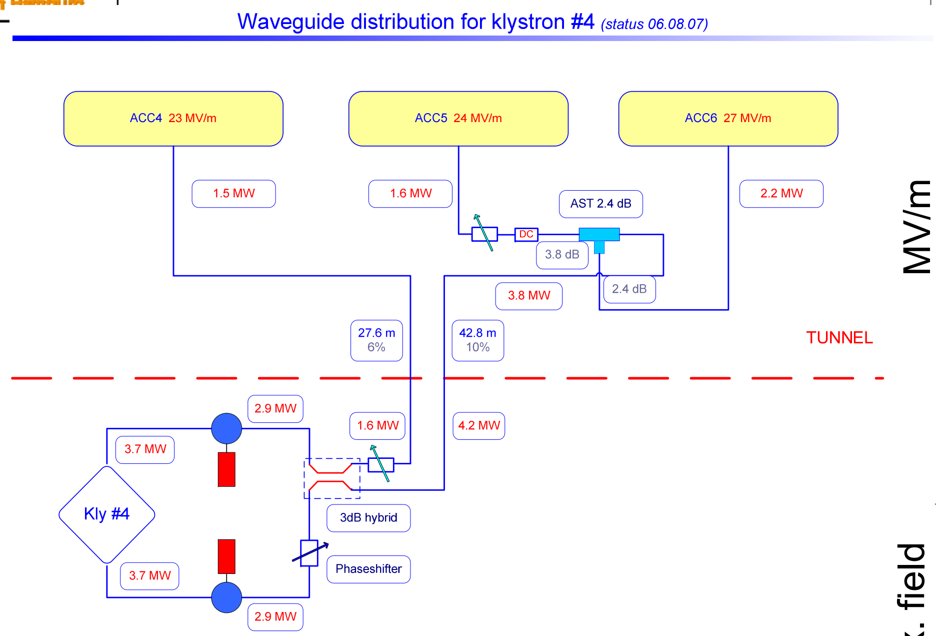
Waveguide distribution for klystron #4 *(status 06.08.07)*

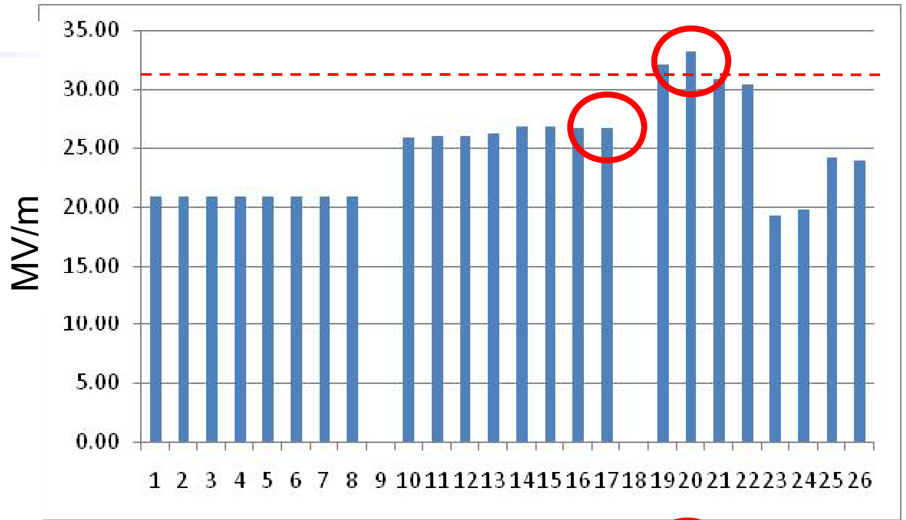


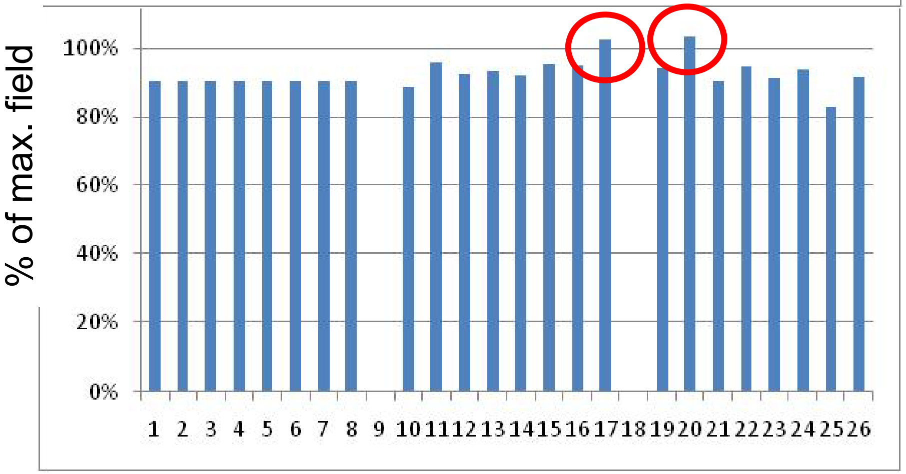


- **Aim for stable 9mA running at this limit**
  - 5% below quench limit
  - Klystron power ~6 MW

9mA Experiment: limits







- **390kW circulator limit (ACC 6 cav #2)**
  - Go above quench limits
  - Klystron power ~7 MW

What are the real limits?

Extrapolation to ILC-S2

- **9mA experiment will not have the 'average gradient' required by S2**
- **Need to extrapolate to address as many of the S2 goals as possible**
- **Understand what the limits of this extrapolation are**
  - Confidence limits
  - What data is really needed under which conditions
- **What goal/test will still require a full S2 test?**
  - Apart from the political one
- **Note: TTF/FLASH the only facility available to us until >2012**

Questions to this meeting

This Meeting and Beyond

- **Primary goal: planning for the main experiment**
  - Detailed list of experiments, goals, schedule etc.
  - What must we learn for ILC (S2) and XFEL
  - Discussions on detail planning → this afternoon
- **How well do we understand the challenges?**
  - Based on TTF/FLASH operations experience as well as results from dedicated shifts
- **What can we do from now until September**
  - Data analysis
  - Modelling
  - Hardware preparation (e.g. SIMCON DSP system commissioning, 3MHz pockels cell installation,…)