CLIC Drive Beam Klystron Modulators

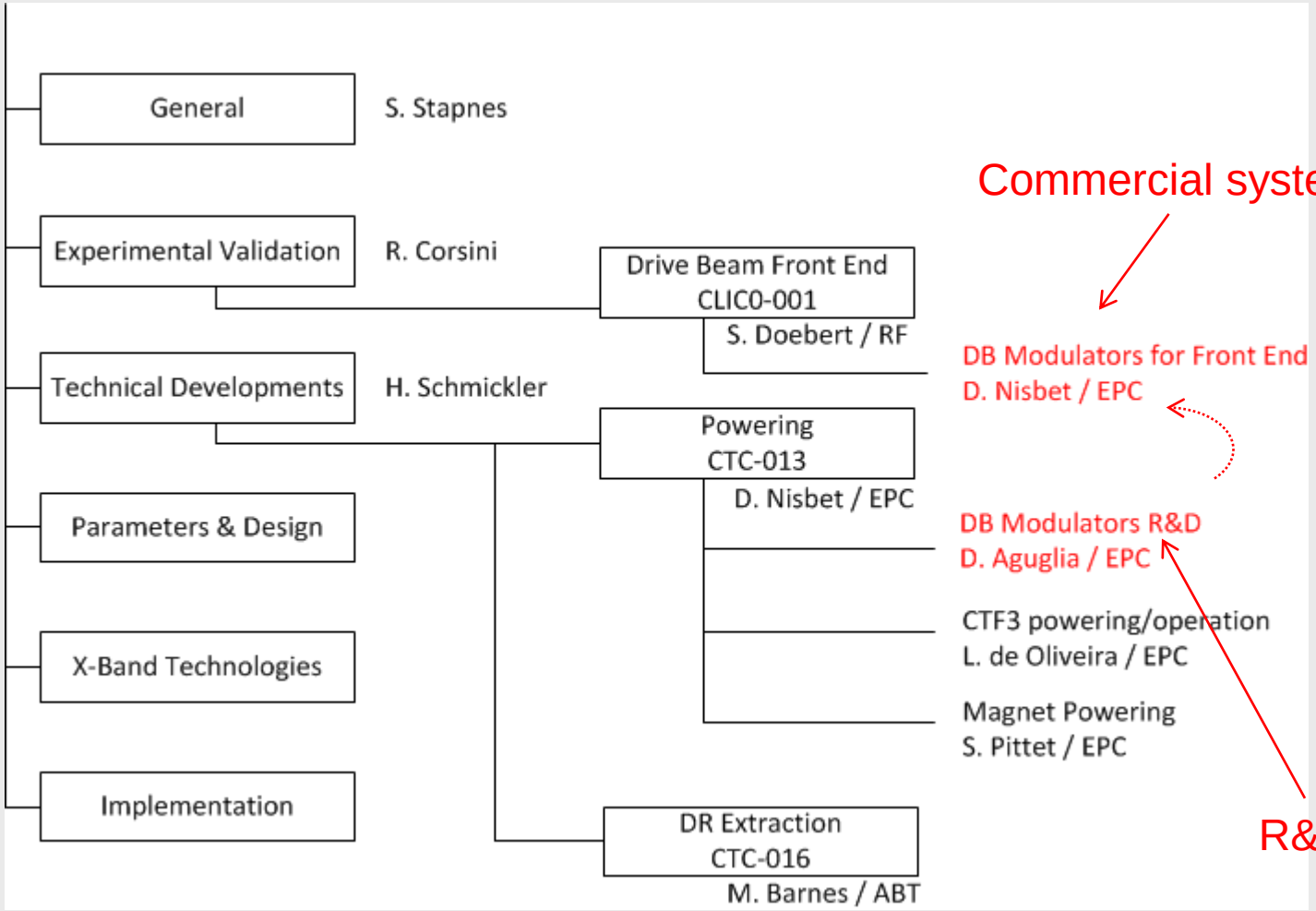
R&D strategy

D. Aguglia & D. Nisbet

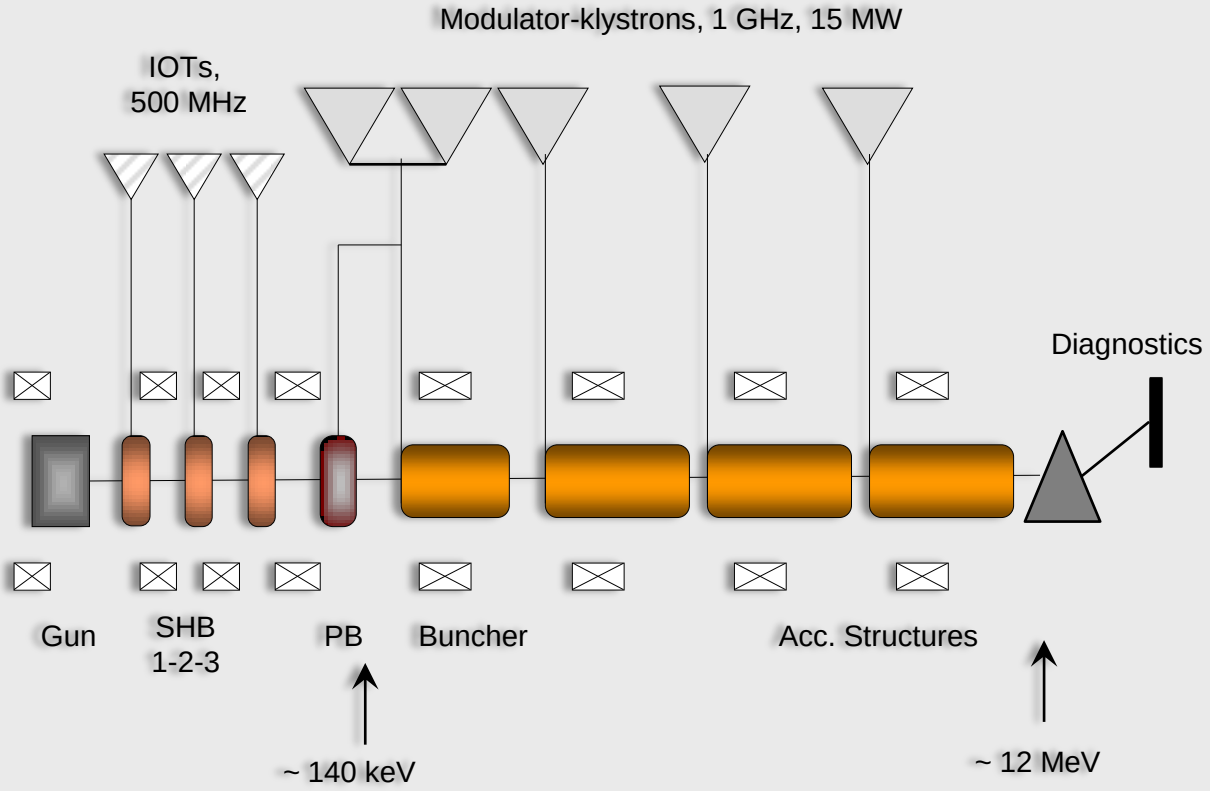
May 2012

Power Systems for the CLIC Project

- The CLIC PBS for powering



CLIC0 Injector Project

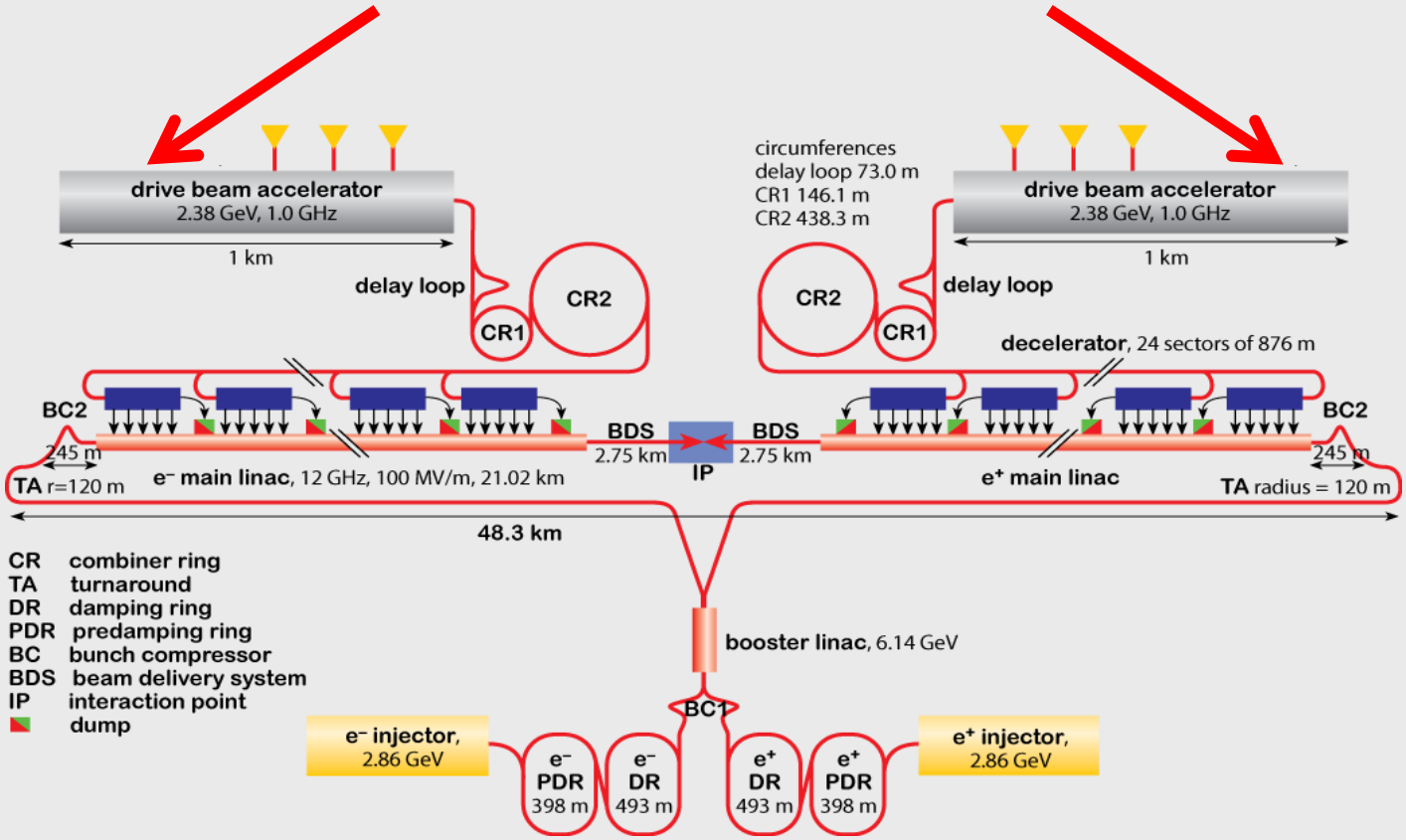


Gun, sub-harmonic bunching, bunching, three accelerating structures, 5 long pulse klystrons and modulators, diagnostics

- 3 commercial systems with reduced specs, delivered from 2014-2015
- 2 R&D systems with full Drive Beam specifications delivered 2016-2017

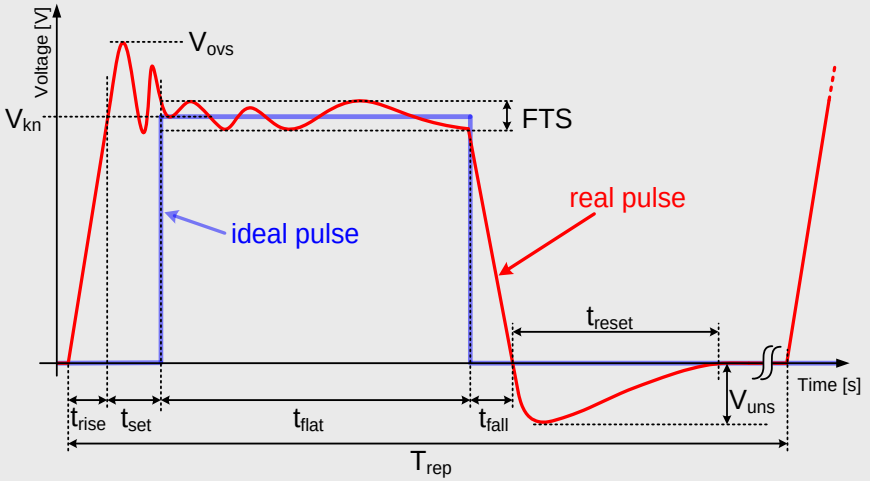
CLIC DB klystron modulators

~1600 klystron Modulators required here



CLIC studies & klystron modulators specs

Modulator main specifications			
Pulse voltage	V_{kn}	150	kV
Pulse current	I_{kn}	160	A
Peak power	P_{out}	24	MW
Rise & fall times	**t_{rise}**	**3**	**µs**
Flat-top lenght	t_{flat}	140	µs
Repetition rate	Rep_r	50	Hz
Flat-top stability	FTS	0.85	%
Pulse reproducibility	**PPR**	**10**	**ppm**



~300MW required for kly. mod.

Pulse efficiency definition $\eta_{pulse} = \frac{E_{ideal\_p}}{E_{real\_p}}$

•CLIC studies goal:

-Demonstrate technical & financial feasibility

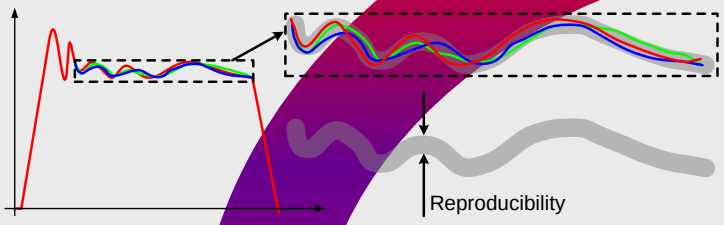
-Full scale kly. mod. prototypes required

-Collaboration to meet resource and expertise needs

CLIC studies & klystron modulators specs

Technology challenges

Pulse to pulse reproducibility: 10 to 100ppm



Modulator and voltage measurement reproducibility **never achieved before**!

Machine availability
With more than 1600 modulators, reliability, modularity & redundancy must be optimized for maximum accelerator availability

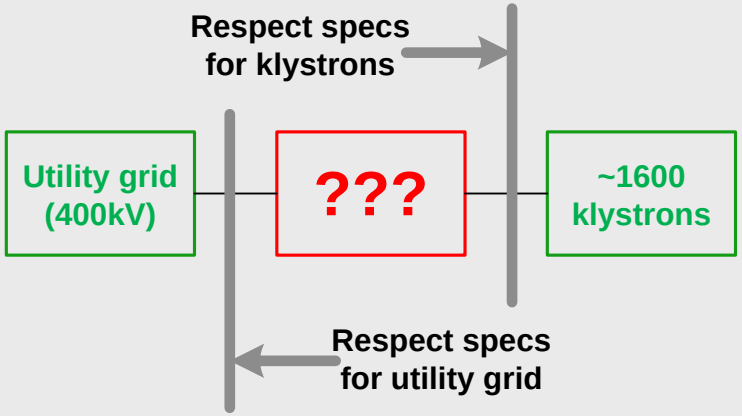
Modulator topology selection considering:
- Efficiency maximization (max. power limited)
- Reproducibility
- Constant power consumption
- Satisfactory accelerator availability

AC power quality optimization
More than 1600 modulators pulsing synchronously! Utility grid power fluctuation minimized (~1%) – tough charger design

Need for a global approach! Different solutions must be explored (transformer based, fully solid state, HV & LV solutions)

R&D philosophy - @ CERN vs. collaborations

The R&D process needs a global approach to the system!



Specifications from grid and from klystrons

What are the modulator specs (Charger, voltage selection, PFS)?

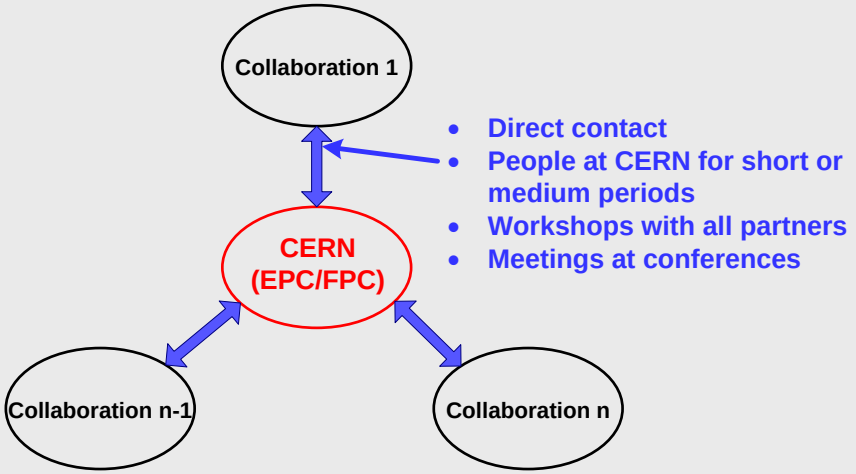
Again, global design approach!

1. Need for partners in specialized fields but with global understanding of the whole system

Very few institutions have all the skills to work in this domain

2. CERN must have the intellectual property and expertise in high performance klystron modulators

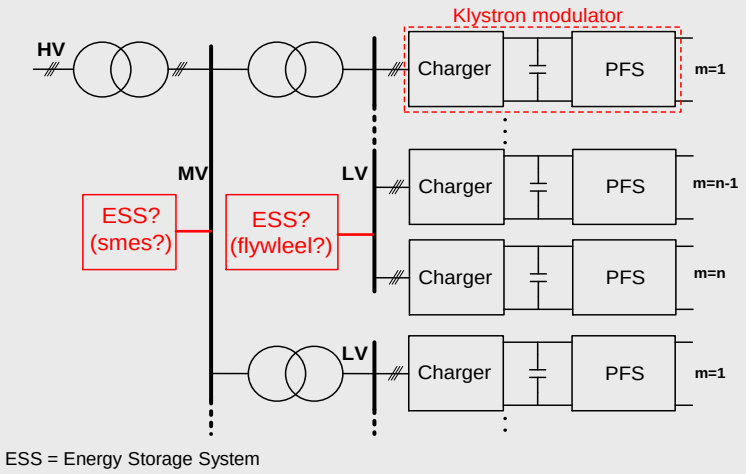
CERN coordinates the R&D program



Modulators general description

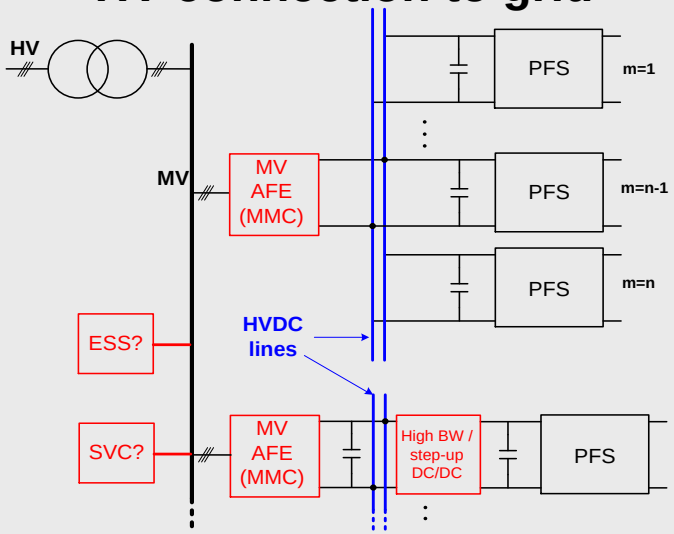
- Several methods for utility grid connection / big impact on performances & cost

LV connection to grid



ESS = Energy Storage System

HV connection to grid



- During CLIC studies the following main questions/topics will be addressed:
  - Is it possible to produce the specified voltage pulse?
  - Fully solid state vs. transformer based solutions…who's best?
  - What is the influence of utility grid voltage selection vs. performances?

R&D partners

- Survey of European Universities and institutions

	Application			PFS Development			Capacitor Charger Development	
Universities	**HV**	**short pulses**	**Long pulses**	**pulse Transfo**	**bouncer**	**SW stack**	**AFE**	**Resonant topologies**
Strathclyde University (UK)	☑	☑						
Loughborough University (UK)	☑	☑		☑		☑		
Ecole Polytechnique Paris	☑	☑						
Research Centre Karlsruhe (DE)	☑	☑	☑			☑		☑
Université de Pau (FR)	☑	☑				☑		
Eindhoven (NL)	☑	☑		☑		☑		
Oxford (UK)	☑			☑				
EPFL (CH)							☑	☑
ETH (CH)	☑	☑	☑	☑	☑	☑	☑	☑
Nottingham (UK)	☑		☑	☑		☑	☑	☑
Institutions	**HV**	**short pulses**	**Long pulses**	**pulse Transfo**	**bouncer**	**SW stack**	**AFE**	**Resonant topologies**
Desy (DE)	☑	☑	☑		☑	☑		☑
PSI (CH)	☑	☑				☑		
ESS (SE)	☑		☑					

ETH Zürich is the only University/Institution having proven experience in all requested domains. The quality of R&D and realizations is also the highest!

R&D partners

- Proposed & qualified partner
  - **ETH Zürich**
  - Expertise in all fields (chargers, grid, HV, pulse transformers, bouncer circuits)
  - Hold enough competencies to optimally design, assemble test and **deliver a full power CLIC klystron modulator**
  - Ready to scientifically and technically COLLABORATE with CERN
  - Already requesting third party funding (Fond National Suisse) – Good chances for succeeding!

R&D partners

- Proposed & qualified partner
  - **LAVAL University, Canada**
  - Expertise in pulsed transformers & general magnetic devices and in long pulse klystron modulators
  - Ready to scientifically and technically COLLABORATE with CERN (small collaborations already worked effectively)
  - Already requesting third party funding (CFI)

R&D partners

- Proposed & qualified partner
  - **SLAC, USA**
  - Experienced team has completed an ILC demonstrator following ~10years R&D, now available for CLIC studies
  - R&D based on oil-free, transformer-free, marx topology
  - Lower R&D risk due to previous experience
  - Will permit CERN to validate SLAC technology
  - Design would be licensed for CERN use

R&D partners

- Proposed & qualified partner
  - **Nottingham, UK**
  - Experienced Laboratory on modular active front ends
  - Ready to scientifically and technically COLLABORATE with CERN
  - Third part funding available
  - Ready to collaborate with other partners in CLIC studies (something required for their part of work)

R&D partners

- **Each partner explores a topologically different solution**
- **After experimental validation of different solutions CERN selects the final one**

ETHZ
- MMC topology
- HV AC side

LAVAL
- Modular
- LV AC side

SLAC
- LV AC side

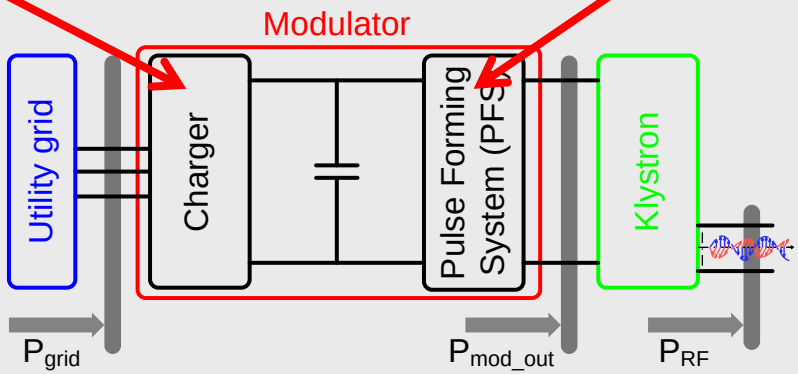
Nottingham
- Modular
- HV AC side
- Considers grid layout

CERN final topology selection

ETHZ
- Parallel Modularity
- LV DC Bus (1-3kV)

LAVAL
- Series Modularity
- HV DC Bus (5-20kV)

SLAC
- Series Modularity
- LV DC Bus (1-3kV)



Collaboration Strategy

- ETHZ
  - Phase 1 & 2:
    - delivery of full power modulator in 2015
- SLAC
  - Phase1:
    - delivery of reduced power demonstrator in 2013
- LAVAL
  - Phase1:
    - delivery of reduced power demonstrator in 2015
- Nottingham
  - Phase1:
    - delivery of reduced power demonstrator in 2014

Collaboration Strategy

- Following development phase from SLAC, LAVAL and Nottingham
  - Phase 2:
    - Choose technical solution depending on technical success
      - LAVAL (a) or
      - Nottingham+LAVAL (b) or
      - LAVAL+SLAC (c) or
      - Nottingham+SLAC (d)
    - Preference for (a) or (b) due to SLAC manpower costs…

Tentative Schedule

- Preparation of contracts
  - ETHZ
    - Letter of intent now (1 Ph.D. started in May)
    - Finance Committee in June.
  - LAVAL
    - Summer 2012 (2 Ph.D. already started).
  - SLAC
    - Finance committee in September 2012?… Issue of manpower cost…
  - Nottingham
    - Summer 2012

Summary

- CLIC DB Modulator powering presents several significant technical challenges
  - Efficiency, reproducibility, availability, power quality
- To ensure a successful R&D phase, several collaborators with appropriate experience have been selected
  - ETHZ (CH), LAVAL (CA), Nottingham (UK), SLAC (US)
- Two full specification R&D systems will be supplied for validation and use in the CLIC0 Injector
  - Three commercial ‘reduced specification’ systems will be purchased to allow the facility to start-up, also demonstrating industrial state-of-the-art