Diamond RF Status
(RF Activities at Daresbury)

Mike Dykes

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  - What does it do?
- Diamond
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ASTeC

ASTeC Accelerator Science and Technology Centre

ASTeC was formed in 2001 as a centre of excellence in the field of accelerator science and technology, carrying out programmes of research and design in support of CLRC's activities.

http://www.astec.ac.uk

ASTeC-What is it?

- Four Groups
  - Accelerator Physics
  - RF Systems (inc Diagnostics)
  - Vacuum Science
  - Ids and Magnets

ASTeC-What does it do?

- Projects
  - Support and development of the SRS
  - Design and procurement for DIAMOND
  - Feasibility of 4GLS and FELs for future light sources
  - Partnership with leading Linear Collider Projects
  - Funds High Power Proton Accelerator and Laser Accelerator research

SRS Development

- Replaced 'old' 50 Hz klystron 50 kV, 15 A DC power supply
- Modular switched mode 52 kV 9 A power supply from THALES Communication

SRS Development

SRS Development

SRS Development

4GLS

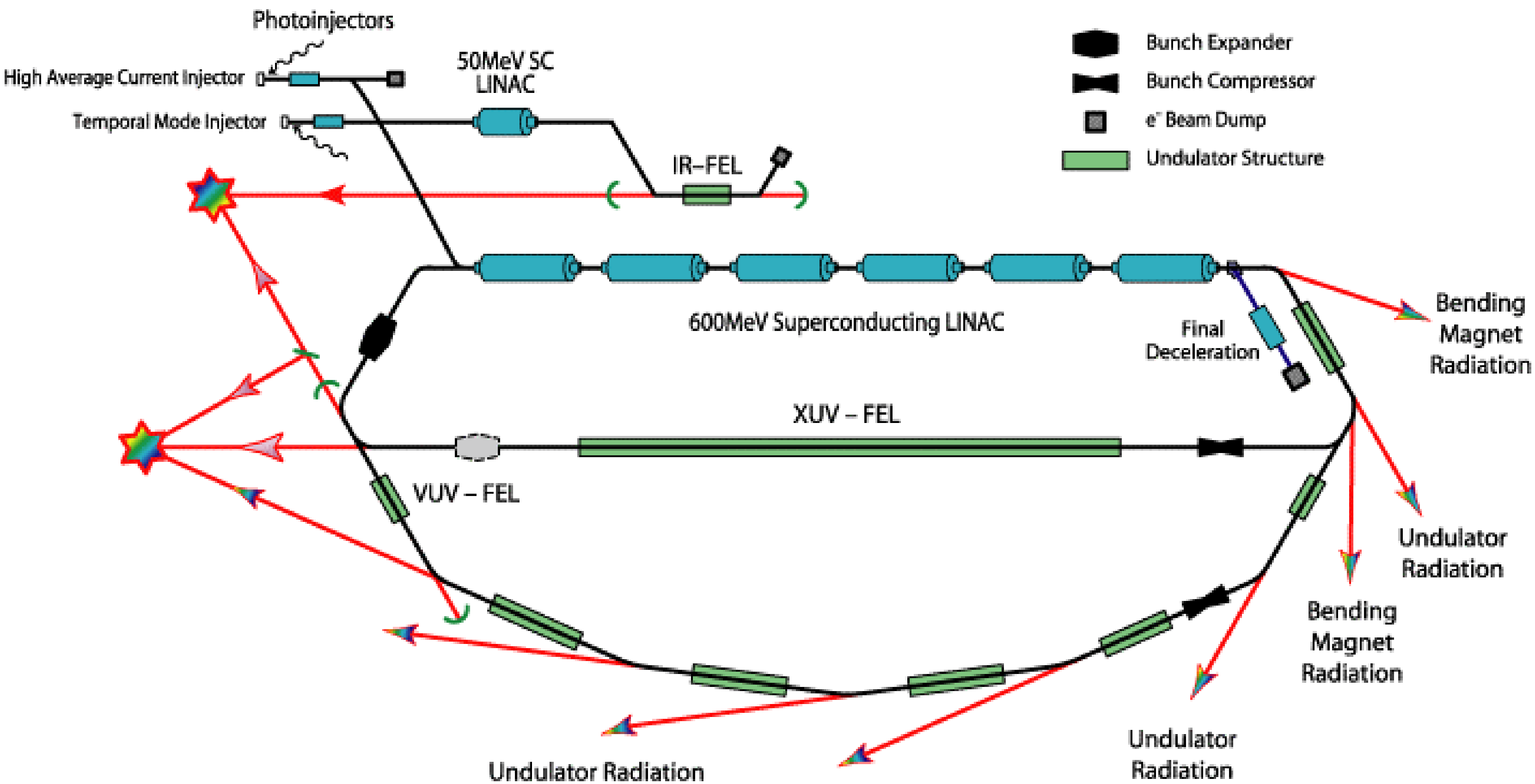
- Is a low energy ring; radiation from a variety of undulators.
- An XUV SASE free electron laser – the XUV-FEL.
- A cavity-based VUV free electron laser – the VUV-FEL.
- An integrated infra-red free electron laser – the IR-FEL.

4GLS

- effectively infinite electron beam lifetime
- very small emittance
- very short pulses
- pulse structure flexibility

www.4gls.ac.uk

4GLS



Photoinjectors
High Average Current Injector
Temporal Mode Injector
50MeV SC
LINAC
IR–FEL
Bunch Expander
Bunch Compressor
e⁻ Beam Dump
Undulator Structure
600MeV Superconducting LINAC
Final
Deceleration
Bending
Magnet
Radiation
XUV – FEL
VUV – FEL
Undulator
Radiation
Bending
Magnet
Radiation
Undulator
Radiation
Undulator Radiation

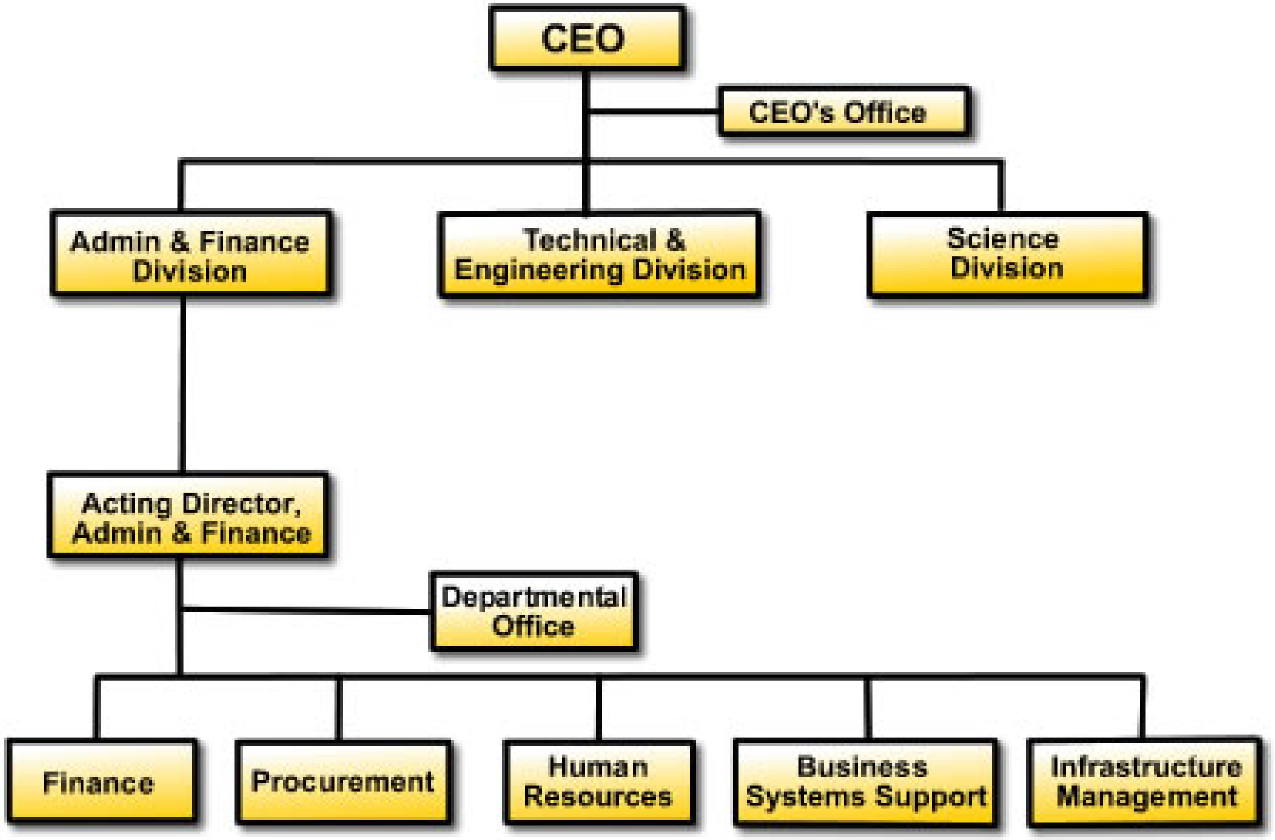
Diamond

- Diamond run by a joint venture company, Diamond Light Source Limited (DLS)

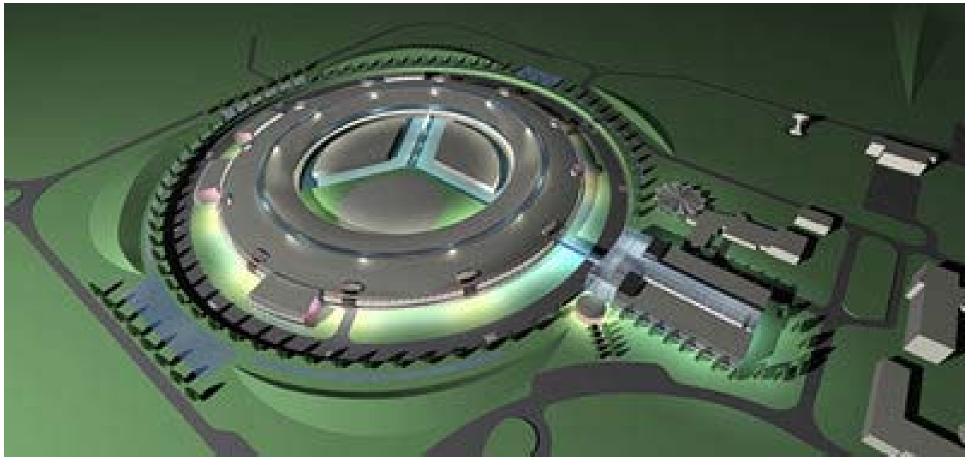
www.diamond.ac.uk

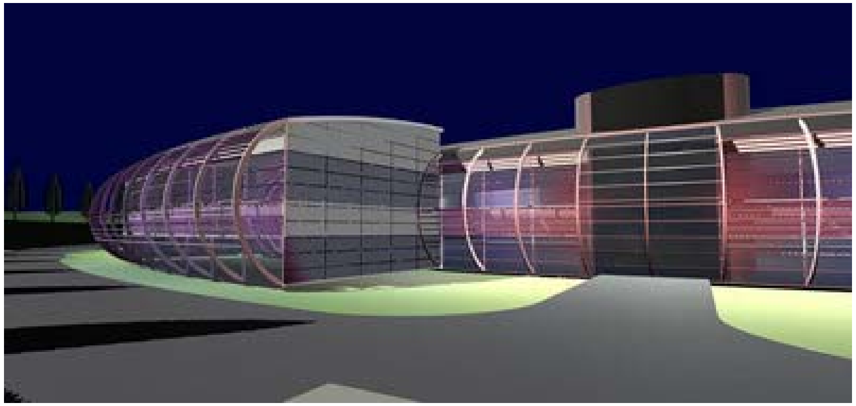
- Shareholders
  - Council for the Central Laboratories of the Research Councils (CCLRC) 86%
  - Wellcome Trust 14%
- Construction cost of £235M at September 2001 prices

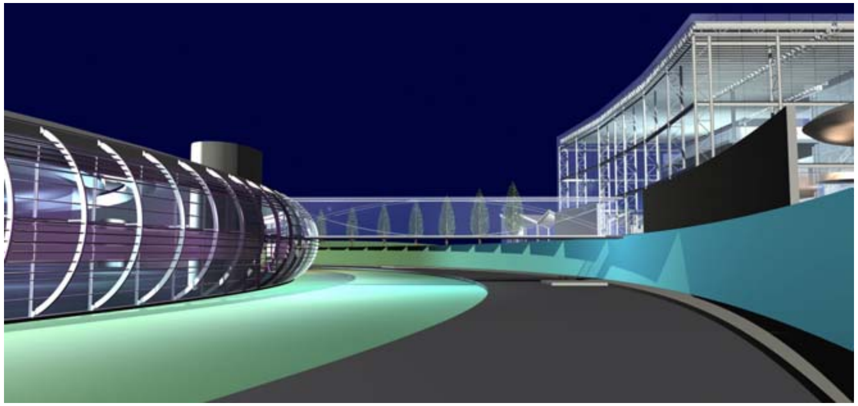
Diamond Organogram



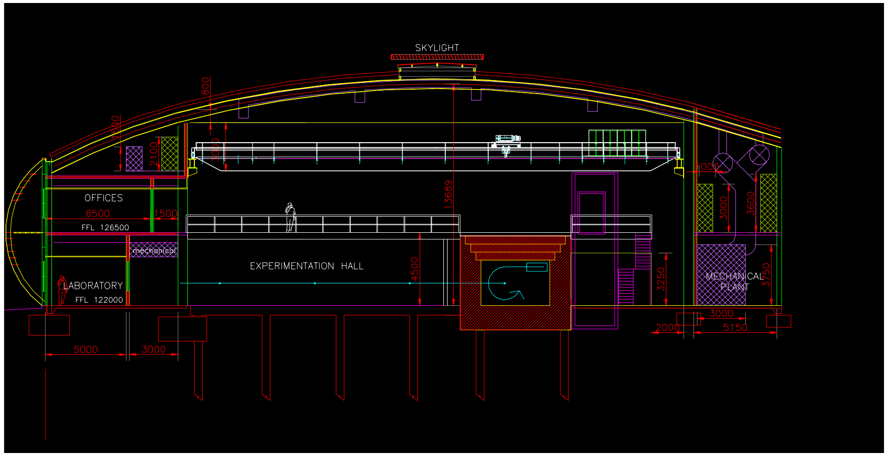
Building

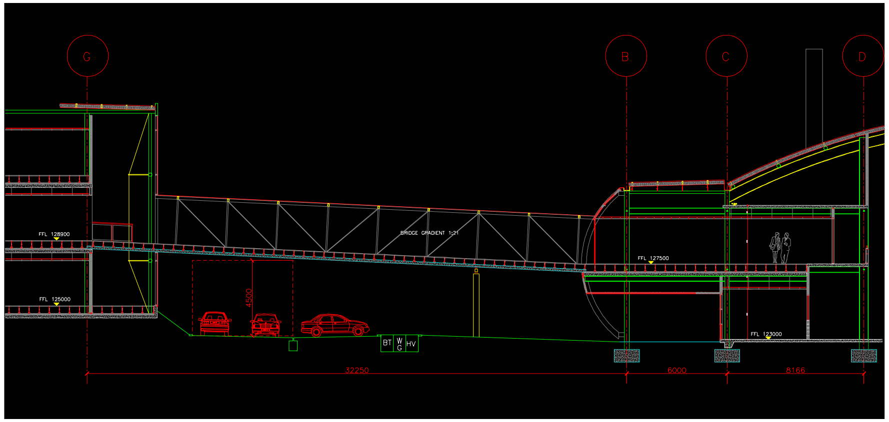






Building Detail





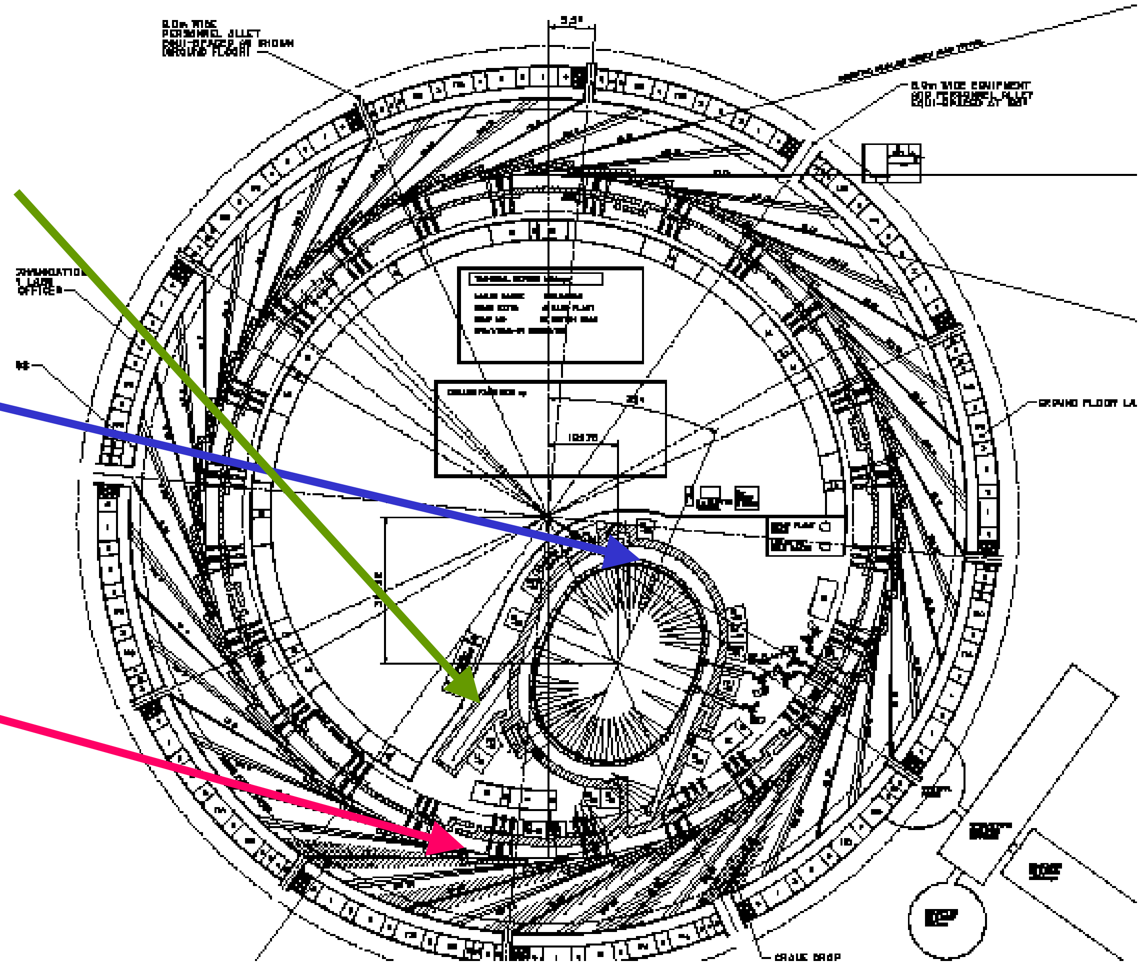
Courtesy of Crispin Wride Architectural Design Studio, JacobsGibb Ltd.

Layout

Linear accelerator (Linac) :
100 MeV energy

Booster synchrotron :
100 MeV - 3 GeV
158 m in circumference

Storage Ring :
3 GeV energy
562 m in circumference



Programme

Linac	Issue tender	Oct. 14th ‘02
	Place order	Dec. 13th ‘02
	Install	Aug. ‘04 - Apr. ‘05
	Commission with beam	May. ‘05 – Jul. ‘05
Booster	Tender for main components	Feb. ‘03
	Order main components	Jun ‘03
	Install	Aug. ‘04 – Aug. ‘05
	Commission with beam	Sep. ‘05 - Dec. ‘06

Programme (biased to RF)

Storage Ring	Start to order main components	May. '03
	Install Cavities	May. '05 - Sept. '05
	Power test cavities	Sept. '05 - Nov. '05
	Install & Test Cryogenics	Dec. '04 - May. '05
	Commission with beam, no IDs	Jan. - Mar. '06
	Install IDs	Apr. '06
	Commission with IDs and FE	May – Jul. '06
Beamlines	Install beamlines	Jan. '05 - Aug. '06
	Commission with beam	Aug. '06 - Dec. '06
Diamond facility	Start of operations	22nd Jan. 2007

Recruitment

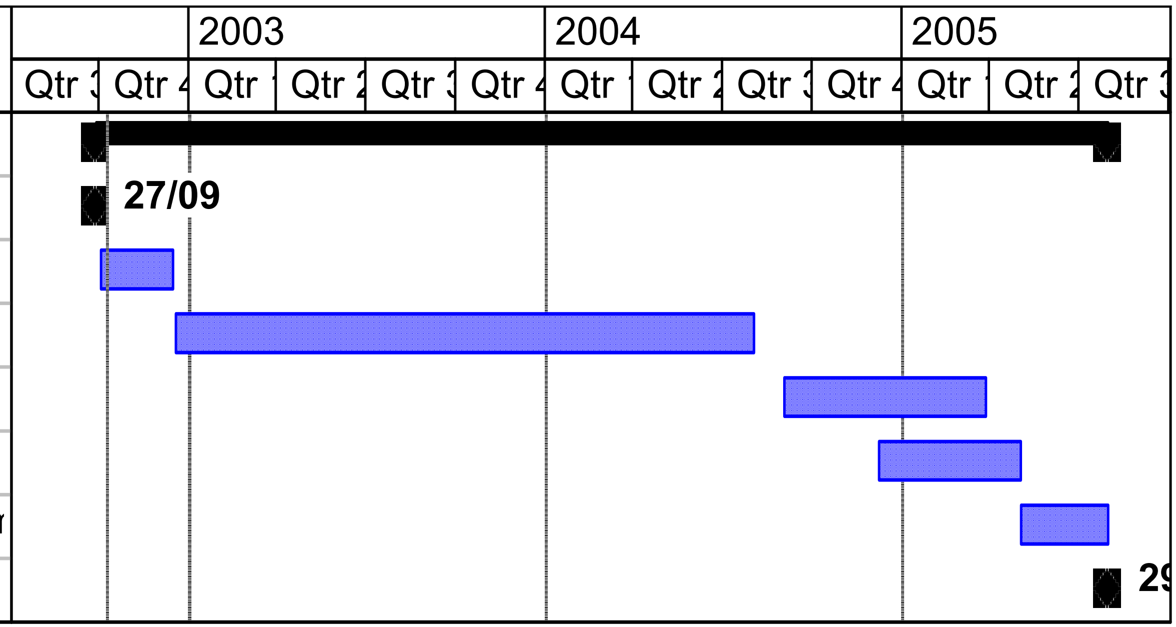
DLS0003	Group Leader for accelerator physics
DLS0004	Group Leader for d.c. and pulsed magnets
DLS0005	Group Leader for insertion devices
DLS0006	Group Leader for r.f. and linac systems
DLS0007	Group Leader for beam diagnostics and feedback
DLS0008	Accelerator physicists
DLS0009	Vacuum scientists and engineers
DLS0010	Vacuum technicians
DLS0011	Radiofrequency and linear accelerator physicists/engineers
DLS0012	Physicists/engineers for magnet systems
DLS0013	Physicist for insertion device systems
DLS0014	Beam diagnostic physicists/engineers
DLS0015	Control system electronics engineers
DLS0016	Control system software engineers
DLS0017	Control system relational database software engineer
DLS0018	Mechanical project engineers
DLS0019	Mechanical design engineers
DLS0020	Electrical project engineers
DLS0021	Electrical design engineers
DLS0022	CAD/CAE systems manager
DLS0023	Power supply engineers
DLS0024	Health physicists

Diamond Linac Scope

- The Linac will be procured as a single turn-key system.
- Various pieces of equipment will be purchased by DLS and free-issued to the Linac Supplier, including beam diagnostic, control system and vacuum system equipment.

Diamond Linac Timeline

ID	Task Name
1	**Linac**
2	Tech. Spec. ready
3	CFT & order
4	Construction
5	Installation
6	Test
7	Linac and LTB beam comm
8	Linac Ready



Multi-bunch

Parameter	Specification
Bunch train length (μs)	0.3 to 1.0
Charge in bunch train (nC)	>3
Energy (MeV)	>100
Pulse to pulse energy Variation (%)	<0.25
Relative energy spread (%)	<0.5 (rms)
Norm. emittance (1σ) (πmm mrad)	<50
Repetition rate (Hz)	1 to 5
Pulse to pulse time jitter (ps)	<100

Single Bunch

Parameter	Specification
Pulse full width (ns)	<1
Charge in bunch train (nC)	>1.5
Energy (MeV)	>100
Pulse to pulse energy Variation (%)	<0.25
Relative energy spread (%)	<0.5 (rms)
Norm. emittance (1σ) (πmm mrad)	<50
Single bunch purity (1%)	1
Repetition rate (Hz)	1 to 5
Pulse to pulse time jitter (ps)	<100

Top-up

Top-up operation may involve two kinds of duty cycle:

1. Single bunches, or single multi-bunch trains, repeated at intervals of 10-300 sec.

2. Sequences of single bunches, or multi-bunch trains, at a repetition frequency of 1-5 Hz, for 1-10 sec, repeated at intervals of 1-5 min.

Tenderers

- Advanced Energy Systems
- ACCEL Instruments
- THALES/EuroMev/Danfysik/OI
- LINAC Technologies

Diamond Booster RF

- See Andy Moss Talk

Diamond Storage Ring RF

- Basic Machine Parameters
- RF parameters
- Choice of cavity
- Cryogenics
- Choice of Amplifier
- Layout

Basic Machine Parameters

Electron beam energy (Storage	3.0 GeV
Storage ring circumference	561.6 m
No. of cells	24 (6 fold symmetry)
Electron beam current	300 mA
Minimum beam lifetime	10 hours
Emittance - horizontal	2.7 nm-rad
Emittance - vertical	0.03 nm-rad
No. of Insertion Devices (IDs)	Up to 22
Free straight lengths for IDs	18x5 m, 6x8 m
ID radiation apertures	Up to 10 mrads H, 1
Dipole radiation apertures	Up to 20 mrads H, 3
ID minimum gap	10 mm
Building diameter	235 m

RF Parameters

Energy (GeV)	3	3
Current (mA)	300	500
Energy Acceptance(%)	4	4
Loss/Turn (MeV)*	1.79	1.79
Acceleration Voltage (MV)	4.0	4.0
Beam Power (kW)	536	893
Number of SRF Cavities**	2/3	3
Total SRF Power (kW)	590	982

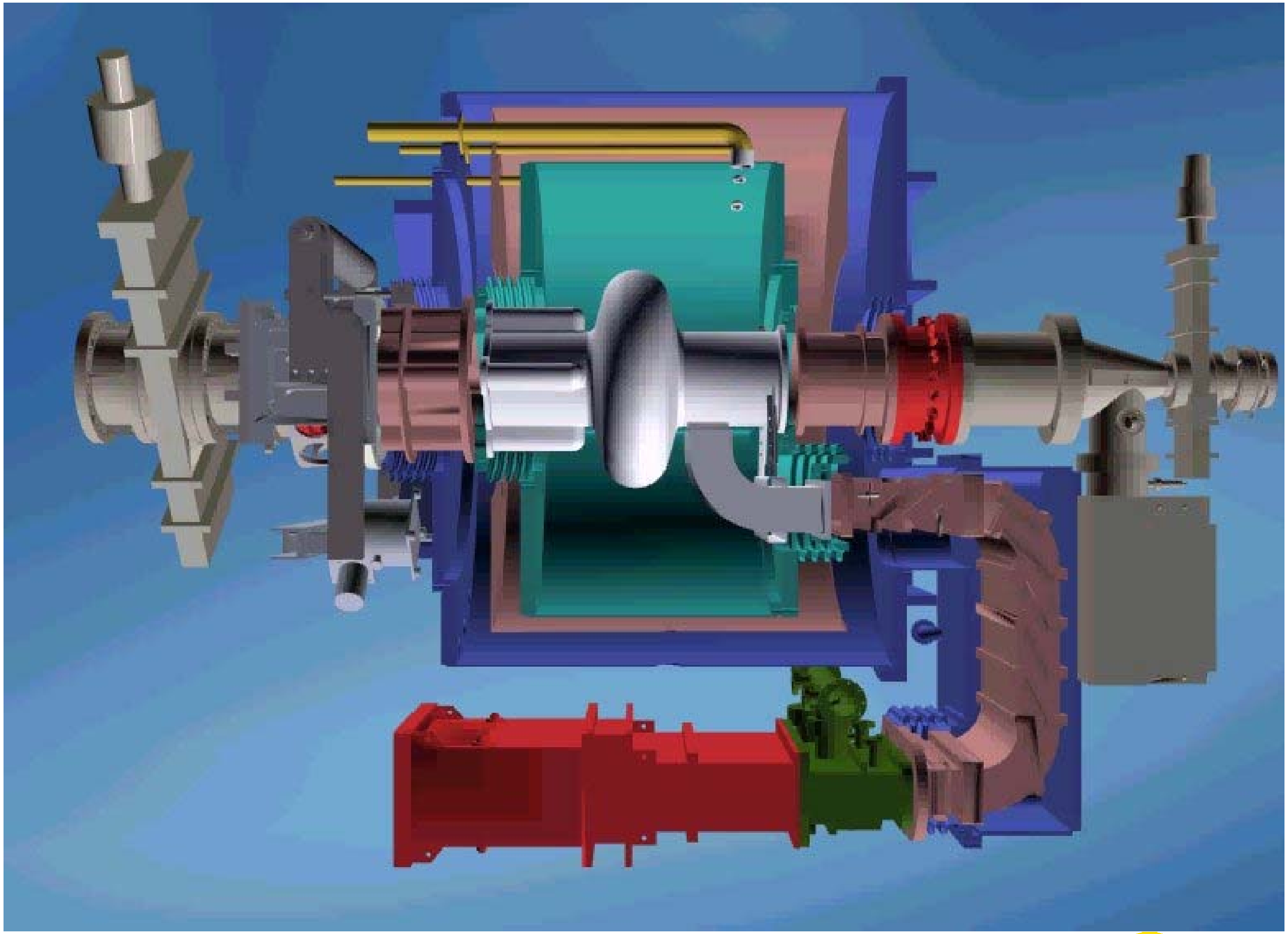
*Assuming full compliment of IDs

**Assuming 300 kW maximum power through coupler

Choice of Cavity

• Normal Conducting	NO
• Superconducting	YES
• Frequency	500MHz
• Cornell	?
• KEKB	?

Cornell



Cornell

KEKB

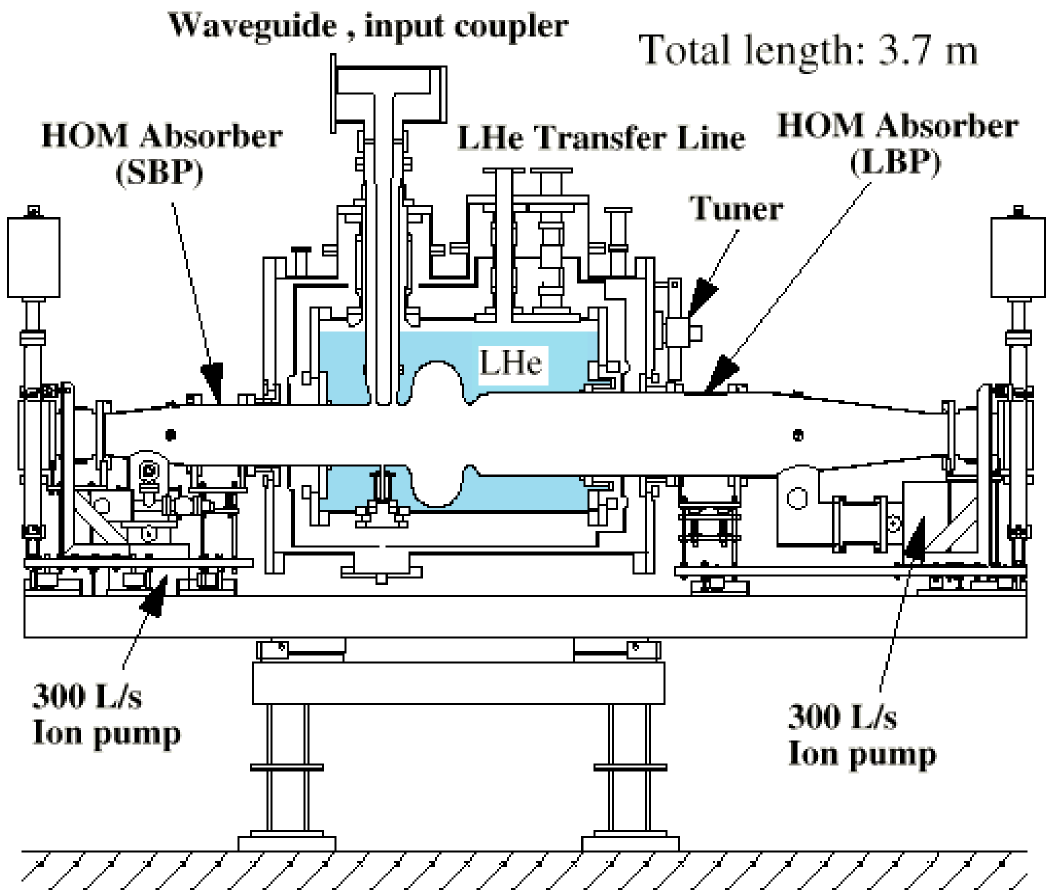
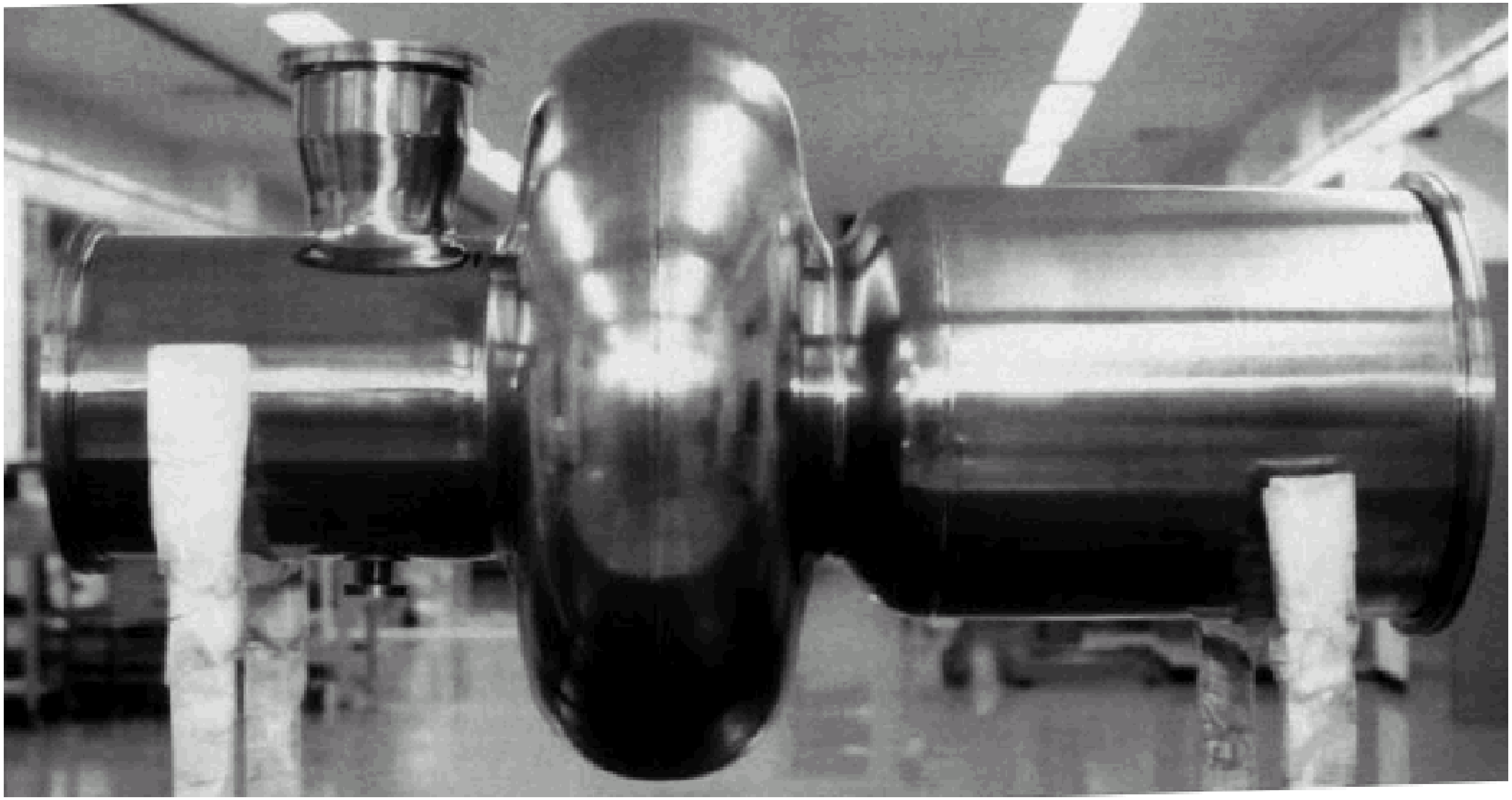


Figure 1: Superconducting cavity module for KEKB

KEKB



Threshold Currents

	Cornell	KEKB
V_{acc}/cell (MV)	2.5	2
Gradient (MV/m)	8.33	6.79
TM_{010} R/Q (Ω)	44.5	46.5
Length (m)	3	3.7
Max $R^{\prime\prime}_{HOM}$ (Ω)	200	1000
Max $R^{\perp}_{HOM}$ (kΩ/m)	2.5	0.85
$I^{\prime\prime}_{th}$ (Amps)	28	5.6
$I^{\perp}_{th}$ (Amps)	6.66	19.6

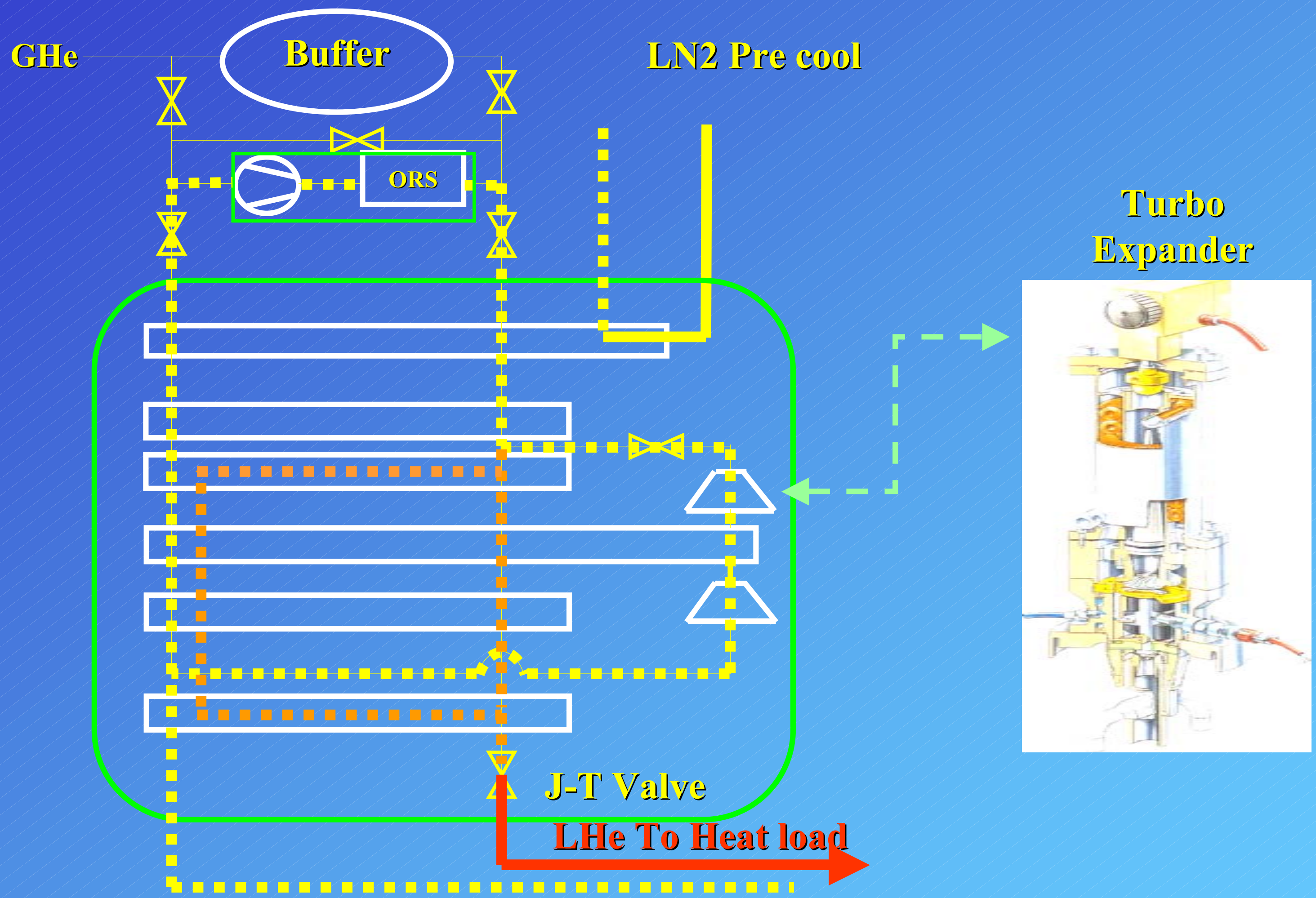
Cryogenics

- Operate at 4.5^{O} K
- Heat load from either cavity is approximately the same ~ 100 W
- Losses in delivery system ~ 50 W
- Designing for 50% overcapacity
- System ~ 500 to 600 W

Cryogenics

- Multiple screw compressors (280 kW)
- Oil removal system
- Gas handling system
- Pre-cooled LN_2 liquifier (220 L/h)
- 2000 L Dewar
- Distribution valve box
- Cryogen Transfer lines

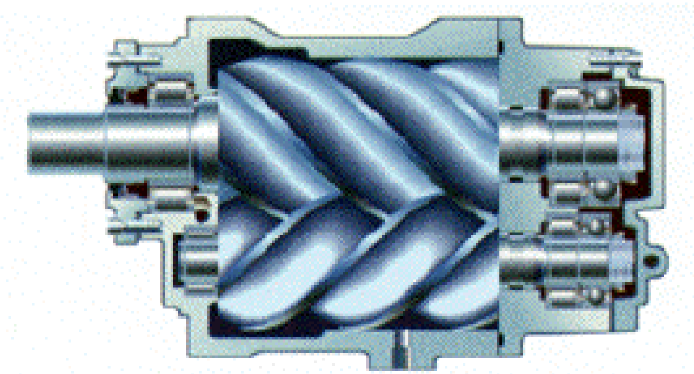
Cryogenics

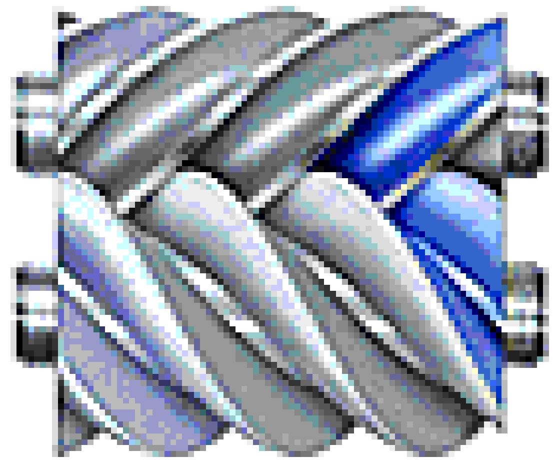

GHe
Buffer
LN2 Pre cool
ORS
Turbo
Expander
J-T Valve
LHe To Heat load

Cryogenics

Cryogenics

Screw compressor





Choice of Amplifier

- One Amplifier per cavity
- Day 1: Two cavities and two amplifiers, cryogenics for 3 cavities
- 2nd Phase: Install 3rd cavity and amplifier
- Finally: Up to 300 kW per cavity (500 mA with full compliment of Ids)

Klystron or IOT

Klystron

- Several bunching cavities
  → Long device

- Considerable velocity spread
- Maximum gap voltage determined by the slower electrons
- Rapid reduction in efficiency for reduced output power
- High Gain

IOT

- No bunching cavities
  → Shorter device

- Little velocity spread
- Higher gap voltage
  → Increased output power
  → Higher efficiency

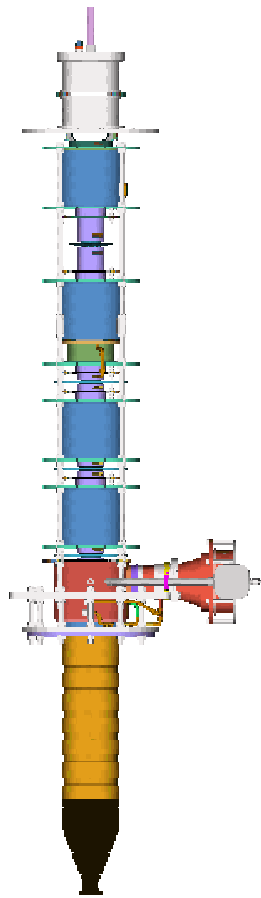
- Efficiency is approximately constant for reduced output power
- Low Gain

Klystron or IOT

Klystron

500 MHz
250 kW
Peak Efficiency = 65%

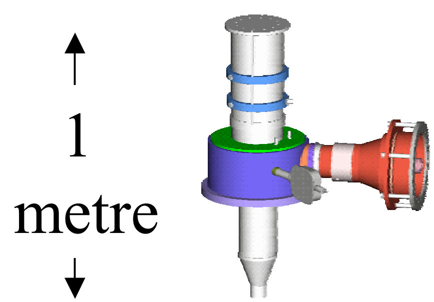
Efficiency at 200 kW ~ 60%



IOT

500 MHz
250kW
Peak Efficiency ~ 75%

Efficiency at 200 kW ~ 74%



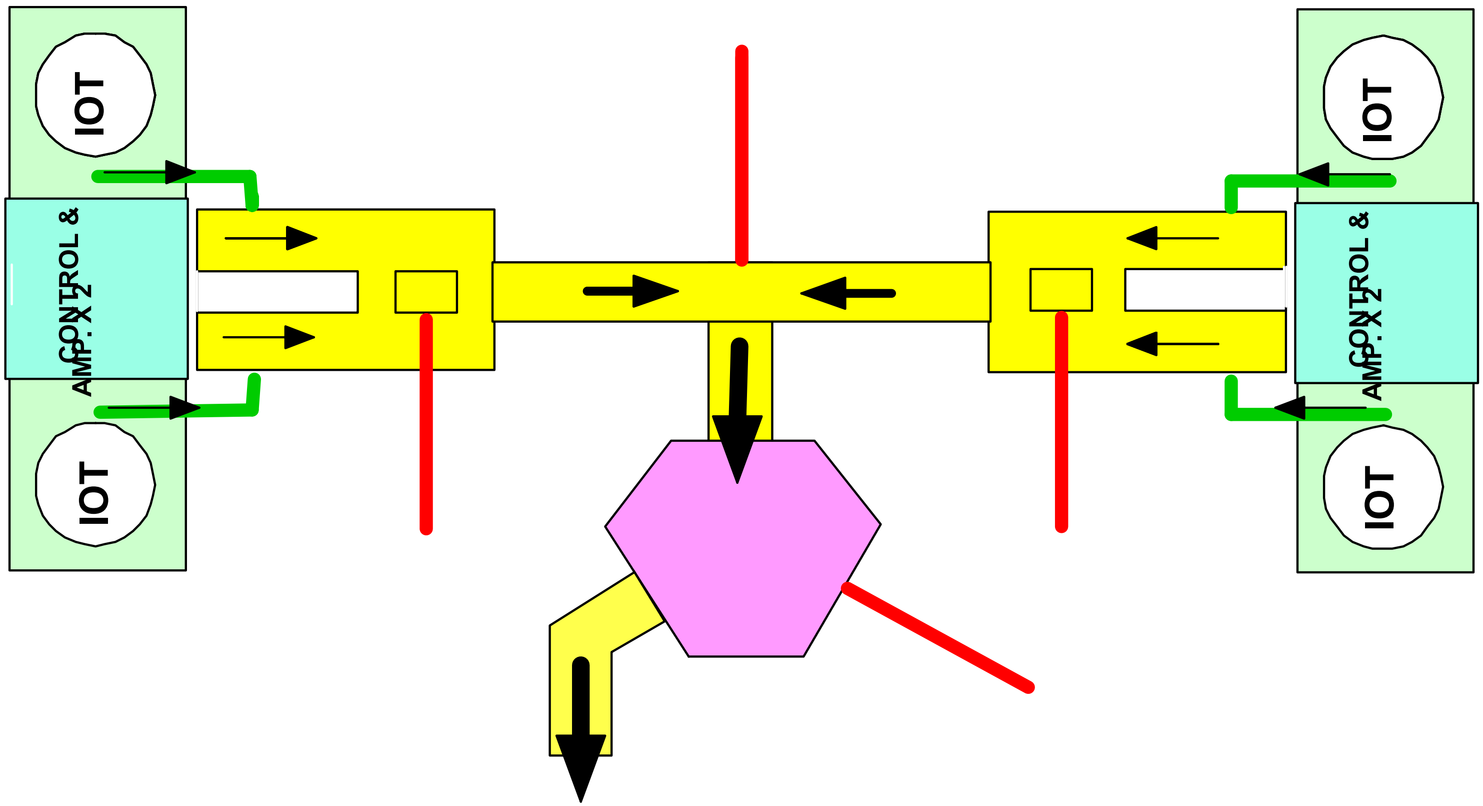
Klystron or IOT

- Superpower Single Beam Klystron market
- Development Time and Cost of Superpower IOT
- Advantages of using Television IOTs
- Development of suitable Power Converters

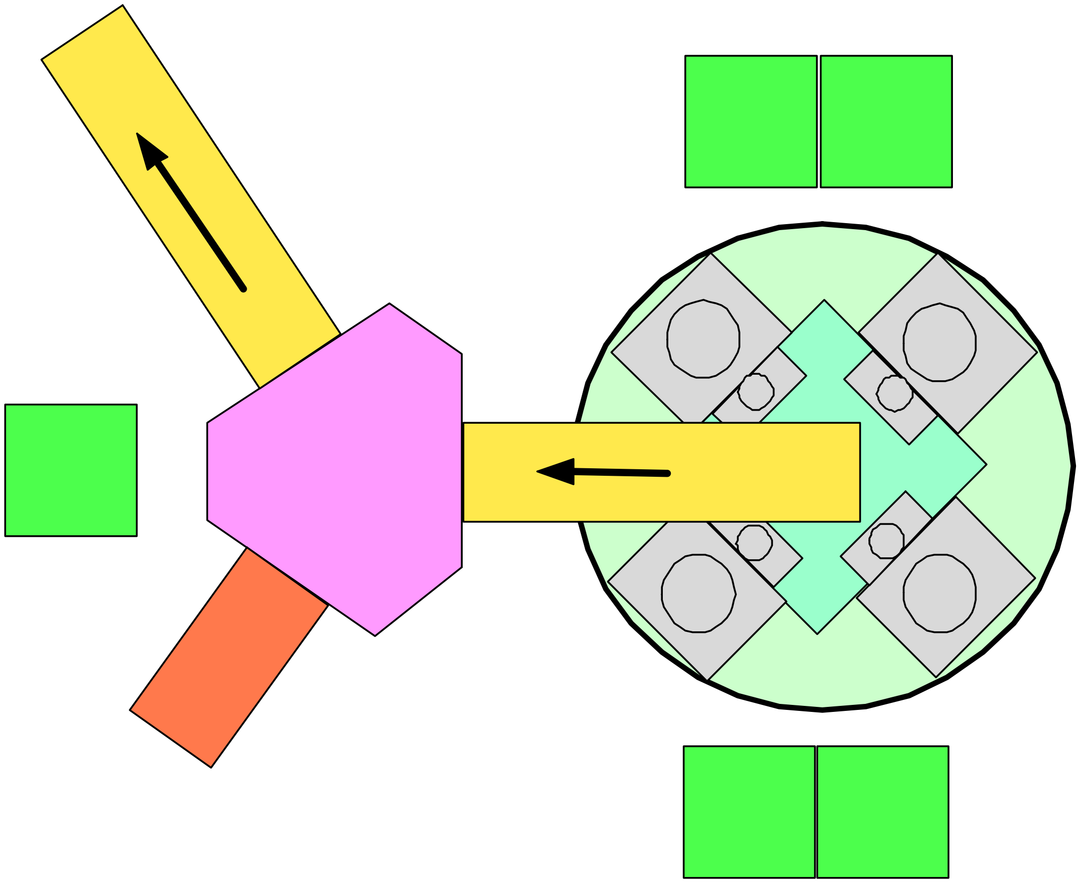
Television IOTs

- Peak output power > 130 kW
- CW power > 80 kW
- Wide band ~ 470 - 810 MHz
- External Cavities
- Many Manufacturers
- For example E2V make ~ 12 per week
- Efficiency only 50%

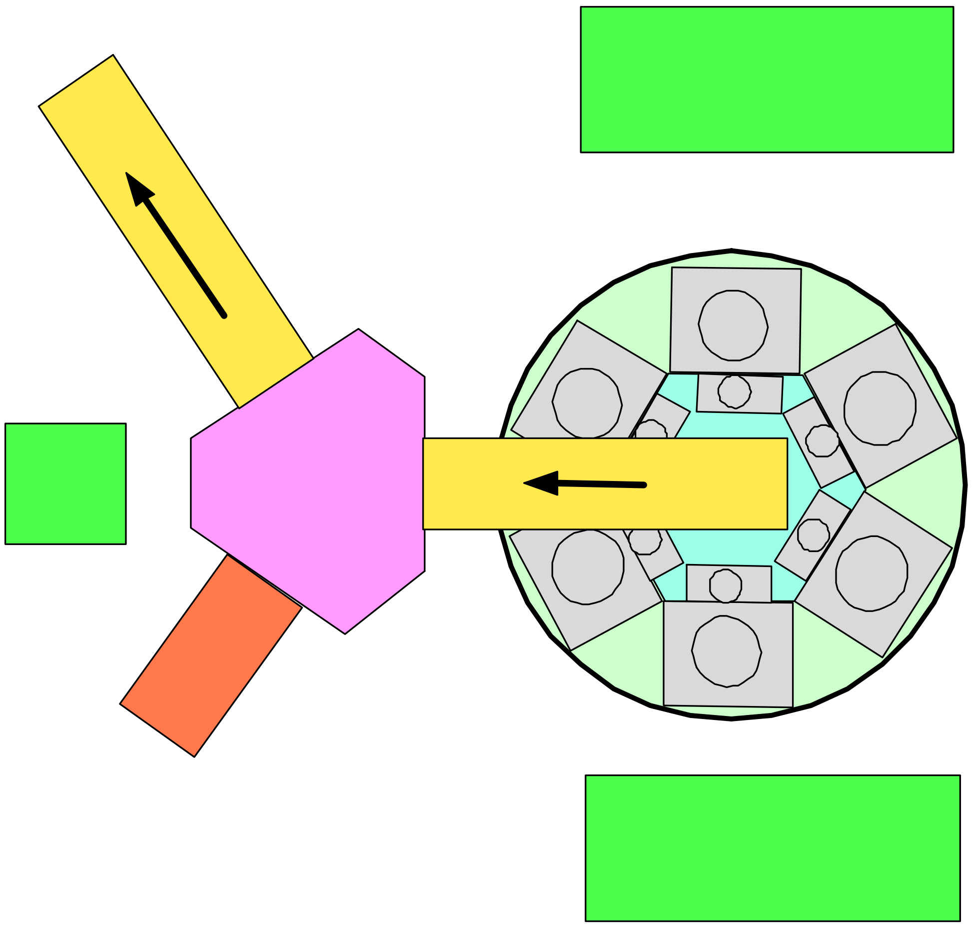
Four IOTs Combined



Four IOTs Combined



Six IOTs Combined

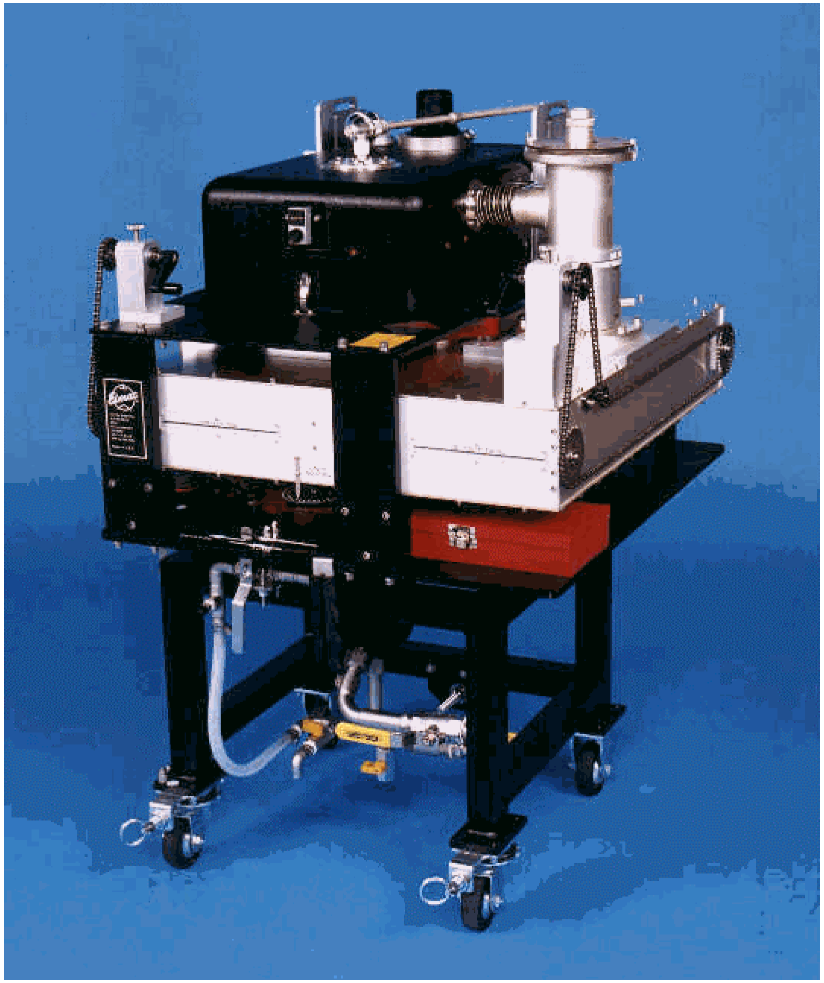


Six IOTs Combined

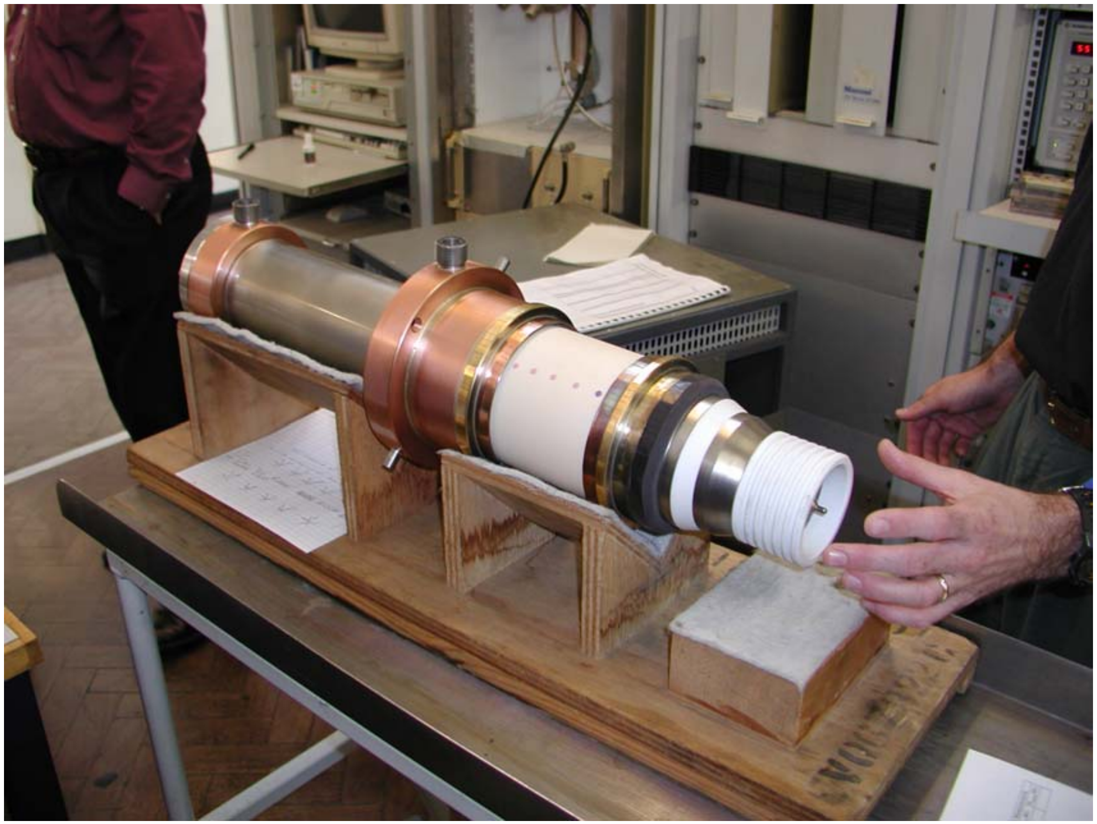
Double-tuned IOT cluster

Central Frequency (MHz)	500
Beam Voltage (kV)	34
Grid Bias Voltage (V)	-75
Output Power (kW)	306.4
Efficiency (%)	72.6
Gain (dB)	25.1

IOTs - CPI



IOTs – E2V



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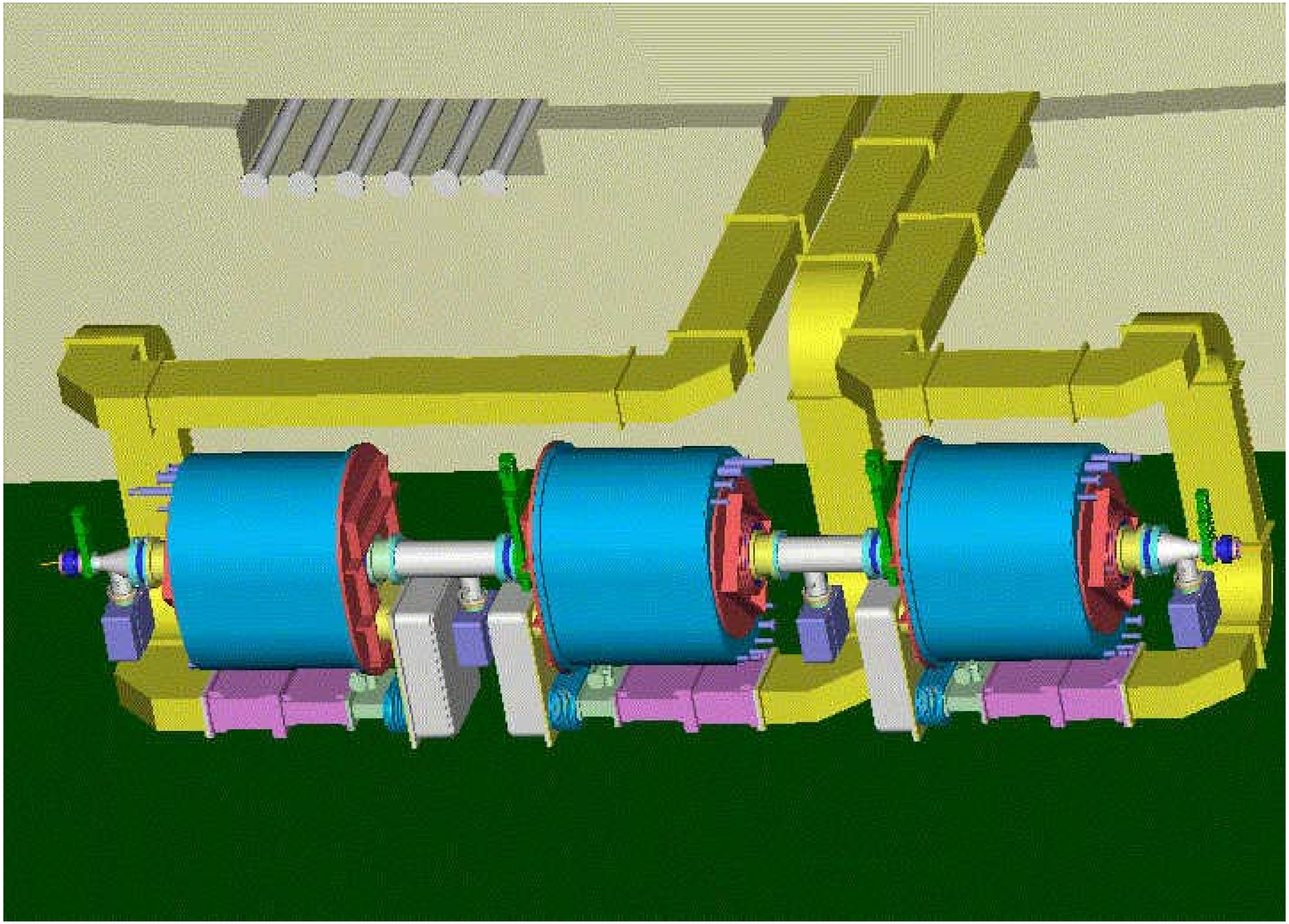
accelerator science and technology centre

diamond

IOTs - THALES

Layout



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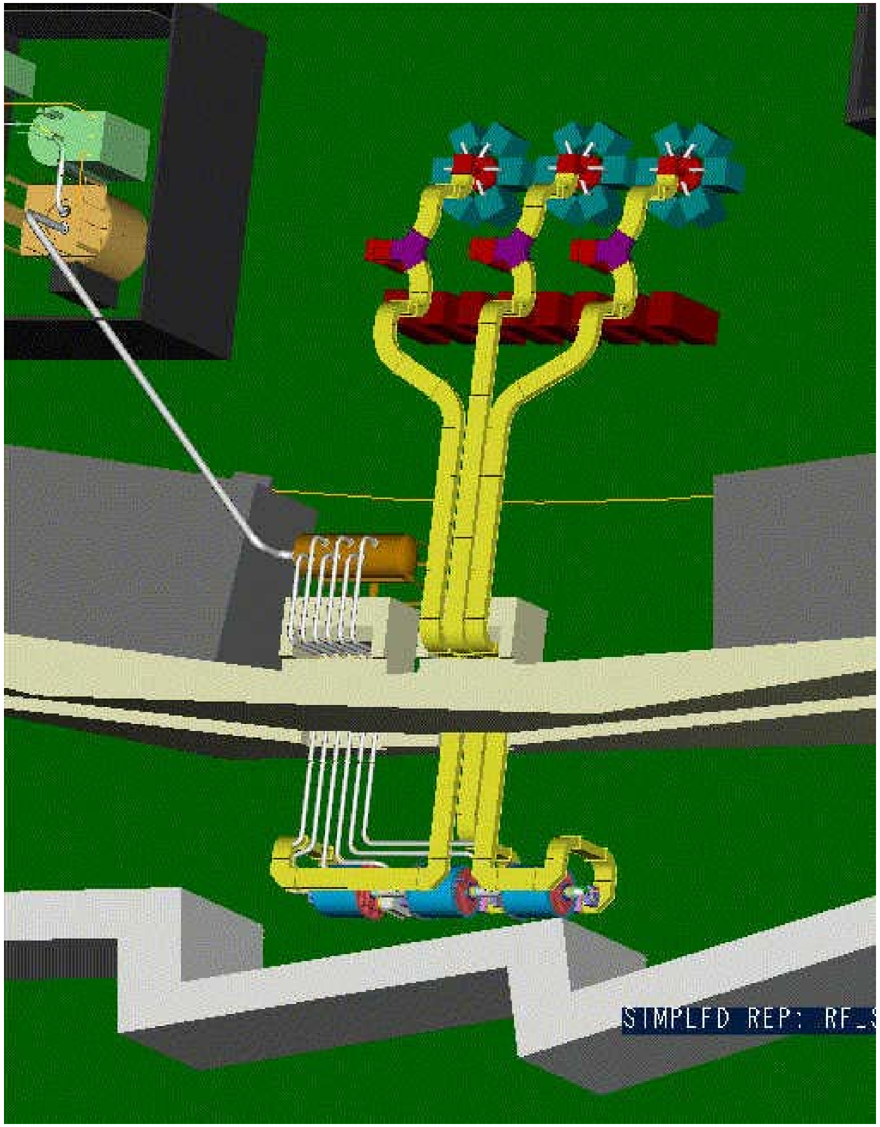

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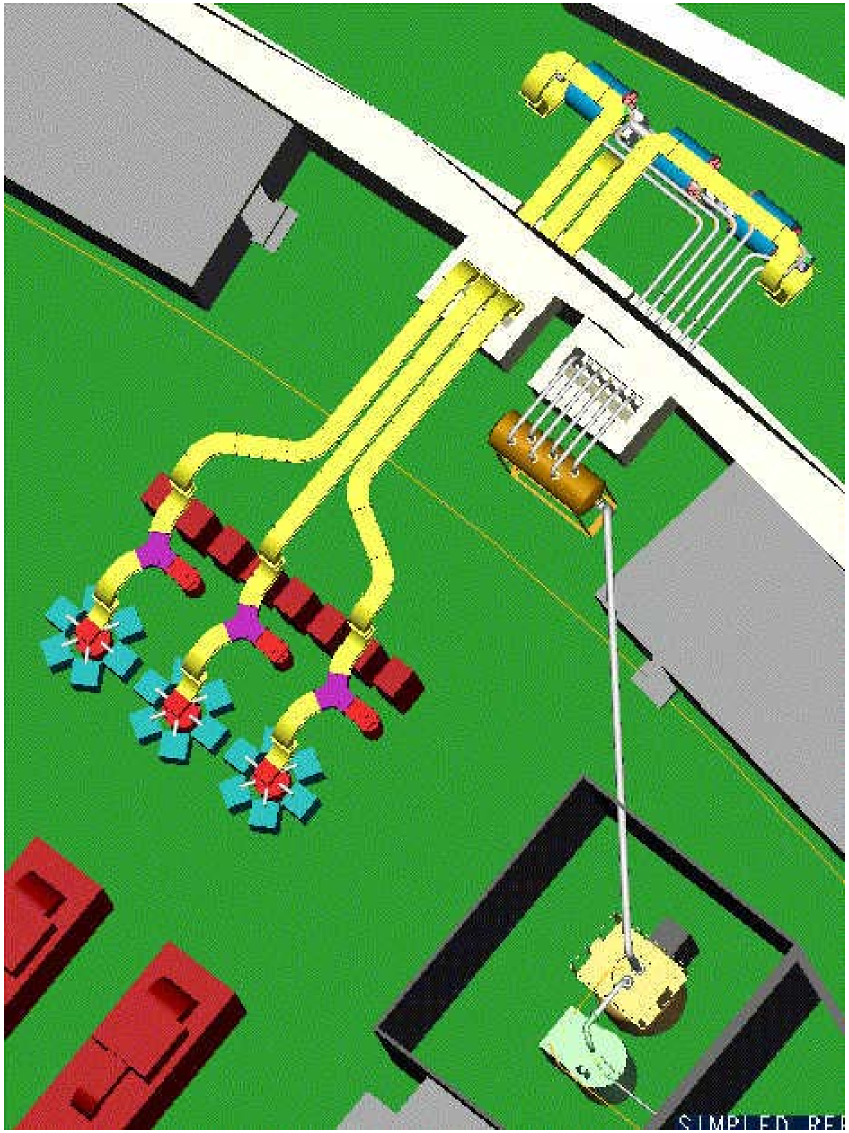

Mike Dykes, 6th ESLS RF Meeting.
Villigen 28th &29th November 2002

ASTeC
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diamond

Summary

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  - 4GLS
- Diamond
  - Project Status
  - Linac
  - Storage Ring RF