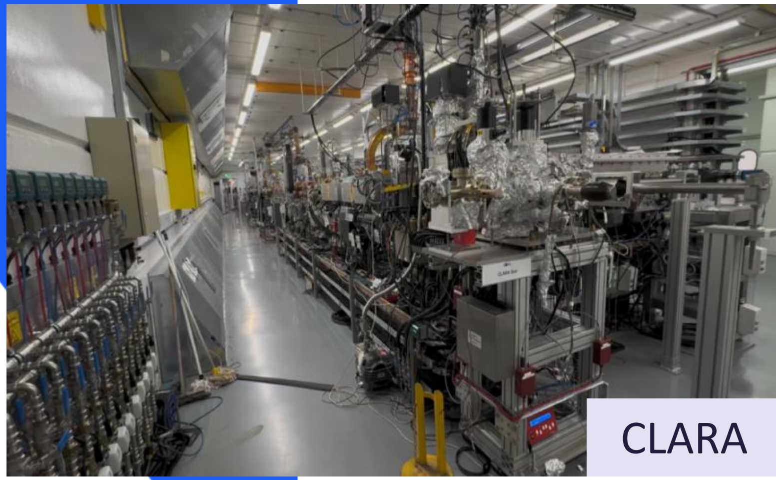
Science and Technology Facilities Council

ASTeC

Making a brighter future through advanced accelerators



Four Decades in Accelerators: A Personal Journey

Deepa Angal-Kalinin
STFC Daresbury Laboratory

IoP Prize Talk
PAB Conference, Lancaster, 30th June 2026

How it all began…..

- After completing my Master's in Physics at Pune University, I faced a choice: pursue a PhD position or join the Bhabha Atomic Research Centre (BARC), Department of Atomic Energy (DAE) Training School.
- I chose BARC.

- It was an intense year covering all areas of DAE - with exams every Monday! Your final ranking determined your field.

- Fortunately, I secured a position in a new accelerator-focused centre in Indore.
  - That is how my journey in accelerator physics began.

"Final ranking opened a door to a field that would shape the next four decades of my life.."

Centre for Advanced Technology, Indore

(Changed to RRCAT in 2005)

- We began in a rather unusual way – in a palace.
- Directorate and accelerator beam dynamics section were initially placed in this beautiful palace.
- First quarters (accommodation) were ready for us to move in 1986.
- Over the next few years, laboratories and other amenities like school, sports facilities, dispensary, shopping complex, gardens were built.

"As young scientists, we had the rare privilege of helping build a new centre."

Computer Facility

Computer Facility

A sophisticated and modern computing facility is a necessity for a Research Centre like CAT. A Computer Centre has been established at CAT to cater to all computing needs of CAT.

Presently the Computer Centre has the following Hardware and Software facilities:

Hardware:

- Two 68020 based super mini UNIX machines, each with 4MB RAM, 500 MB hard disk, mag. tape, cartridge tape & 600 LMP printer. Each machine has 10 intelligent PC terminals installed all over CAT.
- Two drafting workstations based on PC/AT computer. Each has 2.5 MB RAM, 40 MB hard disk, EGA card, high resolution colour monitor, digitizer, plotter and mouse.
- Ten PC, XT's with 640 KB RAM, 20 MB hard disk and color Monitors.

CAT Newsletter, December 1988

A view of the computer facility

Computer Facility.

The computer network at CAT named CATNET consists of two super microcomputers (HORIZON-III) hooked to a local area network (LAN) based on standard ETHERNET with a data transfer rate of 10 M Bits/sec For connecting all future mainframe and mini-computers to this LAN , necessary coaxial cables have been laid underground all over CAT , Workstation and personal computers are connectetd to existing super micro-computers using serial line data communication at the speed of 9600 baud . Presently about twenty five personal computers and workstations distributed all over CAT are using CATNET to access online data bases , electronic mail and super microcomputers.

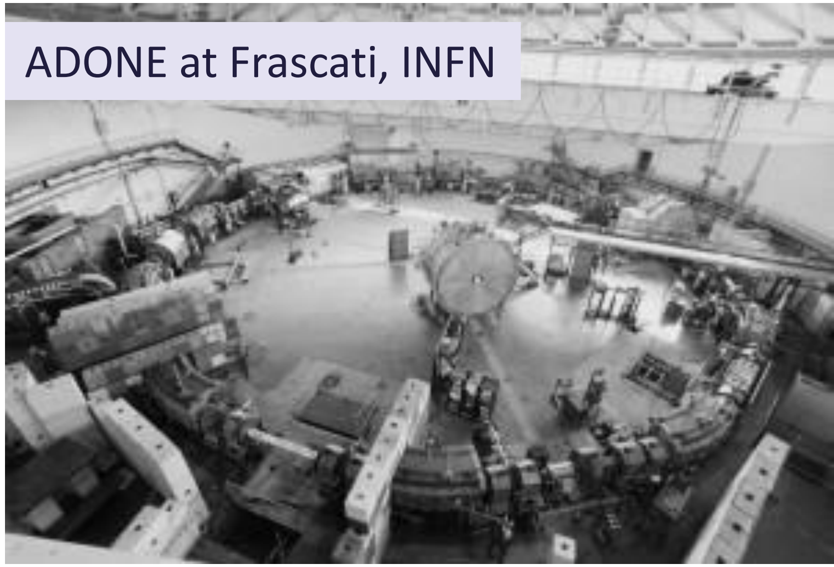
"From two UNIX machines with a few megabytes of memory shared across terminals, to today's world of personal laptops, high-performance clusters and cloud computing—the evolution is extraordinary – we could hardly have imagined in 1988."

First Trip Abroad …..

- My first international trip was to CERN Accelerator School in Salamanca, Spain.

- This was followed by a visit to Frascati in Italy. It was my first experience to see the operational accelerator ADONE (3 TeV CoM electron-positron collider).


CAS, Salamanca, 1988


ADONE at Frascati, INFN

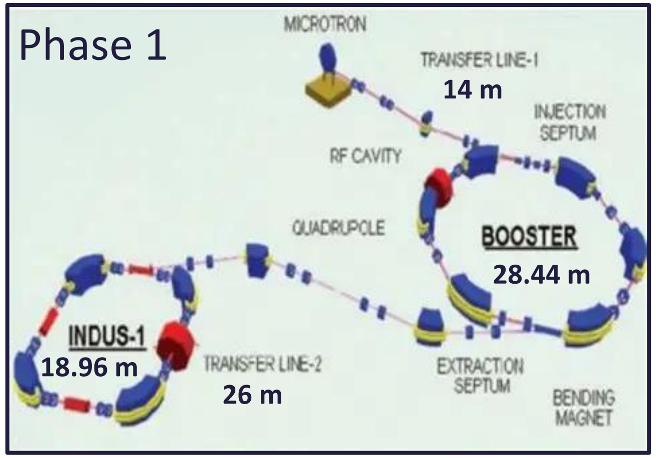
"I quickly realised I knew far less than I thought!"

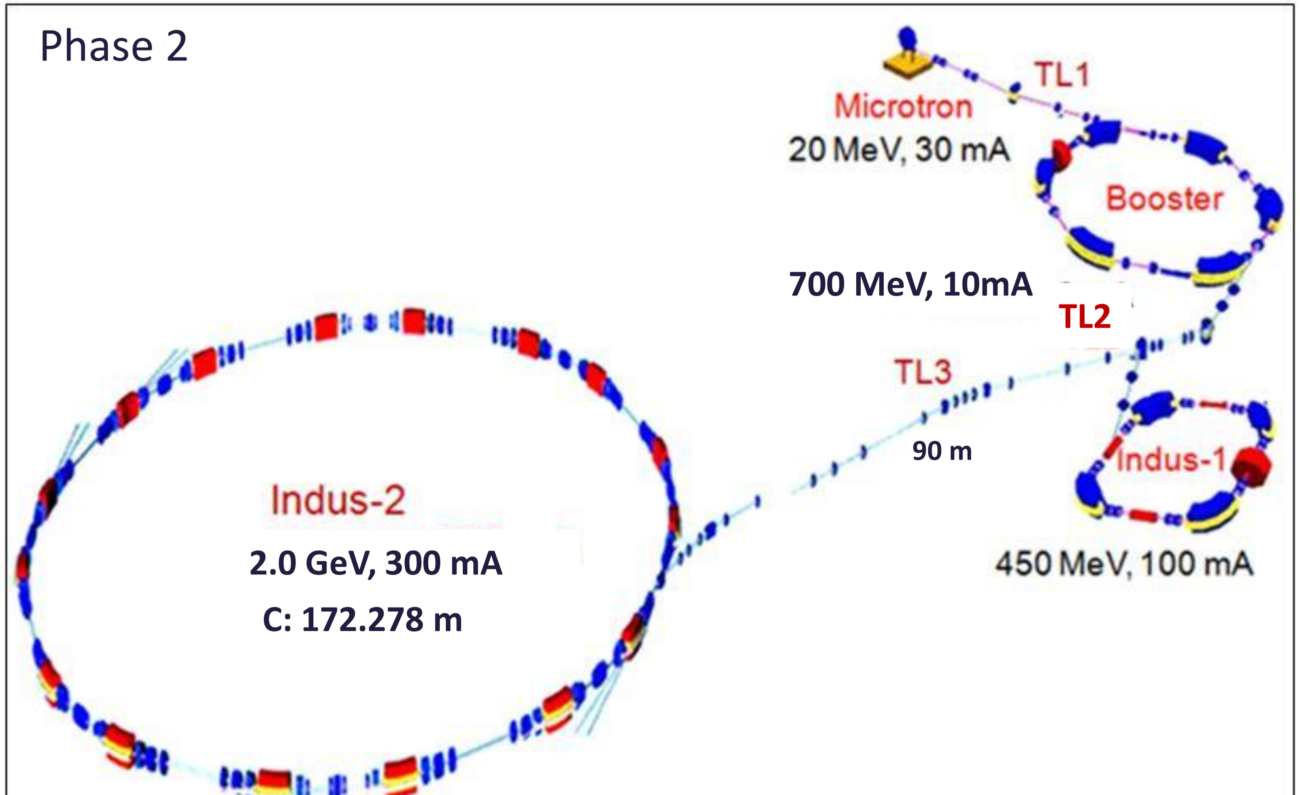
Designing INDUS Facility

- We were tasked with designing India's first synchrotron radiation source from scratch.
- Concept, layouts agreed early 1990s, alongside engagement with users and industry.

"Starting from a blank sheet was both empowering .... and slightly daunting.

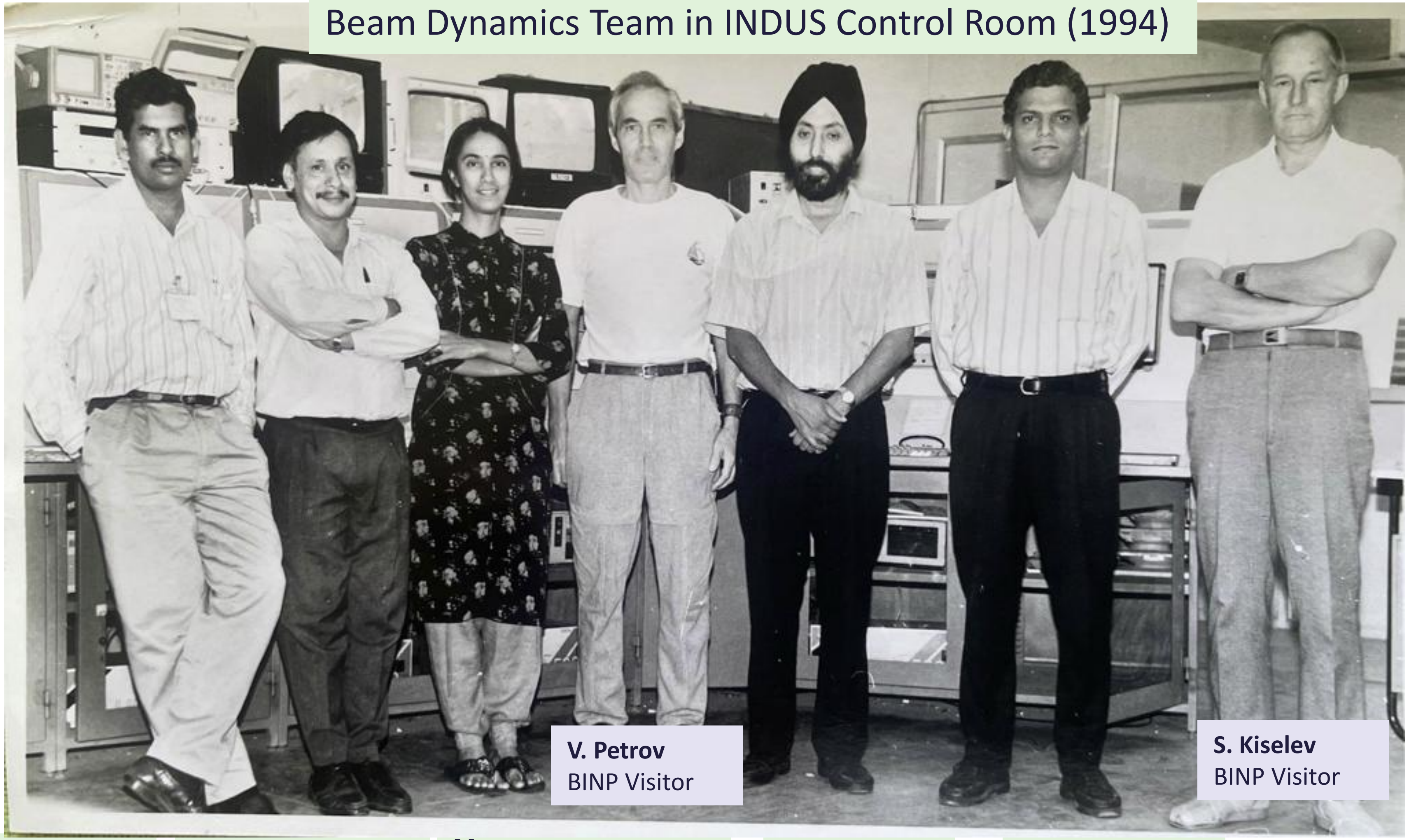
Every mistake was educational – just sometimes very memorable."





Team of Five

Beam Dynamics Team in INDUS Control Room (1994)



V. Petrov
BINP Visitor

S. Kiselev
BINP Visitor

Gajendra Sahoo
Ring Lattice Design, Dynamic Aperture

Beni Singh
Injection, Extraction, Insertion Devices

Me
Transfer lines, Collective Effects, Beam Lifetime

Gurnam Singh
Team lead

Ajay Ghodke
Closed Orbit, Collective Effects

"In hindsight, we were either very brave …. or slightly naïve."

First International Seminar

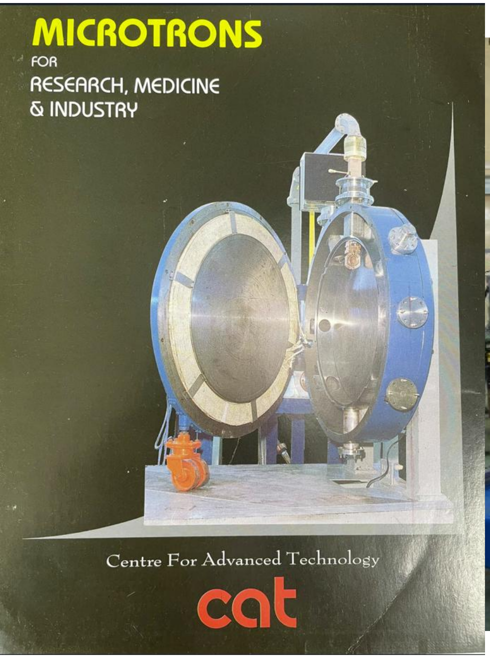
Prof G Kulipanov, BINP, Novosibirsk, Russia
Prof Yash Pal, UGC, India

My first presentation of INDUS-1 design to International experts.

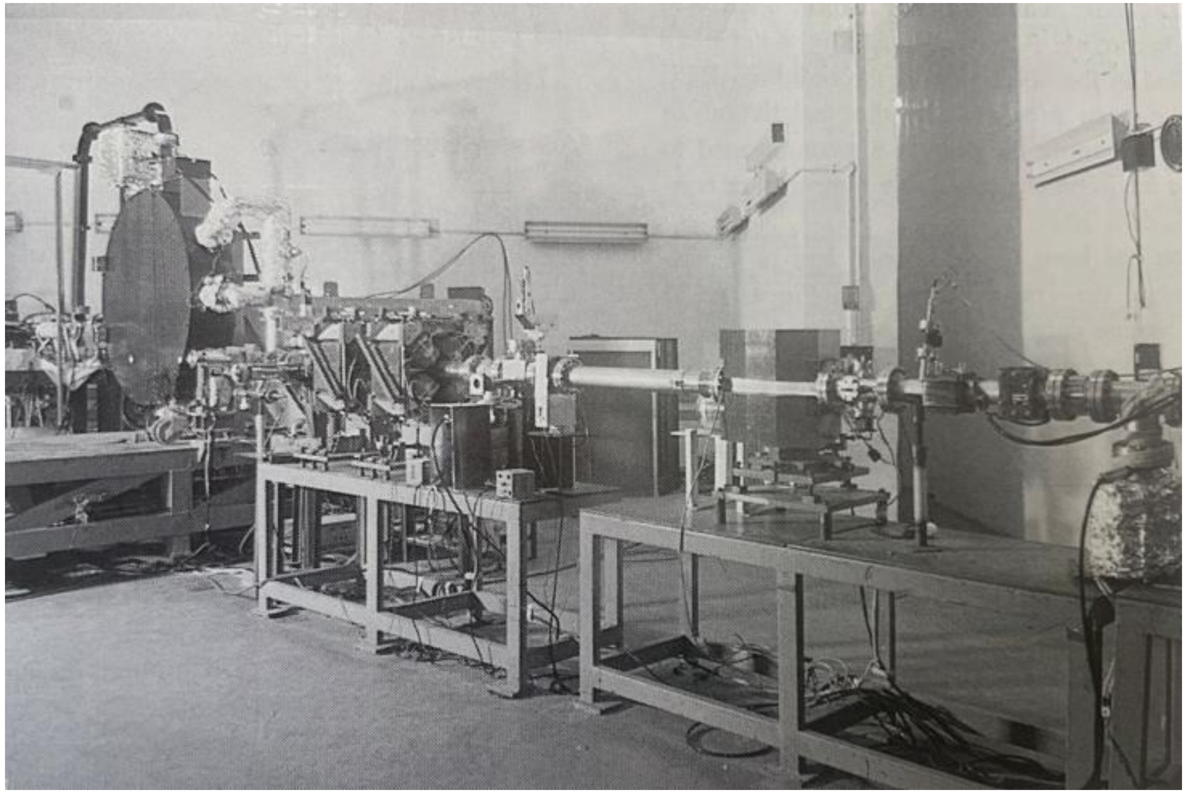
S Ramamurthi
Head, Accelerators

"No animations, no backups. The real challenge was keeping the transparencies in sequence."

The Pre-injector : Microtron



A 20 MeV, 30 mA classical Microtron was designed, developed and constructed at CAT in collaboration with Kapitza Institute for Physical Problems, Moscow.



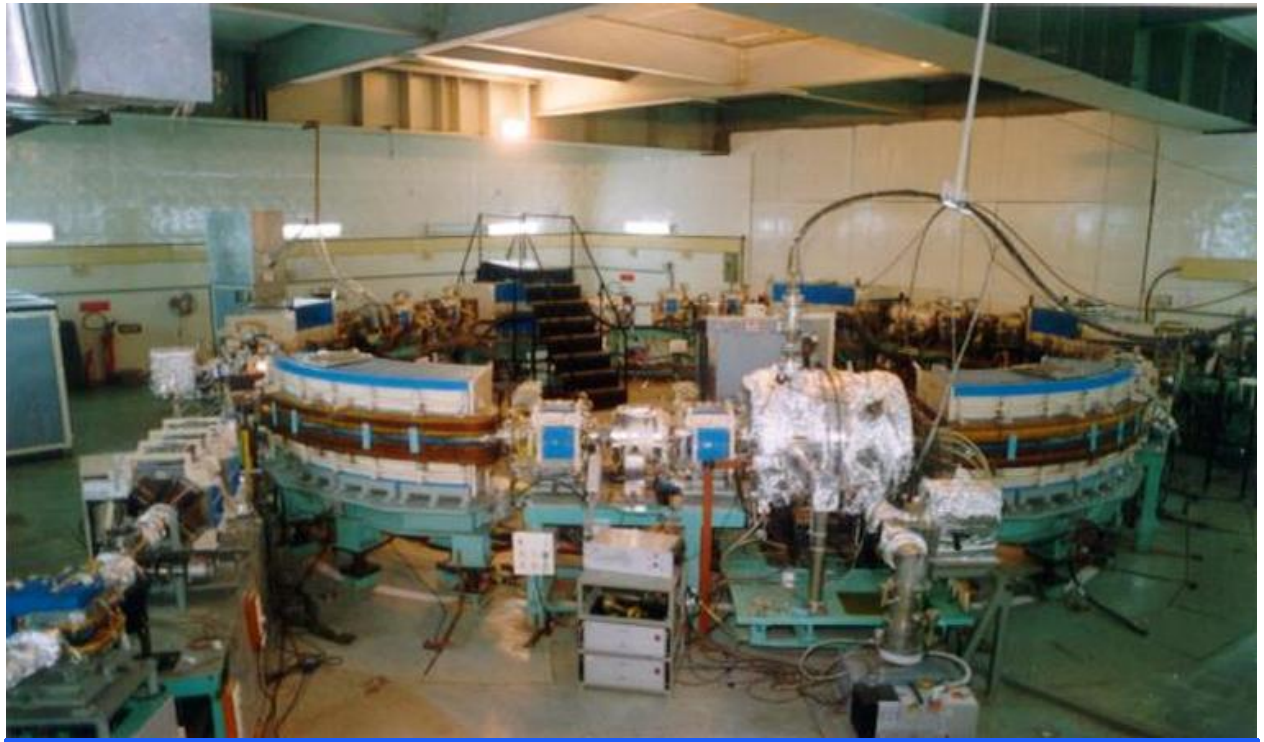
Started commissioning of Microtron in late 1992. The microtron was commissioned towards the end of 1994, with TL1 optics optimised for injection into the Synchrotron.

The Injector System

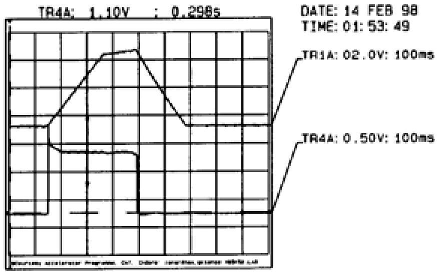
- An injector system with many components – each working perfectly…just not always at the same time.
- Injection, ramping & extraction …and a constant effort to understand losses, orbit and efficiencies!

The synchrotron radiation emitted by accelerated beam in the booster ring was observed first time in September 1995.

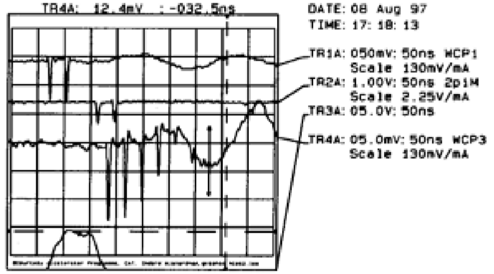
"A complex system that taught us patience, persistence….and a lot about beam behaviour."



Circumference = 28.44 m
RF = 31.613 MHz
Multi-turn injection with 2 μs pulse from Microtron filling 18 turns
Fast kicker extraction of two bunches



DCCT signal during ramping in synchrotron



Current signals in TL-2 and INDUS-1

First International Conference on SRS

Prof Herman Winick, Deputy Director, SSRL, USA, delivering the keynote address at the International Conference on Synchrotron Radiation Sources held at CAT during Feb 3-6, 1992.

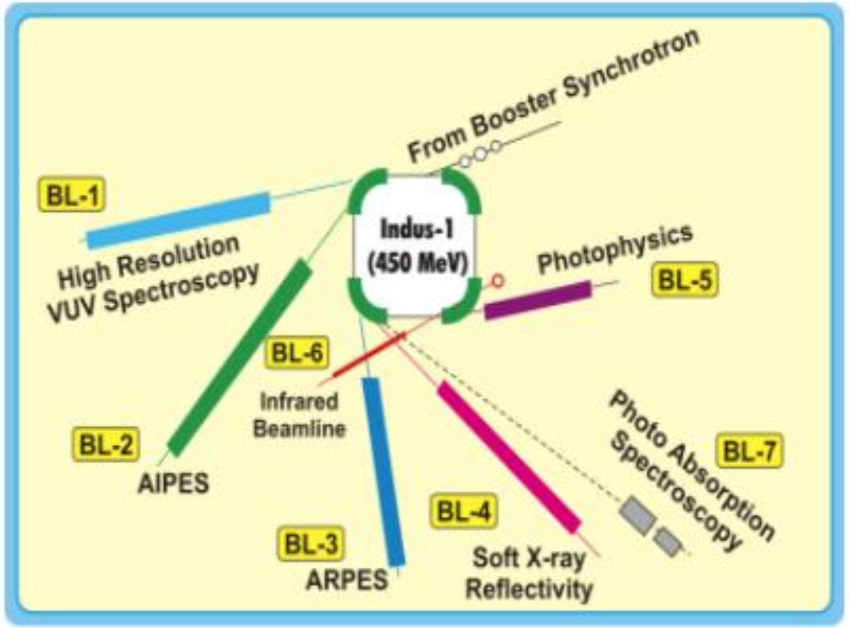
First introduction to Prof Neil Marks

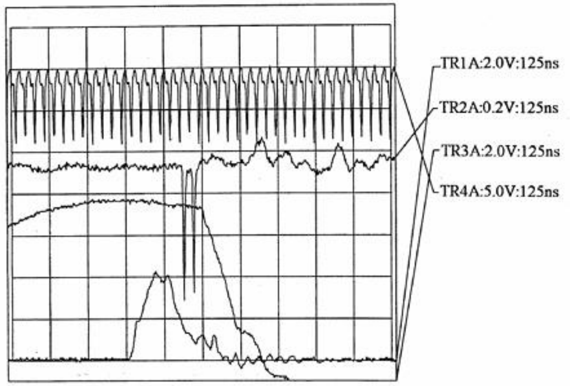
Around this period, Prof Swapan Chattopadhyay (visiting CAT from Berkeley) suggested to register for part time PhD with him; this was turned down by management as our priority was commissioning of INDUS.

INDUS-1 Success

INDUS-1 facility was fully commissioned early 1999.

Energy: 450 MeV
Circumference : 18.966 m
Combined function lattice (FI: 0.5)
Current: 100 mA (**200 mA achieved**)
Bending field : 1.5 T
λ_C : 61.38 Å, 30.69 Å (Wiggler)
RF : 31.96 MHz
Tune : 1.88, 1.22





Current signals in TL-2 and INDUS-1

"24 hours commissioning – many important milestones achieved between midnight to 3 a.m."

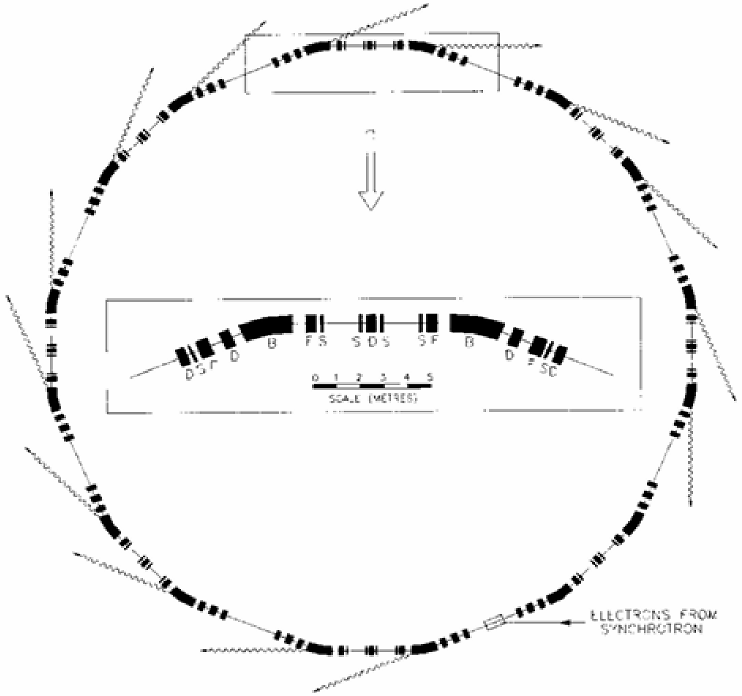
INDUS-2 Design

- We completed 2 GeV INDUS-2 design in 1997.

- On the recommendation of International Advisory Committee in 1998, energy was increased to 2.5 GeV.
- The IAC also recommended to change the RF frequency from 189 MHz to 505 MHz.

- Beam lifetime at the injection energy (700 MeV) was critical to store required beam current.
- Bunch lengthening due to single bunch collective effects and beam emittance increase due to Intra Beam Scattering (IBS) at injection helped to increase lifetime.

Decision to change the frequency was confirmed based on beam dynamics analysis carried out by me working with the RF team.



Energy: 2 GeV → **2.5 GeV**
Circumference : 172.278 m → **172.474 m**
Expanded Chasman Green Lattice
Current: 300 mA
Bending field : 1.2 T → **1.502 T**
λ_C : **1.986** Å (BM), **0.596** Å (HFW), **1.659** Å (MW)
RF : 172.278 MHz → **505.812**
Harmonic number : 109 → **291**
Tune : 9.2, 5.2

Russia Experience

- While INDUS-2 was underway, I visited Novosibirsk, Russia on accumulated Annual Leave (May 1998 - January 1999).
- I was welcomed by Budker Institute of Nuclear Physics (BINP) team to contribute to R&D on Synchrotron Radiation Sources.
- It was invaluable technical and cultural exposure.

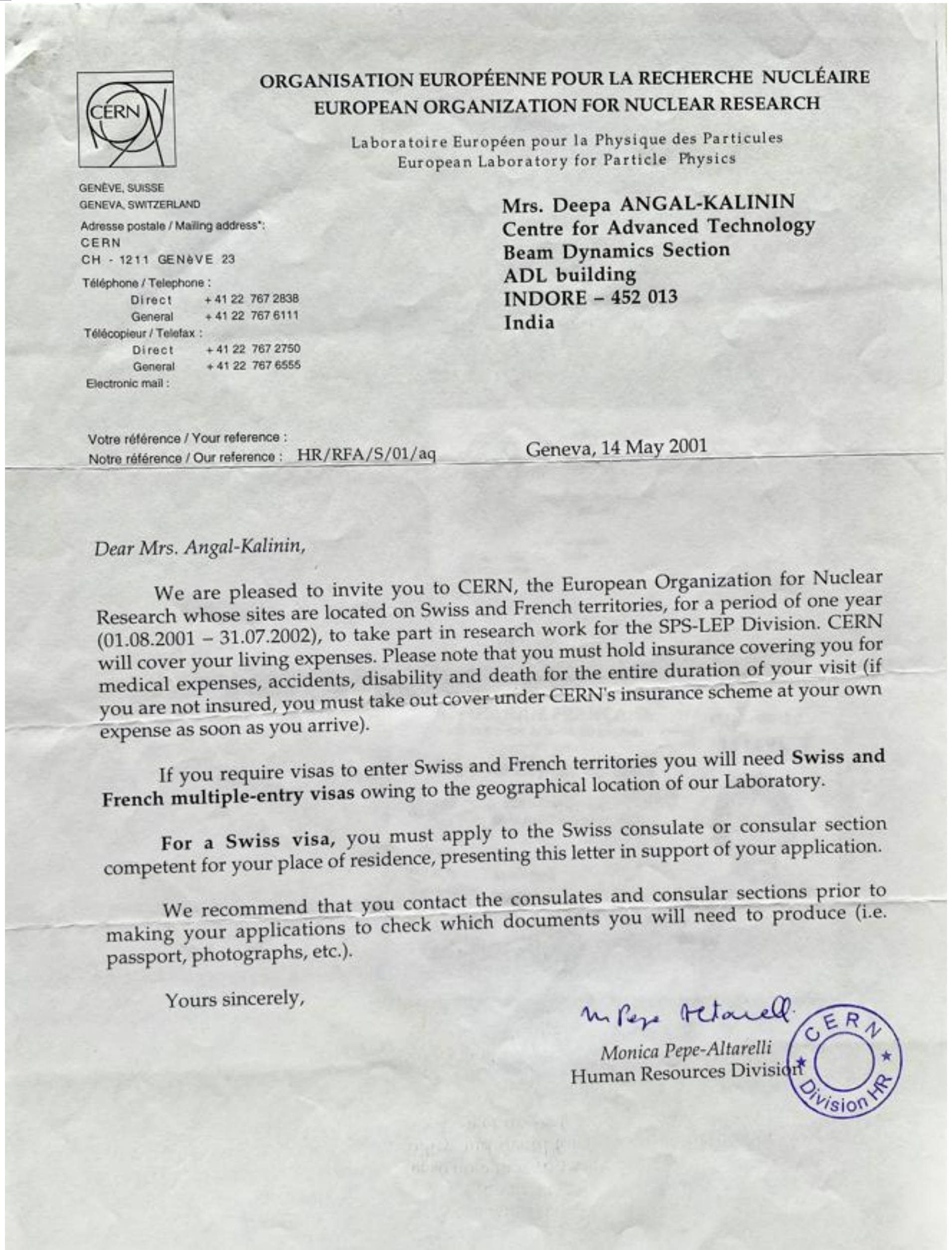
"The temperatures were extreme .... but the keyboard and script were even more challenging."

MOVE FROM INDIA TO EUROPE

- Due to personal reasons, decided to move to Europe in 1999 whilst keeping my job in CAT.

- Secured a position at CERN as Scientific Associate provided my job at CAT remains valid!

- I joined SL/AP group on 1st August 2001 reporting to Daniel Brandt and Luc Voss.


ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Laboratoire Européen pour la Physique des Particules
European Laboratory for Particle Physics

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Electronic mail :

Mrs. Deepa ANGAL-KALININ
Centre for Advanced Technology
Beam Dynamics Section
ADL building
INDORE – 452 013
India

Votre référence / Your reference :
Notre référence / Our reference : HR/RFA/S/01/aq

Geneva, 14 May 2001

Dear Mrs. Angal-Kalinin,

We are pleased to invite you to CERN, the European Organization for Nuclear Research whose sites are located on Swiss and French territories, for a period of one year (01.08.2001 – 31.07.2002), to take part in research work for the SPS-LEP Division. CERN will cover your living expenses. Please note that you must hold insurance covering you for medical expenses, accidents, disability and death for the entire duration of your visit (if you are not insured, you must take out cover under CERN's insurance scheme at your own expense as soon as you arrive).

If you require visas to enter Swiss and French territories you will need **Swiss and French multiple-entry visas** owing to the geographical location of our Laboratory.

For a Swiss visa, you must apply to the Swiss consulate or consular section competent for your place of residence, presenting this letter in support of your application.

We recommend that you contact the consulates and consular sections prior to making your applications to check which documents you will need to produce (i.e. passport, photographs, etc.).

Yours sincerely,

M. Pepe Altarelli

Monica Pepe-Altarelli
Human Resources Division

CERN Division HR

IBS Estimates for LHC

- First time working on protons! I started looking at Intra Beam Scattering (IBS) growth rates for LHC.
- There were inconsistencies in growth rates estimated by different people. Francesco Ruggiero (SL/AP GL) insisted we urgently re-examine every assumption.

"That experience showed me that good leadership in accelerator science is about asking the right questions and making sure the team truly understands the physics behind them."

Deepa Angal-Kalinin

From: Francesco Ruggiero [Francesco.Ruggiero@cern.ch]
Sent: Tuesday, October 16, 2001 8:19 PM
To: Jacques Gareyte; Deepa Angal-Kalinin; Luc Vos; Frank Zimmermann; John Jowett
Cc: Daniel Brandt; Oliver Bruning; Stephane Fartoukh; Hans Grote; Andre Verdier
Subject: Incompatible IBS results for the LHC: urgent action needed

Dear colleagues,

different IBS growth times are estimated for the LHC by different people in our group. Here is a list of the results at 7 TeV:

```
IBS growth times: nominal LHC at 7 TeV (sig_s=7.5 cm, sig_E=1.1x10^-3)
----------------------------------------------------------------------
tau_s = 60 h, tau_x = 100 h  (JG=YB,  ?  (emittances), V = 16 MV)
tau_s = 61 h, tau_x = 80 h   (DA,    ZAP (emittances), V = 14 MV)
tau_s = 63 h, tau_x = 94 h   (FZ,    MAD (amplitudes), V = 16 MV)
tau_s = 30 h, tau_x = 96 h   (LV,     ?      (?),      V = 14 MV)
```

According to Jacques Gareyte (JG) the numbers in the LHC Yellow Book (YB) refer to emittance growth times. Therefore they are about in agreement with ZAP results recently computed by Deepa Angal (DA) and also referring to emittance growth times. However these growth times are about a factor 2 longer than MAD results computed by Frank Zimmermann (FZ) and referring to amplitude growth times. Note that MAD and ZAP use the same formalism by Bjorken-Mtingwa and should therefore give the SAME results!
If the results computed by Luc Vos (LV) refer to amplitudes, then they nearly agree with MAD in the horizontal plane, but are shorter by a factor 2 in the longitudinal plane. If LV's results refer to emittances, they approximately agree with ZAP in the horizontal plane and are a factor 2 shorter in the longitudinal plane (where they agree with MAD).

This situation is embarassing, especially for low intensity proton beams with reduced transverse emittance and even more for lead ions at injection, when IBS growth times become of a few hours and a factor 2 makes the difference between a working or an impossible scenario. This has a direct impact on a decision to be taken about a staged installation of the 400 MHz cavities, and we should quickly provide a RELIABLE result!
There may be implications also for the CLIC damping rings.

Therefore I propose that all people involved make an effort to use the same parameters and to clarify the situation. In particular:
- FZ and JJ, possibly with the help of HG, check whether IBS growth times computed by MAD refer to amplitudes or to emittances, and what are the assumptions about betatron coupling (factor 2 difference in tau_x?).
- DA makes the same checks about ZAP.
- LV documents how he computes IBS growth times and how they can be reconciled with MAD and/or ZAP results (that will hopefully converge).
- JG documents how he computes IBS growth times and how they can be reconciled with MAD and/or Luc's results (that will hopefully converge).

Thank you for your collaboration
Francesco

P.S. We should also clarify why, according to LV and DA, nominal LHC RF parameters at 7 TeV (i.e. 16 MV and 2.5 eVs emittance) are inconsistent with nominal rms bunch length and energy spread in the YB (7.5 cm and 1.1x10^-4, respectively). This may depend on different assumptions on the longitudinal bunch distribution (gaussian vs parabolic), or some

LHC Collective Effects

- Working with Luc Vos and Daniel Brandt, we carried out intermediate review of impedance and collective effects in LHC.
- I also received fantastic support from Bruno Zotter for his BBI code and Scott Berg for his Vlasov code.
- Communications and queries about this work continued until 2010's from CERN.

Proceedings of EPAC 2002, Paris, France

INTERMEDIATE REVIEW OF SINGLE BUNCH COLLECTIVE EFFECTS IN THE LHC

D. Brandt and L. Vos, CERN, Geneva, Switzerland
D. Angal-Kalinin, On leave of absence from CAT, Indore, INDIA

Abstract

This paper presents an intermediate review of the single bunch collective effects in the LHC. It first reviews the LHC impedance budget including all elements for which a design is presently available. Then, based on this updated budget, the corresponding rise times and thresholds for single bunch instabilities are evaluated and discussed.

1 INTRODUCTION

The last review of the LHC collective effects dates back from 1995 [1]. Although detailed in his content, this review was mainly based on educated guesses, since the design of most of the components were not readily available. Despite of that, the review was a fundamental contribution, confirming that, provided the impedance could be kept within the estimations, the LHC could be safely operated from a collective effect point of view. As the final design of new elements became available, the corresponding impedances have been re-evaluated either by applying analytical estimations, by RF measurements or by numerical estimation with the MAFIA code [2]. Whenever applicable, the three sets of results have been used such as to cross-check the validity of the results. When this was not possible, then at least two sets of results were used for the evaluation.
As far as collective effects for single bunches are concerned, the main parameters are the inductive impedance (Z/n) in the longitudinal plane and the relatively high frequency (broad-band) impedance in the transverse planes. The transverse low frequency impedance (resistive wall), is more relevant for coupled-bunch instabilities and will not be considered here, however, it is treated in a dedicated companion paper [3].

2 LHC BOUNDARY CONDITIONS

Originally, feedback systems for both the longitudinal

Proceedings of EPAC 2002, Paris, France

COUPLED BUNCH INSTABILITIES IN THE LHC

D. Angal-Kalinin, On leave of absence from CAT, Indore, INDIA
L.Vos, CERN, Geneva, Switzerland

Abstract

In the LHC, the coupled bunch instabilities will be mainly driven by the RF cavities and the resistive wall effect. The growth times of these instabilities have been estimated taking into consideration the undamped and damped higher order modes of these cavities. These estimates show that the rise times of the longitudinal coupled bunch instabilities are under control. The proposed transverse feedback system allows the same conclusion to be drawn for the transverse resistive wall instability.

1 INTRODUCTION

In the LHC, the coupled bunch instabilities (CBI) can be potentially driven by narrow band structures such as the higher order modes (HOMs) of the RF cavities (both normal and superconducting cavities), other parasitic cavities and the resistive wall effect. The LHC will have two four cells superconducting cavities per beam operating at 400 MHz and four normal conducting cavities operating at 200 MHz for efficient injection capture. The LHC will be operated with a total 2808 bunches per beam, with a bunch separation of 25 ns. CBI problems can be more severe in the longitudinal plane since no longitudinal feedback system is foreseen for the LHC [1]. In the transverse planes, there is a feedback system [2], however, it remains necessary to check that the CBI growth times are slow enough to stay within the power and gain limits of the feedback system as well as to ensure a sufficient margin for the control of the emittances.

The CBI growth times have been first evaluated using the undamped modes of the RF cavities. As expected, they lead to CBI in both the longitudinal and transverse planes and thus would not be acceptable for the LHC operation. However, the estimates using the damped HOMs of these cavities confirm that there will be no CBI due to these HOMs.

and the experimental chambers. For the latter, the trapped monopole modes of the CMS experimental chambers have been estimated with the program MAFIA [6] by Yun Luo [1]. Furthermore, the growth times are estimated for the LHC parameters described in Table 1. It should be noted that, although the 200 MHz cavities will be used at injection only, their contribution to the impedance budget has also to be included at top energy. Finally, it is worth mentioning that the code used for the present CBI evaluations requires a symmetric filling of the machine. As a result, we had to use 3564 equally spaced bunches instead of the nominal 2808 LHC bunches. As a consequence, our results are slightly pessimistic. Similarly, both the nominal and ultimate intensities are considered, in order to ensure that the instabilities are under control for all operation scenarios. The growth times are evaluated for the first two lowest order synchrotron modes for both damped and undamped HOMs. All estimates are computed for parabolic and Gaussian bunch shapes with the program ZAP [7].

Table 1: Parameters of LHC used for CBI estimates

Ring Circumference [m]	26658.883	
Bunch population	1.1×10^{11} (nominal) 1.7×10^{11} (ultimate)	
Total beam current [A]	0.706 (nominal) 1.091(ultimate)	
Momentum compaction	0.000347	
Betatron tunes H/V	63.28/63.31	
Energy [GeV]	450	7000
RF frequency [MHz]	200.35	400.79
Harmonic number	17820	35640
No of symmetric bunches	3564	3564
RF voltage [MV]	3	16
rms bunch length [cm]	17.5	7.73
Rel. rms energy spread	3.06×10^{-4}	1.11×10^{-4}
Synchrotron tune	0.002546	0.00212

Advert at CCLRC – CERN Courier December 2001

Considering my CERN post was associated with my CAT job, I was looking for a job in Europe.

ACCELERATOR PHYSICISTS

(Four Posts)
Rutherford Appleton and Daresbury Laboratories

Applications are invited for four posts in the newly created Accelerator Science and Technology Centre (ASTeC) to lead a programme of development of future accelerators for particle physics.

Two posts are to work on the development of electron-positron linear colliders and would be based at Daresbury Laboratory, and two posts are to work on the development of the neutrino factory and would be based at the Rutherford Appleton Laboratory. Possible areas of work include the beam delivery system and advanced damping rings for the linear collider, and high current proton accelerators, high power targets, muon collection and acceleration for the neutrino factory, but there will be considerable scope to contribute in all relevant areas. The work will involve close collaboration with staff in CLRC's Particle Physics Department, university teams and other international accelerator laboratories. More details can be found on http://www.astec.ac.uk/jobs

A leader is required for both projects, and suitable candidates would be expected to have at least 5 years relevant experience, with an initial salary up to £31,250. The other posts would have a salary up to £24,620. In both cases, a higher salary could be considered for suitably qualified candidates. Candidates should have a first degree in physics or a closely related subject, and a Ph.D. or equivalent would be of benefit.

Application forms can be obtained from: HR Operations, HR Division, Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire, OX11 0QX. Telephone (01235) 445435 (answerphone) or email recruit@rl.ac.uk quoting reference VN2189. For informal discussions about the posts please contact Ken Peach (Ken.Peach@rl.ac.uk).

Applications must be returned by 7 January 2002.

Interviews will be held week commencing 21 January 2002.

CCLRC is committed to Equal Opportunities and is a recognised Investor In People.

A no smoking policy is in operation.

INVESTOR IN PEOPLE

CLRC

COUNCIL FOR THE CENTRAL LABORATORY OF THE RESEARCH COUNCILS

Deepa Angal-Kalinin

From: Bryan, CJ (Caroline) [C.J.Bryan@rl.ac.uk]
Sent: Tuesday, January 15, 2002 3:05 PM
To: 'deepa.angal-kalinin@cern.ch'
Subject: Invitation to Interview at the Rutherford Appleton Laboratory.

Importance: High

ACCINT.DOC1.doc Access to medical reports.doc medical Q.doc VN2189.doc

Dear Mrs Angal-Kalinin

VN2189 - Accelerator Physicists

We are considering your application for a post with the Council and would like you to attend for interview on 22nd January 2002 at 9:00am . The interview will be a panel interview and will last approximately one hour.

On the day of your interview you should bring this letter with you and report to the Main Security Gate of the Laboratory. Quote both the vacancy reference and my name to the Security Warden and you will be directed as appropriate.

If you live in the UK we will pay travelling expenses from your home to the Laboratory based on normal car or public transport rates. If you are travelling from abroad expenses are only payable from within the European Union, however assistance in this case will also be given to those outside the European Union. If you are travelling by rail please inform us as early as possible before the date of your interview and we will arrange transport from the station.

If you are coming a long way and need to stay overnight near the Laboratory please let me know and I will book a hotel for you. We will refund reasonable hotel expenses or sleeper fares for overnight rail journeys. Please keep tickets and receipts or bills to support your claim.

Please complete and return the enclosed form to let me know whether you will be able to attend the interview and if you will require accommodation.

Please bring with you a recent passport size photograph of yourself. We will refund the cost. Please also bring with you your birth certificate or passport and documentary evidence of your academic qualifications. I enclose a pre-employment medical history questionnaire that should be completed and handed in on the day of your interview.

If you have any queries, do not hesitate to write or telephone.

Yours sincerely

Miss CJ Bryan
Operations Group
HR Division

encl. Form of acceptance

1

Interview at RAL

Big Panel (7 members)

Ken Peach (Chair), Head of PPD

Vic Suller & Susan Smith, ASTeC for LC

Chris Prior & Peter Norton, RAL for NF

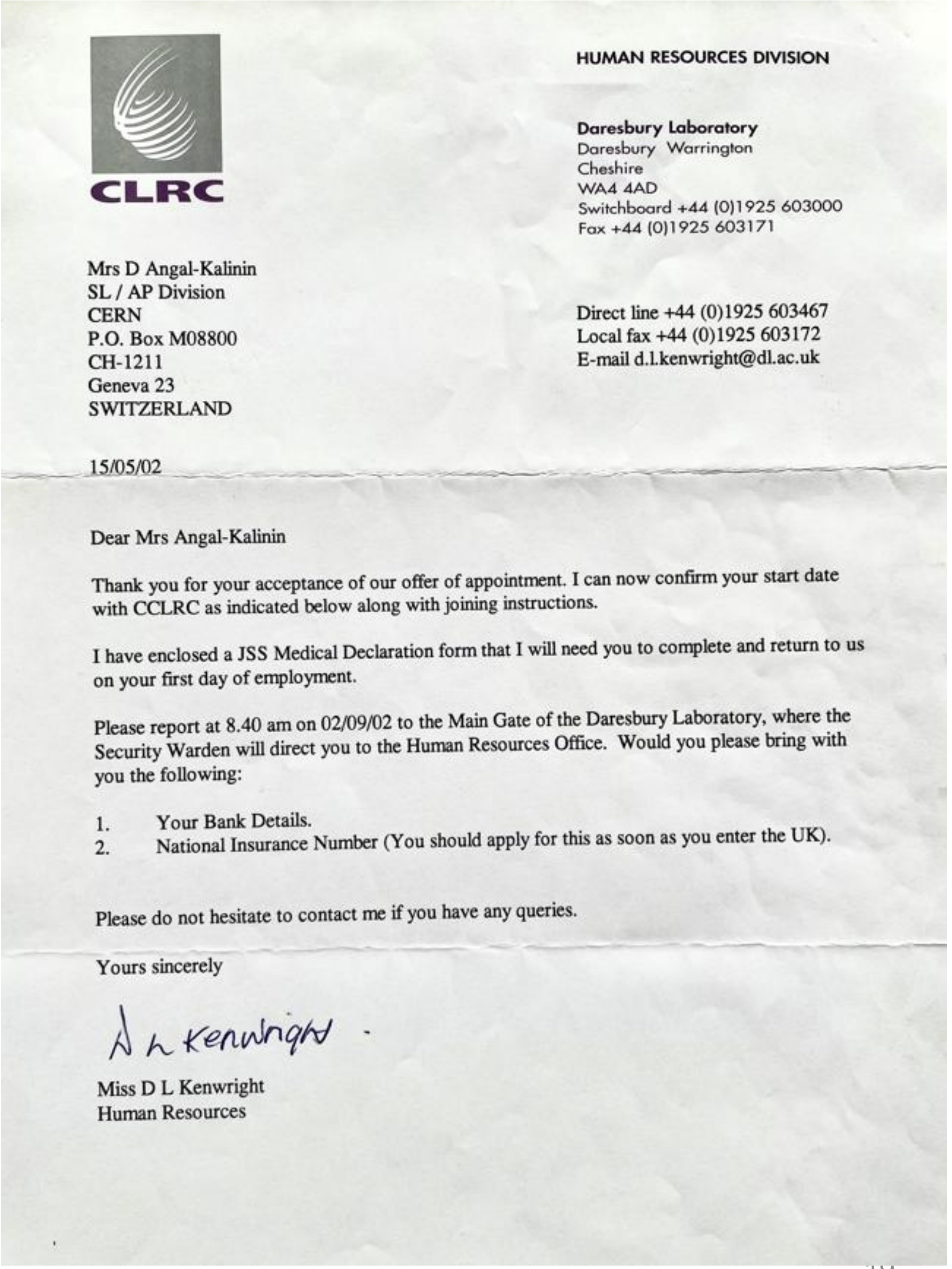
HR Person

Tour of ISIS by Ian Gardener

CCLRC Interview Outcome

- I received a call from Ken Peach next day with the offer for me to choose between leading LC or NF.
- **Without visiting DL,** I took a decision to lead LC.
- However, I wanted to complete my year at CERN and so requested if I can join CCLRC after completing my CERN contract in August 2002.
- CCLRC/ASTeC kindly accepted my request to start on 2nd September 2002 **(that was 8 months after my interview)!**

"One of my boldest decision to choose DL without visiting the lab – and one I never regretted."



CLRC

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Geneva 23
SWITZERLAND

Direct line +44 (0)1925 603467
Local fax +44 (0)1925 603172
E-mail d.l.kenwright@dl.ac.uk

15/05/02

Dear Mrs Angal-Kalinin

Thank you for your acceptance of our offer of appointment. I can now confirm your start date with CCLRC as indicated below along with joining instructions.

I have enclosed a JSS Medical Declaration form that I will need you to complete and return to us on your first day of employment.

Please report at 8.40 am on 02/09/02 to the Main Gate of the Daresbury Laboratory, where the Security Warden will direct you to the Human Resources Office. Would you please bring with you the following:

1. Your Bank Details.
2. National Insurance Number (You should apply for this as soon as you enter the UK).

Please do not hesitate to contact me if you have any queries.

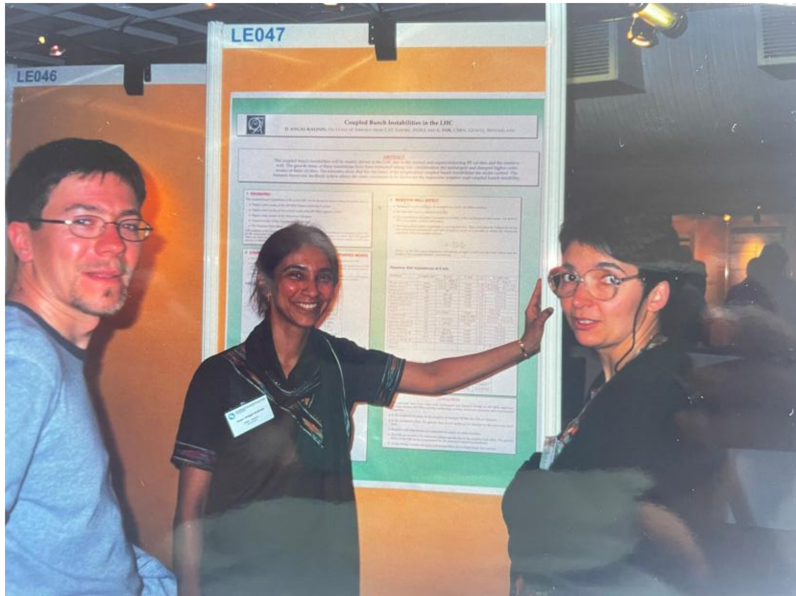
Yours sincerely

D L Kenwright

Miss D L Kenwright
Human Resources

First Introduction to ASTeC Team

I had an opportunity to meet some members of ASTeC team at EPAC02 in Paris first time in June 2002 before joining ASTeC.



End of a Remarkable Journey at CAT

I officially left CAT in August 2002 after 17 years.

INDUS-1 was fully operational and INDUS-2 installation was underway.

I continued to support queries on INDUS-2 until early 2010's.

Group photo at my leaving do (August 2002): In 17 years, the Beam Dynamics team was doubled & the only female left.

Indus-2 Bunch Filling Scheme

G gurnam@cat.ernet.in
To Angal-Kalinin, D (Deepa)

Reply | Reply All | Forward | ...

Wed 07/05/2008 13:50

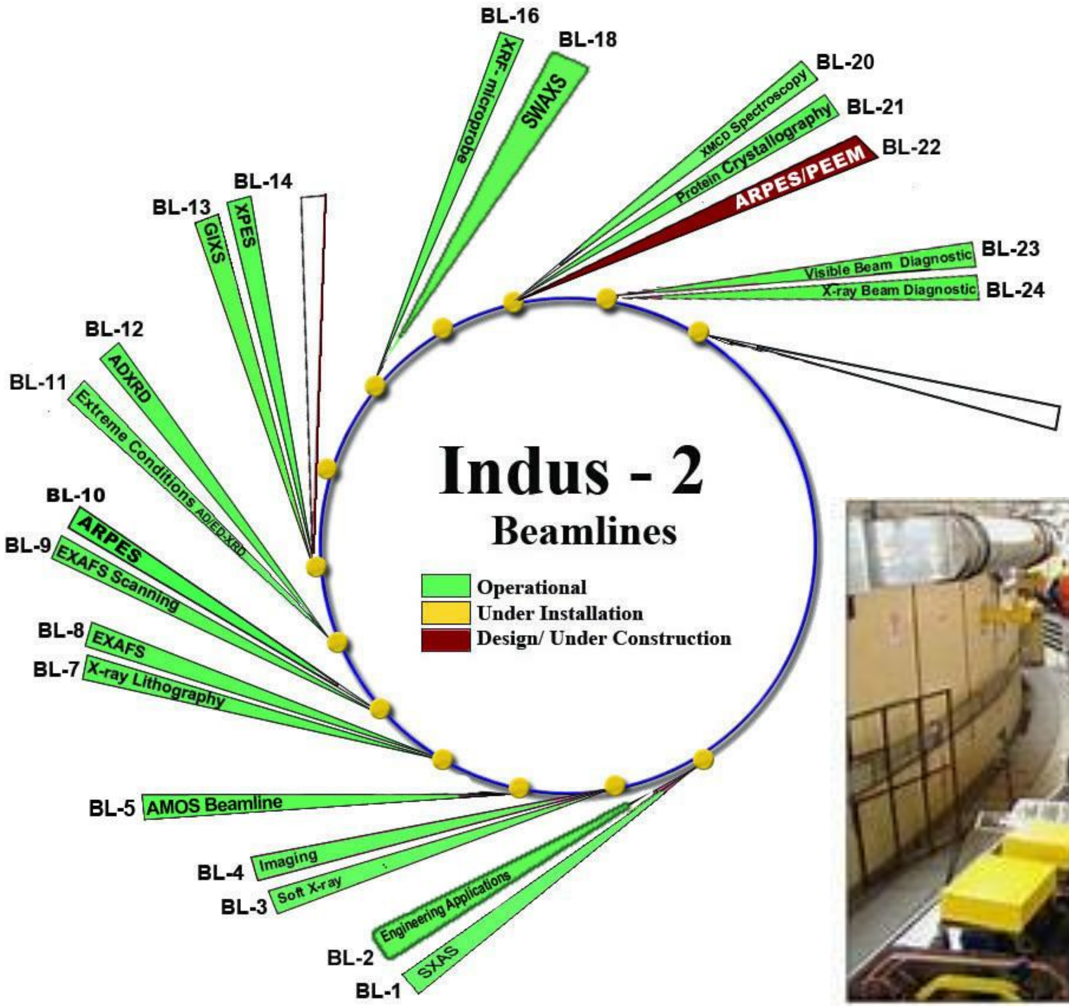
You replied to this message on 08/05/2008 16:58.
We removed extra line breaks from this message.

Dear Deepa,

I want to share with you a good news that the filling scheme proposed by you have started functioning. So far, when we were operating the timing system in the single bunch mode configuration, the machine was getting filled with many bunches randomly. Yesterday, after reduction of the noise in the circuit, the problem has been rectified. Now,when Indus-2 is operated in this mode, it is filled with two bunches as 2 bunches are extracted from the booster. I would like to congratulate for your good contribution to this part of the machine.

INDUS-2

INDUS-2 was commissioned in 2005 with 17 beamlines operational from 2010.



Continued success and future expansion plans.

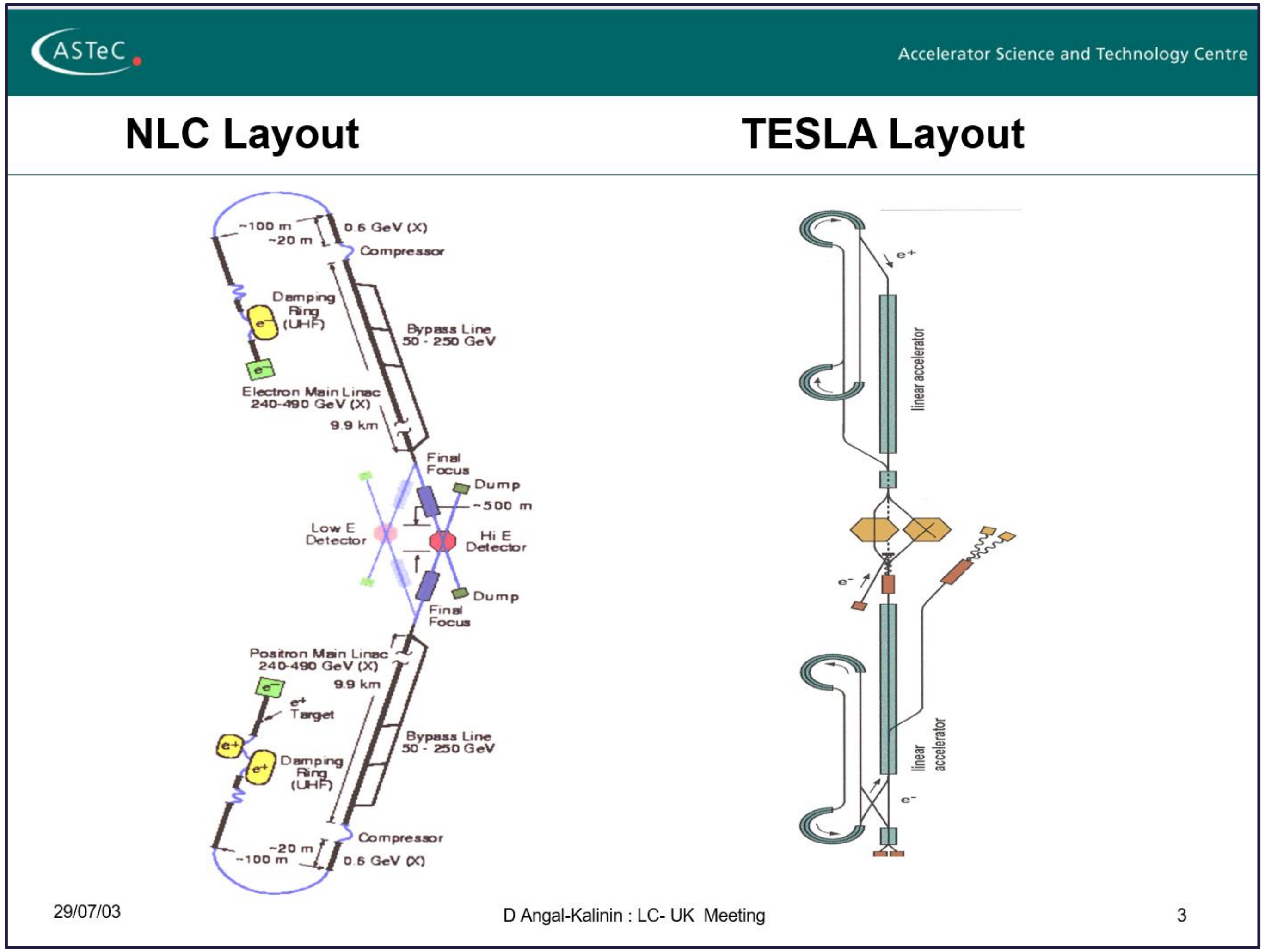
Funding to build a 6 GeV INDUS-3 has been announced in February 2025.

Linear Collider Era

- Linear Collider activities were just getting started in UK, with start of collaborations on TESLA with DESY.

- I convened the meeting to review Optics and Collimation review of TESLA BDS – Zeuthen, 20th January 2004 with help from Nick Walker, DESY.

"This was the beginning of strong collaborations with Philip Bambade (LAL) and Oliver Napoly (CEA)."



Next Linear Collider
Warm normal conducting technology
Crossing angles: 20 mrad & 30 mrad

TeV Energy Superconducting Linear Accelerator
Main IP Head-on
34 mrad for $\gamma\gamma$ Collider

LC ABD1

- Linear Collider Accelerator Beam Delivery (LC ABD) bid was funded for three years (2004-2007) – 9.11 M

- The collaboration consisted of CCLRC & 12 UK Universities

- At the same time, two accelerator institutes were funded and exciting period started…..

- Proposal for ATF2 at KEK, Japan as BDS final focus test facility to demonstrate 37 nm beam size was published in August 2005.

UK funding for accelerator science for particle physics 2004 - 2007

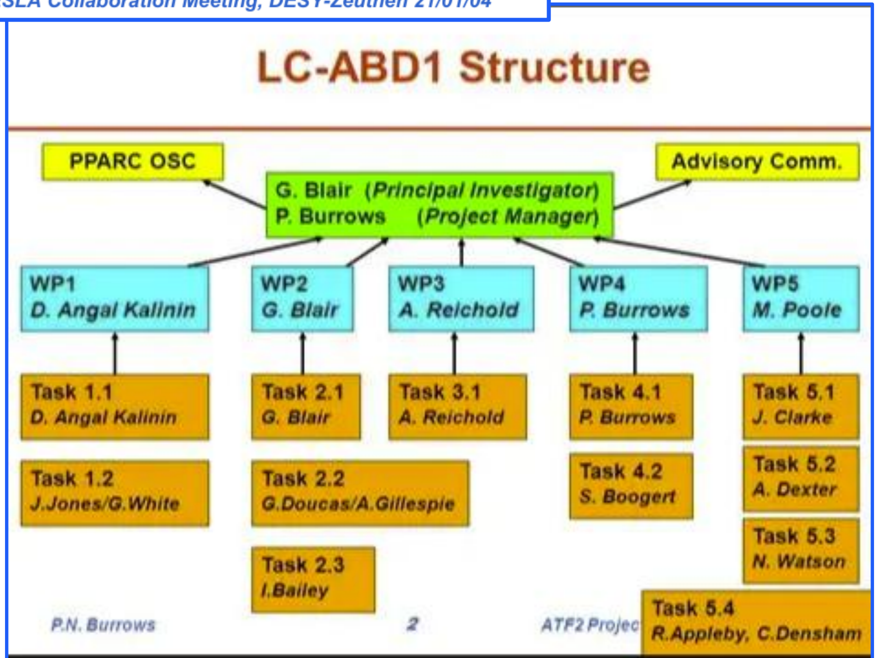
- UK funding agency, PPARC, secured from Govt. 15MEuro for ‘accelerator science’ for particle physics, spend period April 04 – March 07

- Called for bids from universities and national labs; large consortia were explicitly encouraged

- 5 bids received:
  A total in excess of 30MEuro was requested!

- Bids peer-reviewed and preliminary allocations made Oct 21 2003:
  LC-Beam Delivery recommended to receive 10MEuro
  UKNF received 2.4MEuro
  2.6MEuro for national university-based accelerator institute

Philip Burrows *TESLA Collaboration Meeting, DESY-Zeuthen 21/01/04*



Linear Collider Momentum

- International Technology Recommendation Panel chaired by Barry Barish was formed by ICFA early 2004. Decision on choice of **cold technology** was announced in **August 2004**.

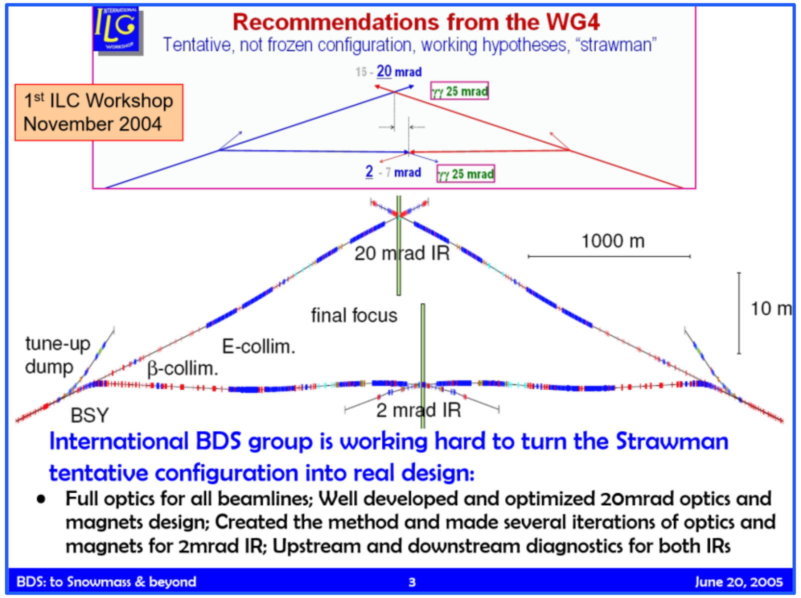
- **Crossing angle & solutions for extraction line** after collision needed addressing urgently.

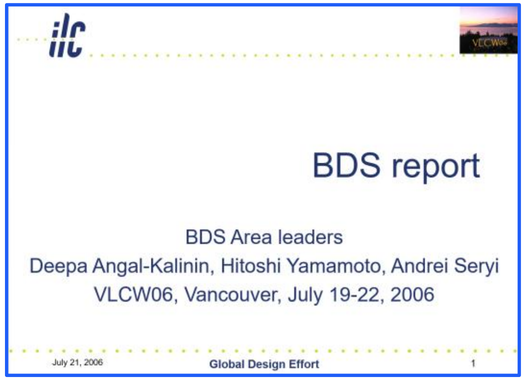
- EuroTeV programme of 28 institutes was funded by EU (2005-2009).

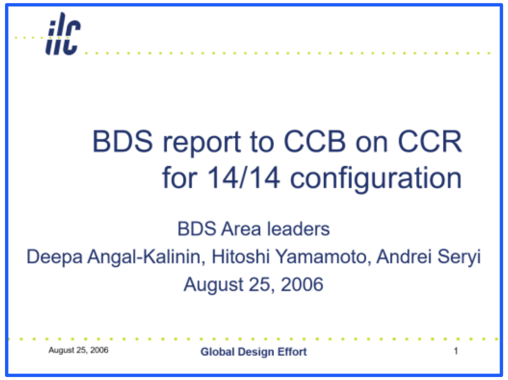
- I had three roles: WP leadership of LC ABD, WP Co-ordinator of EuroTeV and European Area Leader for BDS for Global Design Effort (GDE).

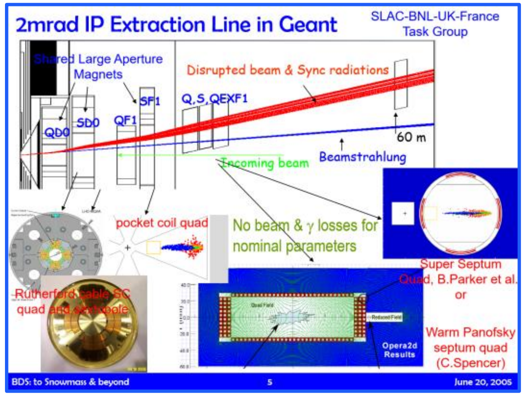
"This is where my accelerator journey became a frequent flyer programme…".

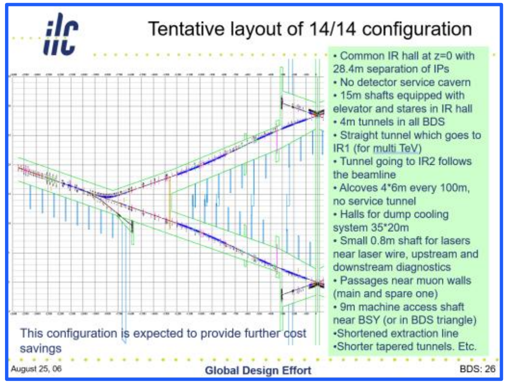
Crossing Angle/ Costing/ 24h Work Cycle

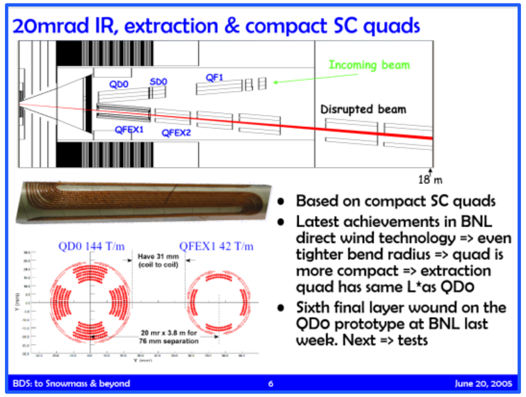


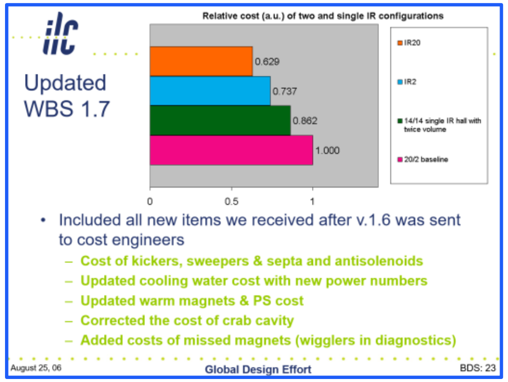




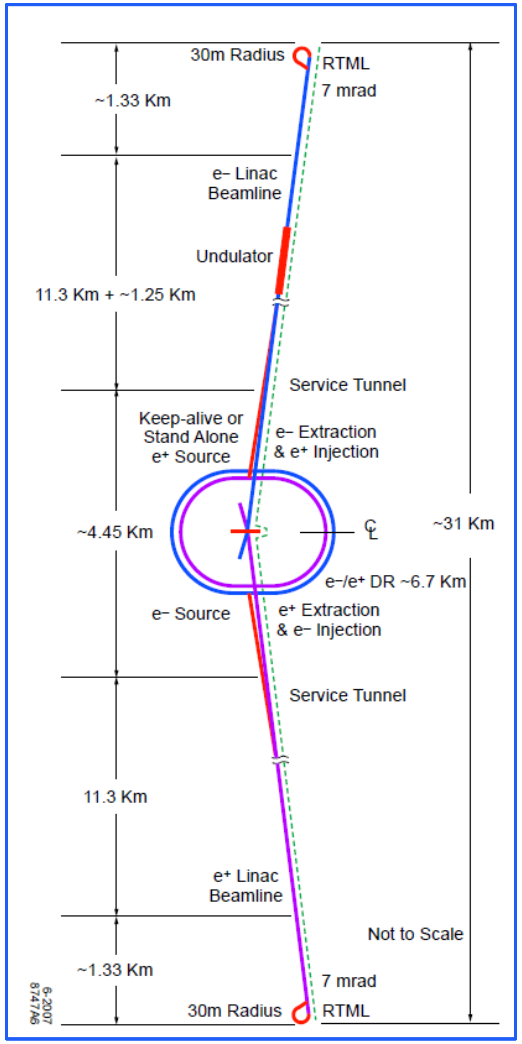








- 24-hour work across three regions – progress never stopped, sleep occasionally did.
- My first experience to carry out costing of large-scale accelerator, steep learning curve!



RDR BDS Design Aug 2007
14 mrad crossing angle
1 IR and 2 push-pull Detectors

LC ABD2/ Funding Reality

- We started bid preparations for the next phase in 2006.
- PPARC and CCLRC had merged as STFC in April 2007.
- Cut down request of 3M/year for 3 years. Matching funding was through another EU program (EUCARD).
- However, due to funding shortfall, STFC announced **"UK to withdraw from ILC"** in the "Delivery Plan" on 11th December 2007.
- STFC agreed to pay UK contribution to ILC common funds, and we were encouraged to develop a "generic" programme on linear colliders.

"Just as the design was converging… reality diverged."

PARTICLES AND INTERACTIONS | RESEARCH UPDATE

UK confirms withdrawal from ILC

07 Feb 2008 Matin Durrani

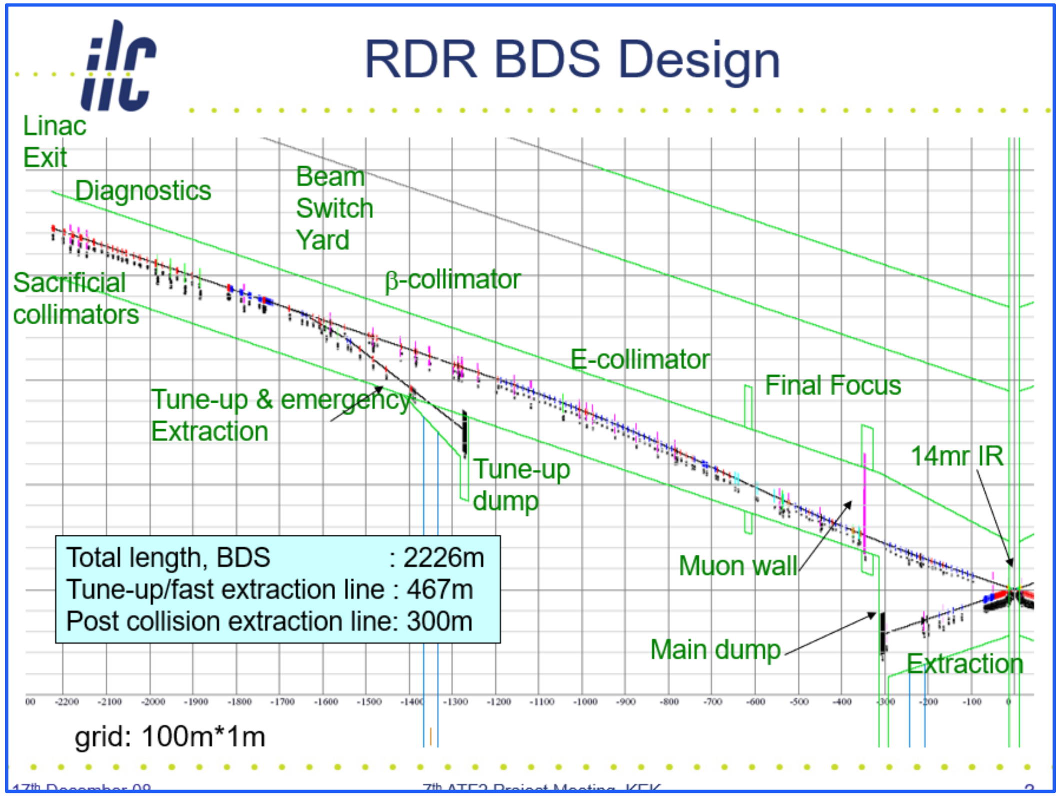
Superconducting cavity for the ILC

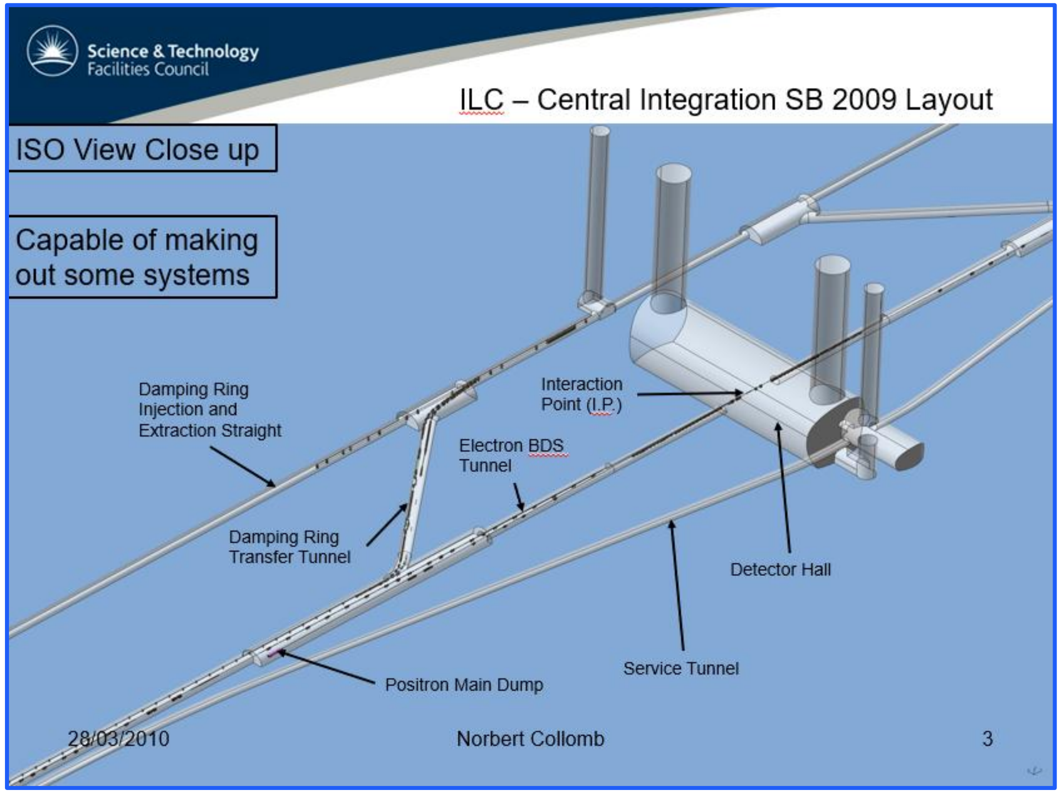
Physicists in the UK have failed to persuade research council bosses to rejoin preparations for the International Linear Collider (ILC). The decision to pull the UK out of the project had been announced in December by the Science and Technology Facilities Council (STFC) after it was awarded an average annual funding increase of just 4.5% over the next three years, which left it with £80m less to spend than planned.

But despite strong protests from physicists, the STFC says in a statement released today that it has "reaffirmed its decision to stop funding the ILC", which is seen as the next big experiment in particle physics after the Large Hadron Collider at CERN. The statement was released following a meeting of the STFC's council last week.

ILC- Minimum Machine

Concerns over few aspects of RDR design were raised in 2008. We started looking at Minimum Machine with Central Region Integration.





Implications to installation, commissioning and running due to complexity of the central integration region.

"My work on ILC period taught me that in large-scale accelerators, the technical challenges are only part of the story—the rest is costs, funding, coordination and communication"

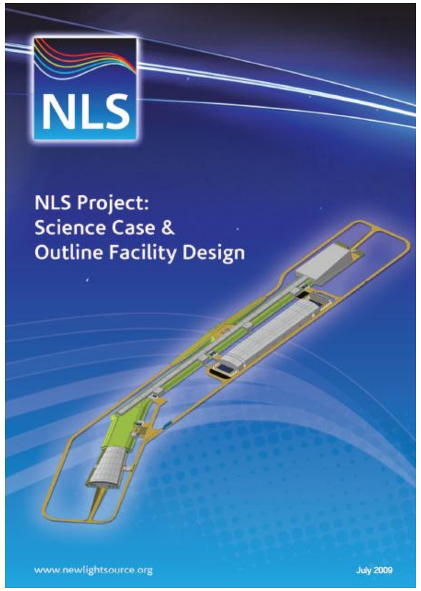
Back to Light Sources from Colliders

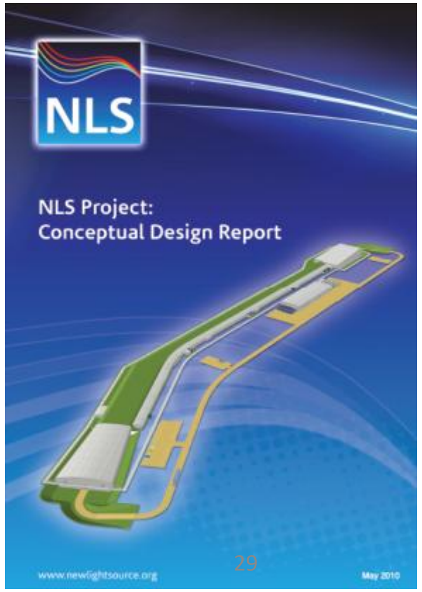
With ramping down LC activities, I had a possibility to work on ALICE. At the same time discussions around soft X-ray FEL design study were gathering momentum.

- We produced a world-leading design for a 4th generation soft X-ray facility motivated by an undisputedly excellent scientific case within 18 months.

- **Due to financial constraints, the NLS project was put on hold, and we were told to come back in a few years time.**

Recognising need to develop switchyard/spreader designs, I registered for part time PhD in 2009 with Swapan – 17 years after first suggested ….. And project paused!





CLARA Idea Emerging

"When one project stops, another quietly begins.".

Several critical R&D areas were identified during NLS design.

Ideas for FEL test facility at Daresbury started taking shape.

PROPOSAL FOR A LIGHT SOURCE TEST FACILITY

NEIL THOMPSON, DAVID DUNNING, BRIAN MCNEIL, ALLAN GILLESPIE, DAVID HOLLAND, ROBERT DONOVAN, GRAHAM BUSHELL-WYE, STEVE JAMISON

NOVEMBER 2010

PROPOSAL SUMMARY

This document presents a proposal for a test facility at Daresbury Laboratory dedicated to the development of advanced Light Source facilities. It is clear that future light sources will depend heavily on Free-Electron Laser (FEL) sources, so the core strategy of the facility is the development of FEL Science. In this context FEL Science encompasses the dual strands of FEL Physics and FEL Exploitation.

Some specific FEL Physics aims are:

- To demonstrate and develop, at low electron beam energy, generic techniques for the production of ultrashort pulses from free-electron lasers.
- To demonstrate and develop techniques for the generation and amplification of coherent harmonics from input seed fields
- To demonstrate and develop novel laser-driven techniques for electron bunch compression and

CLARA – A PROPOSED NEW FEL TEST FACILITY FOR THE UK

J. A. Clarke[1,2], D. Angal-Kalinin[1,2], R. Bartolini[3,4], D. J. Dunning[1,2], S. Jamison[1,2], J. K. Jones[1,2], I. P. S. Martin[3], J. W. McKenzie[1,2], B. L. Militsyn[1,2], N. R. Thompson[1,2], P. H. Williams[1,2]

[1] STFC Daresbury Laboratory, Warrington, UK
[2] Cockcroft Institute, Daresbury Science and Innovation Campus, Warrington, UK
[3] Diamond Light Source, Harwell Oxford, UK
[4] John Adams Institute, University of Oxford, UK

Abstract

A Free Electron Laser (FEL) test facility, CLARA (Compact Linear Advanced Research Accelerator), is proposed to be constructed at Daresbury Laboratory in the UK. The aim of CLARA is to develop a normal conducting test accelerator able to generate longitudinally and transversely bright electron bunches and to use these bunches in the experimental production of stable, synchronised, ultra short photon pulses of coherent light from a single pass FEL with techniques directly applicable to the future generation of light source facilities. In addition the facility will be an ideal test bed for demonstrating innovative technologies such as high repetition rate normal conducting RF linacs and advanced undulator designs. This paper will describe the design of CLARA, pointing out the flexible features that will be incorporated to allow multiple novel FEL schemes to be proven.

INTRODUCTION

X-ray FELs with demonstrated outstanding performance characteristics are now operational in the USA and Japan, and others are being constructed in Europe and elsewhere. In spite of these impressive achievements it is clear that the potential for FELs is even greater in terms of further optimising the output performance to match the ever demanding needs of the science community. There are many ways in which FELs could be further improved: better temporal coherence, tighter control of pulse synchronisation, greater intensity stability, shorter pulses, shorter wavelengths, tailored pulse structures, and so on. There are numerous schemes which have the potential to address one or more of the above but which have not yet been tested in practice. We propose to build a dedicated FEL test facility, called CLARA [1], so that several of the most promising schemes can be proven and subsequently be directly implemented into a new national light source facility from conception.

applicable to the future generation of light source facilities.

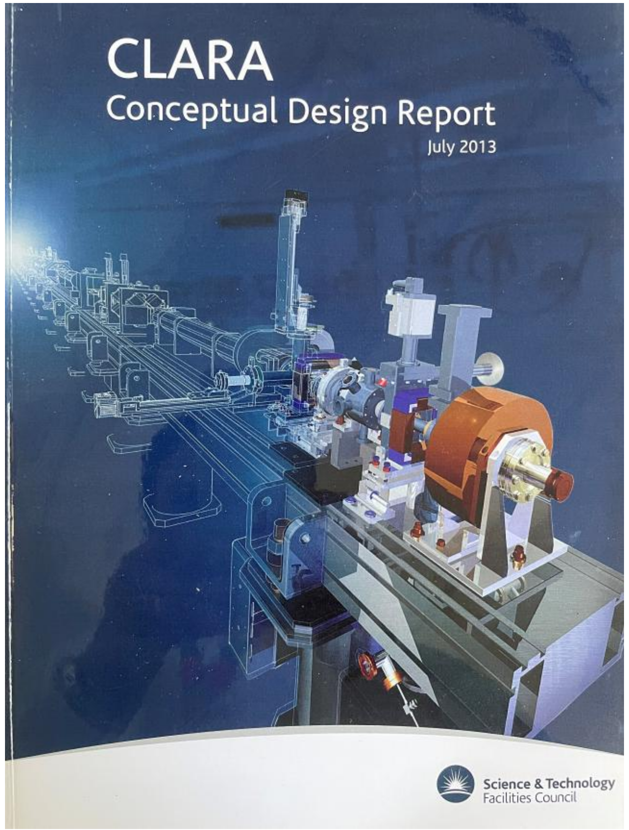
In the context of the above, stable means with little variation in transverse position or intensity from shot to shot, synchronised means the photon output pulse should be sufficiently well synchronised to a timing signal to simultaneously control a conventional laser used in a pump-probe experiment, and ultra-short means the photon pulse length should be shorter than, or of the order of, the FEL cooperation length.

There are a number of other aims and prerequisites to make maximal use of this dedicated test facility. These include:

- To lead the development of low charge single bunch diagnostics, synchronisation systems, advanced low level RF sysems, and novel short period undulators.
- To develop skills and expertise in the technology of normal conducting RF photoinjectors and seed laser systems.
- To develop novel techniques for the generation and control of bright electron bunches including manipulation by externally injected radiation fields and mitigation against unwanted short electron bunch effects (e.g. microbunching and CSR).
- To demonstrate high temporal coherence and wavelength stability of the FEL, for example through the use of external seeding or other methods.
- To develop the techniques for the generation of coherent higher harmonics of a seed source.
- To develop new photon pulse diagnostic techniques as required for single shot characterisation and arrival time monitoring.

Parameter Selection

The parameters of CLARA are dictated by the requirement to interact with conventional laser seed sources. The primary external radiation source will be a Ti:Sa laser operating at 800nm. This can be used on its



Electron Beam Test Facility (EBTF→VELA)

- We started exploring a possibility of designing a FEL test facility based on baseline NLS photoinjector at 1 KHz.

- Whilst these ideas are being explored and developed, ASTeC received 2.5 M funding from Capital windfall in 2011 (to be spent before end of March 2012!)

- Electron Beam Test Facility (Versatile Electron Linear Accelerator) based on a photoinjector was proposed by ASTeC.

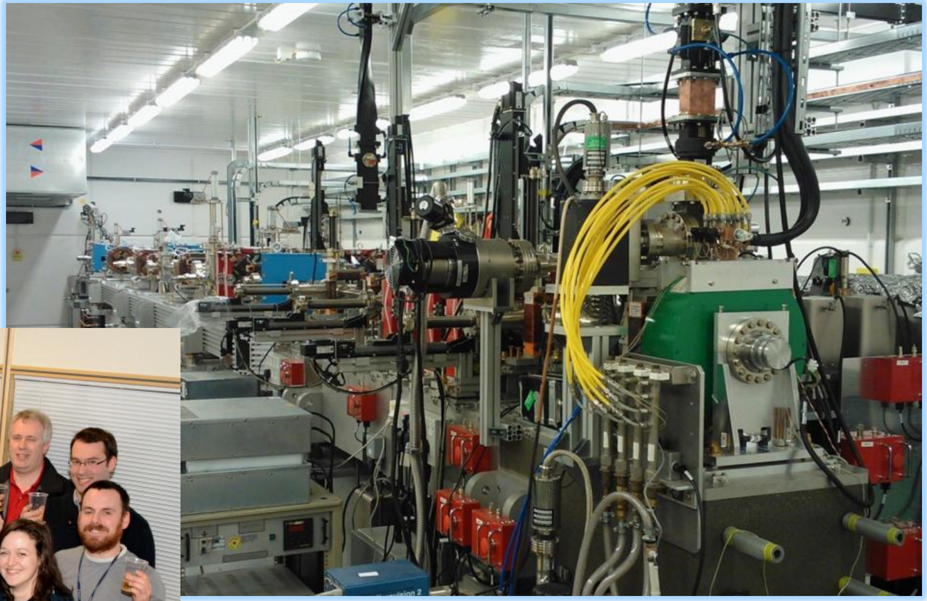
PM Confirms £10M Investment @ DSIC

"Nothing focuses the mind like 'spend it before end of March'.."

Versatile Electron Linear Accelerator

Accelerator design, technical systems specifications and Strathclyde gun …..
From funding announcement to first beam in less than two years!

First beam April 2013



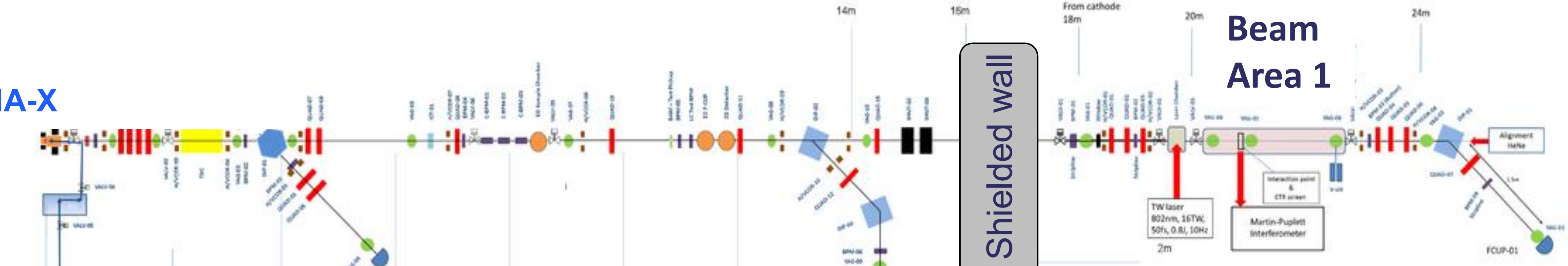
"We celebrated first beam briefly…and immediately followed by a long to-do list"

VELA Beam Delivery to Users

User exploitation experiments delivered from Sep’2013 – 2015 with 5 MeV beam.
First proof-of-principle Electron Diffraction experiments carried out.

“Experiments worked… which was both a relief and the start of higher expectations.”

10 Hz ALPHA-X gun from Strathclyde



Schematic of VELA

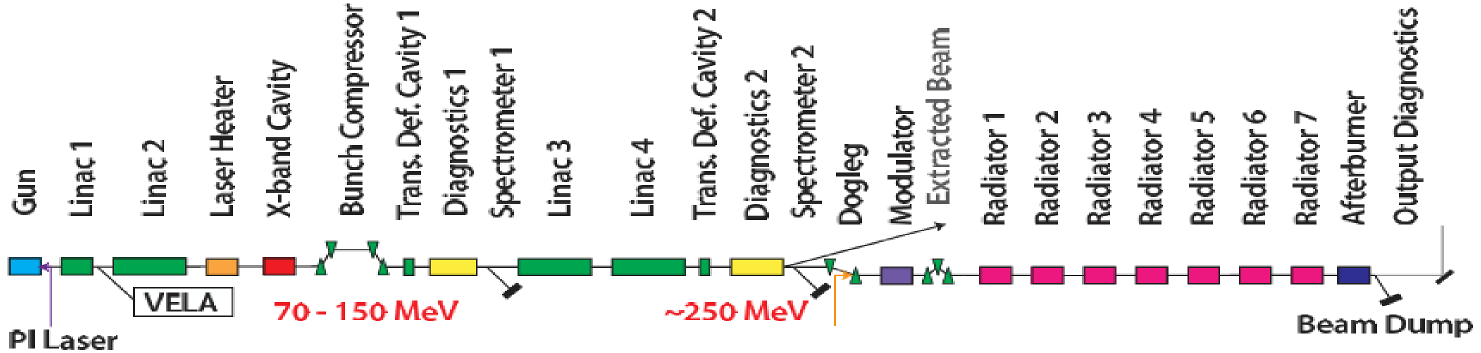
CLARA Front End (Phase 1) and VELA Beamlines

We had two highly successful user runs on CLARA Front End – 2018/19 and 2021/22.

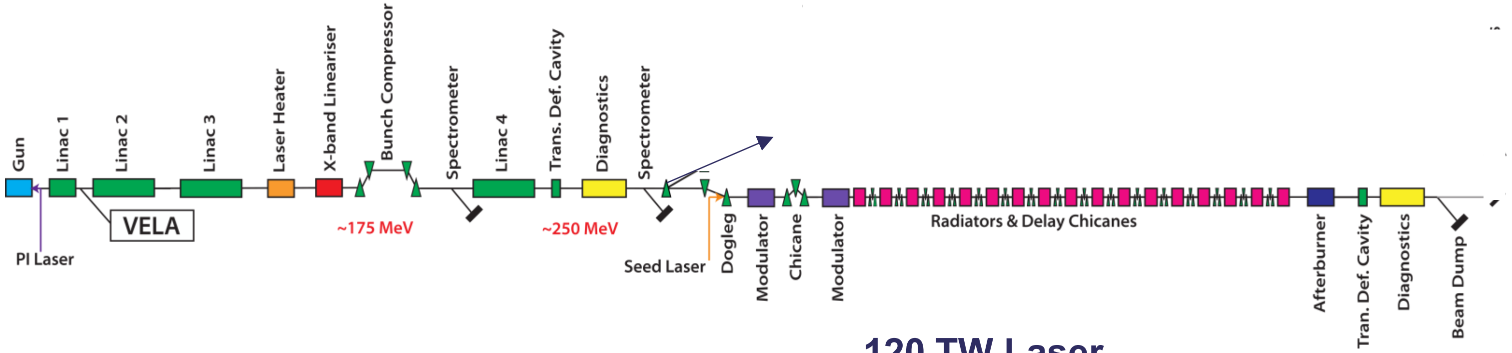
"Oversubscribed by a factor of two—which was very satisfying… and slightly stressful. It is when we realised that success means people want more beam time."

CLARA Evolution

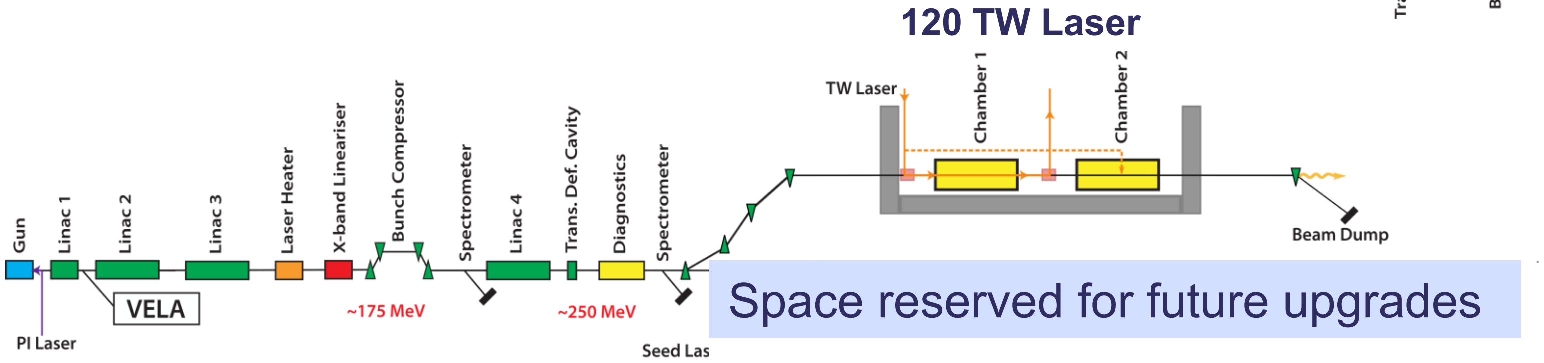
Many iterations were carried out for CLARA layout since CDR + FEBE line added in 2019



CLARA CDR Layout



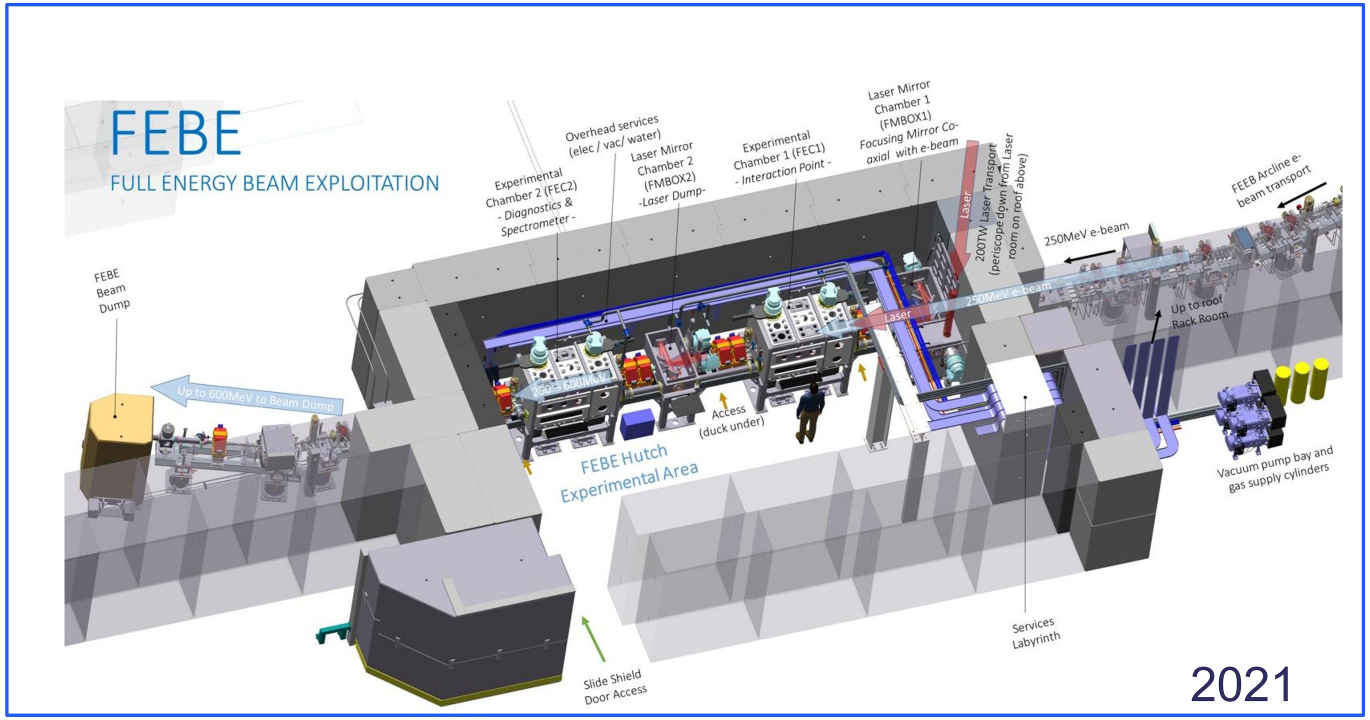
CLARA schematic before 2019



CLARA with FEBE - Current

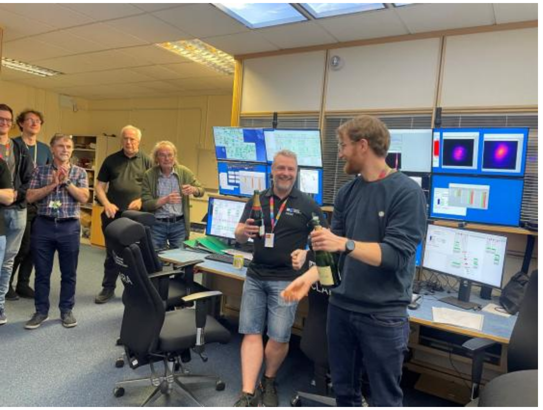
FEBE & New Capabilities

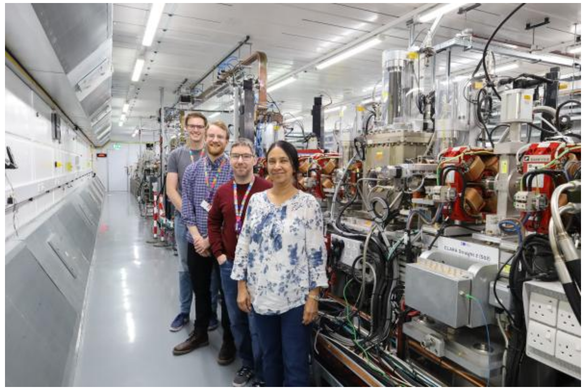
- FEBE beamline was approved ahead of Phase 3 (FEL). We started design of FEBE in 2018 with stakeholder engagement and lessons learnt for CLARA FE experiments.
- Design was reviewed in September 2020 before construction & procurement started.
- With impact/demand for high power laser, STFC approved funding for 120 TW laser in 2023.

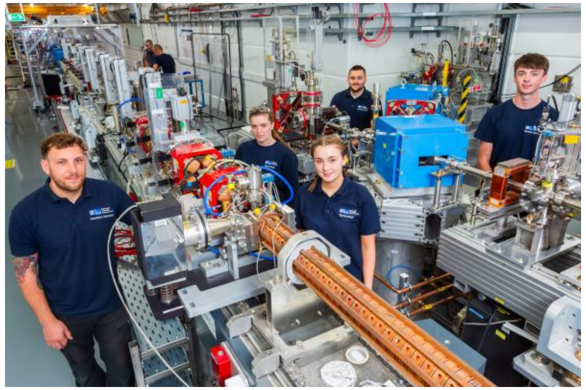


Incredible & Resilient CLARA Team

CLARA achieved full capability in 2025 - more than a decade after CDR was published.
Without the incredible CLARA Team this would not have been possible…..

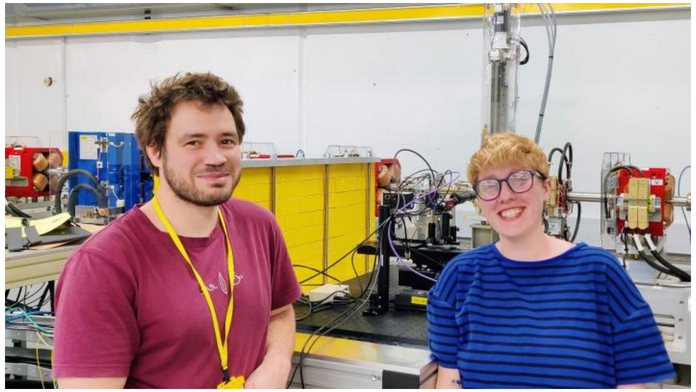


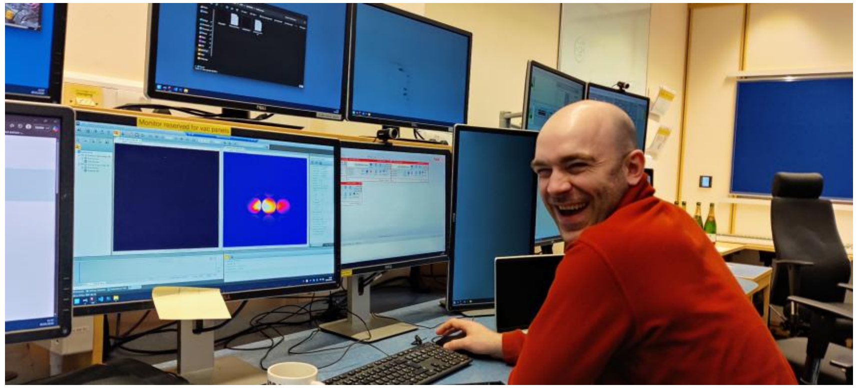


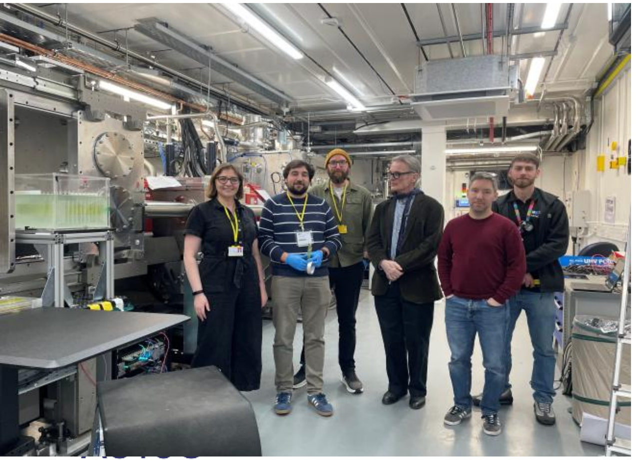


First CLARA User Experiments (2026)

The flexibility of setting variety of experiments in FEBE was fully tested and validated during friendly user run this year.



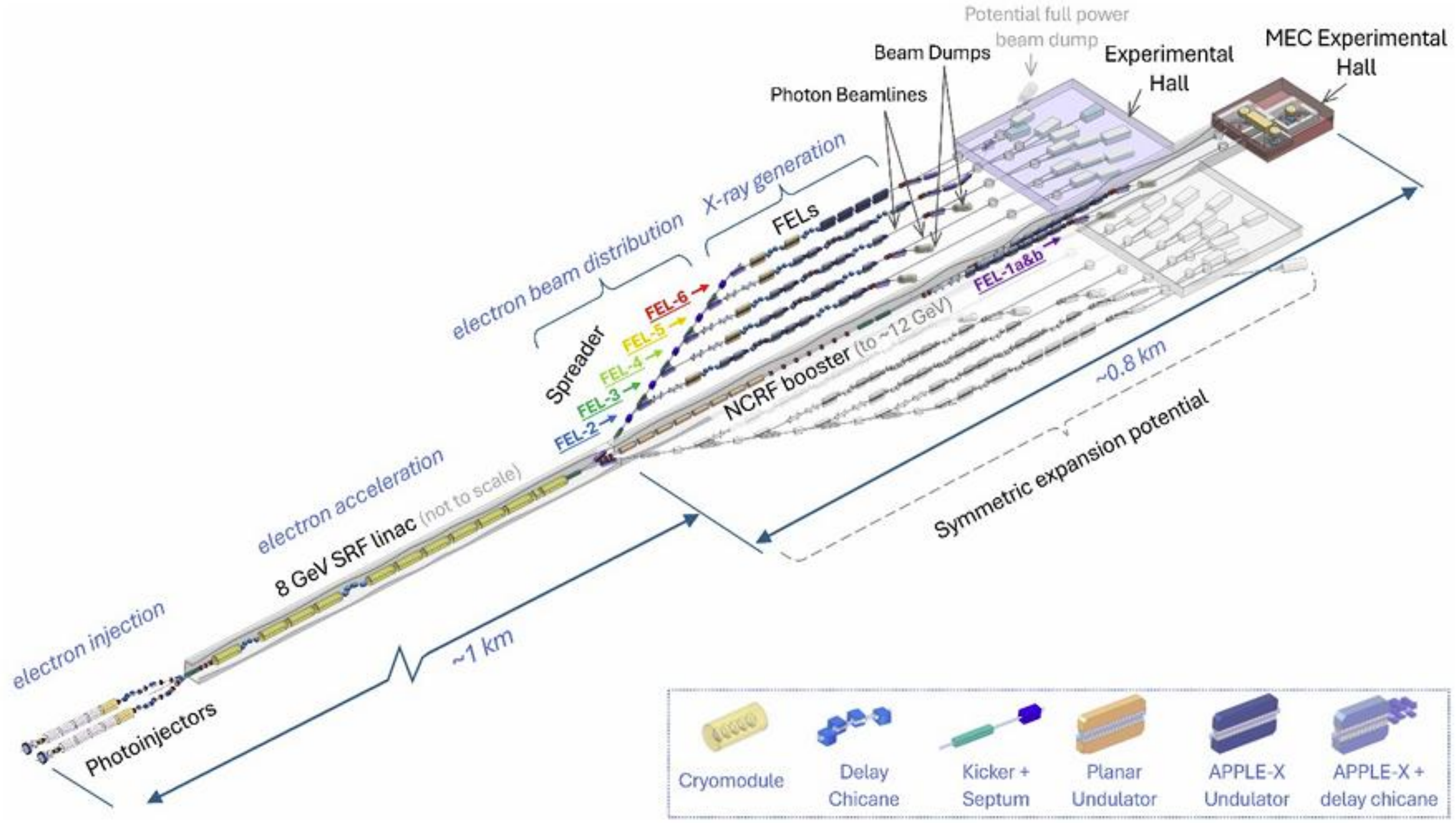




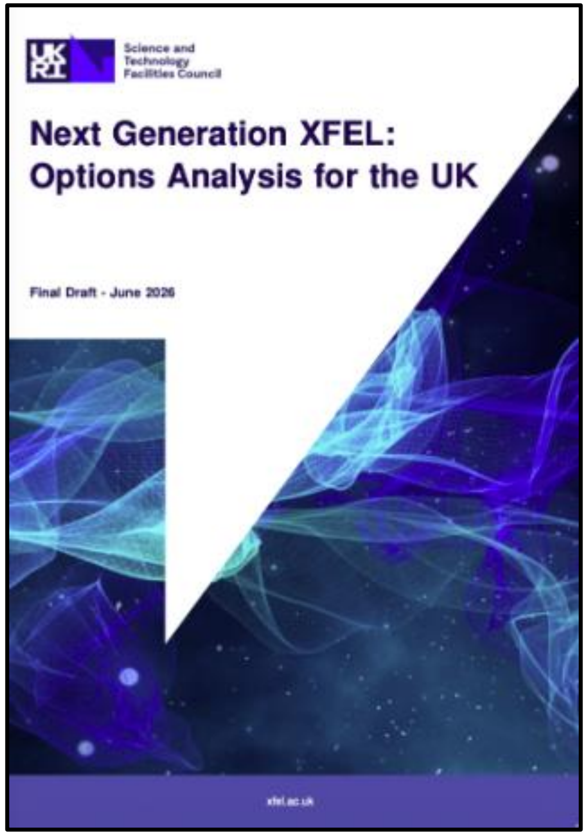
UK XFEL CDOA (2022 – 2025)

A compelling science case was published and the demand for hard X-rays clearly emerged.

We have developed a conceptual design for next generation XFEL while assessing strategic options to meet user needs.



UK XFEL CDOA



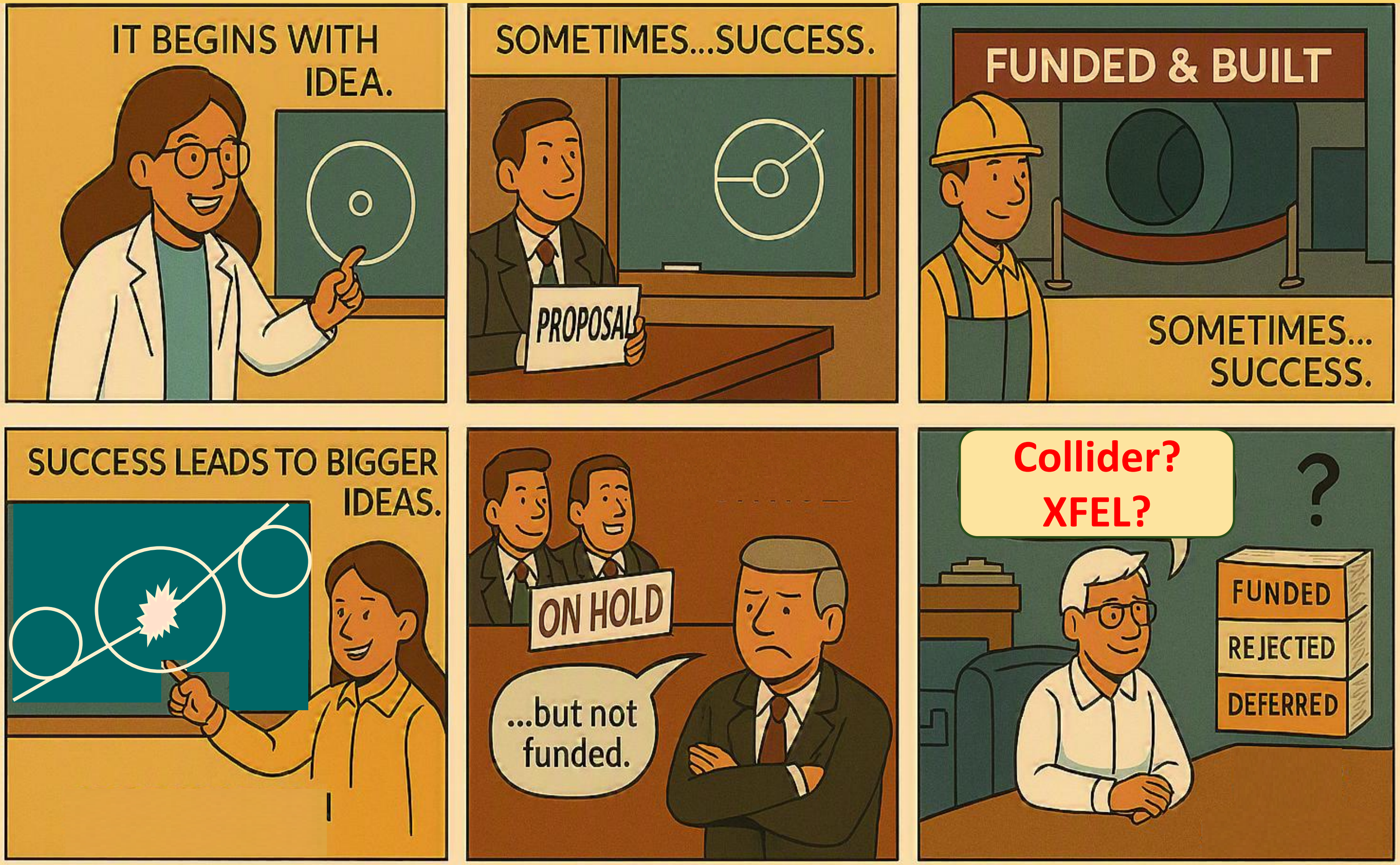
Over total 950 pages in total – to be published soon.

"Some people write novels—we write design reports."

Acknowledgements

- I have had the privilege of working across many laboratories and projects, alongside exceptional mentors, colleagues and collaborators.
- Every success has been the result of collaborative, cross-disciplinary teamwork, shared expertise, and collective effort.
- Along the way there were setbacks, moments of frustration and disappointment, and I am especially grateful for the people who helped me pick myself up and find motivation to move forward again – sometimes more than once.
- I am deeply grateful to those I have worked with over the years; there are too many to name, but each of whom has shaped my journey in meaningful ways.
- **My sincere thanks to the Institute of Physics Particle Accelerators and Beams Group for this award — it is a great honour and truly means a great deal to me.**

FOUR DECADES IN ACCELERATORS



"Four decades later, I am still discovering that accelerator projects take longer than expected."

Thank you for listening!