Proposal by Liverpool University to join the CDF Collaboration

P.Booth, A.Galloni, M.Houlden, R.McNulty
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Introduction to the Liverpool University Particle Physics Group

The physics department at the University of Liverpool has a long and distinguished history in the field of particle physics. The Particle Physics Group, which is one of the three largest in the UK, consists of 13 academic and 37 support staff. It is well supported by a Design Section and Mechanical Workshop, together with excellent in-house computing facilities and fast links to outside laboratories.

The Group is currently involved in the following high energy physics experiments:

ep physics : H1 and HERMES at HERA

ee physics : DELPHI at LEP

CP physics: CPLEAR, BABAR and LHCb

pp physics: ATLAS

Proposed Liverpool Personnel to work at CDF

Four Liverpool physicists (P.Booth, A.Galloni, M.Houlden, R.McNulty) are the principal applicants to join CDF. Together, they have considerable hardware and software experience in the use of Silicon Detectors at DELPHI, RD20 and ATLAS R & D. Consequently, after recent discussions at Fermilab, our proposal is to contribute in the areas of hardware and software, to both the baseline and beyond the baseline silicon projects within CDF.

In addition to the names mentioned above, a Post-Doctoral Fellow (G.Casse), with particular expertise on radiation-hard silicon development, will work full time on silicon hardware for 2 years.

The department will also provide design effort, mechanical workshop effort and technician support.

Details of Personnel and their time commitment to CDF are provided below :

Dr Ronan McNulty

Ronan McNulty will take up a permanent position at Liverpool from October 1st 1998, with the status of Senior University Research Fellow (equivalent to lecturer status but with 100% of his time for research). He has had five years postdoctoral experience, initially at Liverpool University as a Research Associate, then as a UK PPARC Fellow, and most recently as a CERN Fellow.

He has worked on DELPHI and was responsible for the alignment of the Microvertex Detector and the Outer Detector. He pioneered new tracking algorithms which led to large scale improvements in the reconstruction efficiency and purity and consequently the physics output. For example, the backgrounds for b-tagging were halved. He has built a data acquisition system for the RD20 collaboration to readout silicon detectors and to provide on-line graphical monitoring, perform pedestal and

background subtraction, identify hit clusters, and to sparcify and store the data.

He has measured the tau lifetime and tau neutrino mass and was instrumental in the tagging of b decays and the measurement of R_b by reconstructing secondary vertices. He was involved in searching for the Higgs decay to two B mesons. His silicon knowledge, DAQ, tracking, alignment, and b-tagging experience should be directly applicable at CDF.

He will spend 100% of his time on CDF with long term attachment at Fermilab.

Dr. Andrew Galloni

Andy Galloni completed his Liverpool Ph.D. in 1997 on the DELPHI experiment, taking as his thesis topic, the measurement of the hadronic spectrum of tau decays and a measurement of the tau neutrino mass. This work was dependent on the clean and efficient reconstruction of vertices in dense tracking environments, which again should be directly applicable at CDF. Since completing his PhD, he has been resident at CERN as a Liverpool Research Associate working on SUSY searches at LEP2. This has involved looking for characteristic low multiplicity topologies.

He has been responsible for the operation and data quality of the Outer Detector at DELPHI for the past 2 years. In addition, he has been involved in the setting-up and analyses of silicon test beam runs at CERN for RD20.

From October 1998, Andy will commit 100% of his time to CDF with long term attachment at Fermilab.

Dr. Mike Houlden

Mike Houlden has many years experience in software development for HEP experiments. He has worked on the DELPHI experiment since 1982 and was responsible for all the code development for the Outer Detector. He co-ordinated the development of the pattern recognition code

and tracking algorithms used for both on-line monitoring and off-line processing. He has also worked extensively on simulation studies and physics analyses for DELPHI, and more recently on simulation studies for ATLAS.

He has on-going responsibilities for the departmental HEP computing facilities as well as major responsibilities in ensuring effective network connections for the particle physics community, both within Britain and from
Britain to Europe and America. He was Chairman of the UK Particle Physics Network Committee from 1992 to 1997.

He will be involved in all aspects of software development at Liverpool, supervision of postgraduate students and preparations for physics analyses.

He will commit 50% of his total time to CDF and will visit Fermilab at frequent intervals to participate in all aspects of the data taking and to attend all necessary meetings.

Prof. Paul Booth

Since 1985, Paul Booth has led the Liverpool group working on DELPHI. He was responsible for the design and construction of the DELPHI Outer Detector (5 layer, 5m long, 2m radius, precision tracking detector) and has been involved at all stages of the development of the DELPHI Microvertex Detector.

From 1989 to 1994, he was DELPHI deputy spokesperson with the specific responsibility of overseeing all the on-line development and data-taking in the early years of DELPHI running. Together with his group members, he has been involved in a wide range of physics analyses, with particular emphasis on those physics channels using the Microvertex Detector to tag secondary vertices. Over the past 4 years he has also been closely involved in the R&D for the forward silicon tracking in ATLAS.

He will commit 50% of his total time to CDF and will be primarily based in Liverpool. He will provide the overall co-ordination of the

Liverpool effort both at CDF and in Liverpool and will be actively involved in all aspects of this work. He will visit CDF at frequent intervals to participate in the data taking and to attend all necessary meetings.

Dr. Gianluigi Casse

Gianluigi Casse has worked since 1996 as a Scientific Associate in the ECP division at CERN. He has been principally involved, within the RD48 Collaboration, on the development and testing of Radiation-Hard Silicon Detectors. Over the past 2 years, he has given 5 conference presentations and is co-author of 16 publications in Silicon Technology.

In October 1998, he will begin a two year Industrial Fellowship at Liverpool, in collaboration with Micron UK, to continue his work on Radiation-Hard Silicon Detectors and their performance.

He will commit up to 70% of his time to CDF as required and will be available to work with Micron on the Layer 00 sensors.

Liverpool Graduate Students

One new graduate student will be assigned to the CDF experiment in October each year for the foreseeable future.

The student will spend the first 6 months of their 1st year at Liverpool attending courses on HEP and learning about the CDF hardware/software, with occasional visits to Fermilab. The student will then spend between 12 and 15 months resident at Fermilab working on CDF before returning to Liverpool to complete their physics analysis and thesis preparation. Again, there will be visits to Fermilab to present their physics results to the CDF Collaboration. Whilst at Fermilab, the student will be supervised by a Liverpool physicist on long term attachment and will be expected to participate in all aspects of the experiment.

Support Staff

In addition to the academic staff mentioned above, we also have access to a number of support staff who can assist both with SVX II/ ISL projects and Layer 00.

The Departmental Mechanical Design Section is equipped with CAD and CAE facilities and can be used to design silicon modules, detector cooling and mechanical support structures, etc. Thermal and mechanical modelling of silicon modules and other structures can be undertaken using the ANSYS software package.

We will commit 1 Man-year/year of Design Effort to CDF.

The Departmental Mechanical Workshop is fully equipped to machine high accuracy components. The staff are experienced in the production of low mass, high accuracy components applicable to silicon detector arrays, having produced mechanical components for both the DELPHI Microvertex Detector and the ATLAS Silicon Module Development programme.

We will commit up to 1.5 Man-years/year of precision mechanical construction effort to CDF.

In addition, up to 2 man-years/year of high level technical effort, with expertise in silicon hardware, is available at Liverpool. For example, to work on sensor testing, prototype module assembly, module testing pre- and post- irradiation for Layer 00.

Summary of Personnel

The following table summarises the people involved in our proposal. All the numbers are averaged over three years, except for G.Casse who currently has a fixed term 2 year Fellowship at Liverpool from Oct. 1998.

Summary of effort /year for next 3 years

Name	Title	% of total time available for research	% of research time on CDF	Other Projects & Duties	FTE CDF
R.McNulty	Sen.Fellow (perm. posn.)	100	100	None	1.0
A.Galloni	Post-doc	100	100	None	1.0
M.Houlden	Sen.Lect.	70	70	ATLAS	0.5
P.Booth	Prof.	100	50	DELPHI ATLAS	0.5
G.Casse	Industrial Fellow(2 years)	100	70	Generic Si R&D	0.7
	Grad. Students (one/year)	100	100	None	X

Liverpool plan to maintain a permanent presence at Fermilab of at least 1 physicist and at least 1 graduate student with the other physicists commuting frequently to participate in all aspects of the experiment.

Liverpool Hardware Facilities and Experience with Silicon

The Liverpool Group's experience in silicon includes :

The DELPHI Microvertex detector - detector specification, hybrid design, mechanical mounting, cooling, surveying .

CERN RD20 and RD48 projects - design and testing rad-hard detectors

ATLAS Forward Silicon Tracker R & D

LHCb Vertex Detector R & D

We have existing facilities and infrastructure at Liverpool for building and testing silicon detectors. Also we have in-house mask design capability using Cadence, which has been used to design both p-in-n and n-in-n devices, subsequently fabricated by both Micron and Hamamatsu. These detectors have been fully tested both pre- and post radiation at doses up to $3x10^{14}$ (1 MeV neutron equivalent) /cm^2. The subsequent time-dependent annealing properties have also been studied.

Silicon Laboratory Facilities

The Departmental silicon facilities, available to CDF, are situated in 2 clean rooms housing :

1 automatic and 1 manual bonder

1 automatic and 1 manual probe station

Precision apparatus for module assembly

Electronic stations for binary and analogue readout

2 Keighley Source Measuring Units and Wayne-Kerr variable frequency CV meter (operating under Labview)

3 Faraday cages

1 Infra-Red (1064nm, 5ns) pulsed laser test station

Cosmic and Source test stations

Digital oscilloscopes and microscopes

Cadence mask design software

3 PC's and DEC-Alpha workstation + links to HEP farm

Environmental cold chamber for testing irradiated detectors

Low mass hybrid design and test facilities

Liverpool Software Experience with Silicon

The Liverpool applicants to CDF were responsible for formulating the ideas and developing the algorithms which were used to align the DELPHI Microvertex Detector. We specifically addressed questions concerning intrinsic resolution, mechanical stability and detector geometry, and produced excellent alignment parameters, resulting in an impact parameter resolution of 21 microns for hard tracks. This work led us to being the first group at LEP to directly observe the beam profile, providing important feedback to the machine physicists. It also led to the first LEP measurements of the tau and B lifetimes.

A further task which Liverpool initiated and developed was the complete rethink of the tracking strategy and the redesign of the tracking algorithms. Rather than attach the vertex detector points to existing tracks, the track search and fit took full account of the information in the vertex detector. The physics gains from this improvement were large, for example, a doubling of reconstructed $D^{*+} \rightarrow (K^- \pi^+ \pi^- \pi^+) \pi^+$ decays and a doubling of reconstructed 3-prong tau decays. Most notable for b-physics and Higgs searches was a 50% improvement in b-tagging efficiency at a given purity.

Members of the Liverpool team to CDF have also worked extensively on the development of b-tagging algorithms and successfully employed them in the recent DELPHI measurement of R_b, accomplished by reconstructing events with both single and double secondary vertices.

Proposed Initial Programme of Work within CDF

Following discussions during August with the CDF Management and Project Leaders, and taking into consideration the experience of our group, a number of tasks have been identified to us, where we could quickly and usefully contribute to the Run 2 effort .

A possible initial programme of work for the group, to be carried out in a combined effort with other groups (who may already be working, or planning to work, on them), is outlined below:

Layer 00

Optimisation of Pitch - for occupancy, resolution and 2-track separation in hard B jets.

Optimisation of Rad-Hard Detector Design (with Nicola Bacchetta)

Mask Layout (if required)

Prototyping

Testing Pre- and Post- Irradiation.

Module testing with remote hybrid

Final Sensor Production and Probe Testing.

Provision of the sensors for Layer 00.

This programme of work will be conducted at Liverpool and will involve setting up the 'Burn-in PC based Data Acquisition System'. The irradiation will take place at the CERN PS.

The time scale envisaged for this work is:

Final Sensor design by	Feb. 99
Prototype/ Rad. Test	Oct. 98 to May 99
Final Sensor production and testing	May 99 to Aug. 99

Design and Mechanical Construction

Liverpool will provide 1 man-year/year of high level mechanical design effort and 1-1.5 man-years/year of precision machining effort to work in the areas of ISL/SVX II/Layer 00 as prioritised by CDF.

Commissioning the SVX II / ISL /Layer 00 at Fermilab

In parallel to the hardware/software work at Liverpool, we aim to have a continuous presence of at least 1 physicist and 1 graduate student at Fermilab. They will integrate fully into the work necessary to build and commission the silicon system prior to installation. Initially, we expect that this work will involve issues concerning SVX II / ISL and should eventually allow for the incorporation of Layer 00 into the system.

A possible time-ordered sequence of work, which is subject to change as required by the priorities set by the Project Leaders, and which will be undertaken in a combined effort with other groups, is outlined below :

Testing of SVX II / ISL / Layer 00 ladders.

DAQ Commissioning and System Testing for SVX II / ISL /Layer 00.

Data Base Commissioning for SVX II / ISL / Layer 00.

Monitoring for SVX II / ISL / Layer 00 if required.

SVT Alignment / Monitoring if required.

Development of Tracking Algorithms if required.

We envisage that software for some of the above tasks can also be developed by the physicists not on long term attachment at CDF.

Data Taking

The Liverpool applicants want to take part in all aspects of the data taking, including undertaking specific responsibilities for certain hardware and/or software support and maintenance. This will involve the long term attached Liverpool physicists at CDF, graduate students during their 12 - 15 month term at Fermilab and physicists commuting from Liverpool.

Liverpool ‘in-kind’ contribution to CDF

The salaries plus associated overheads for 1 Design Engineer/year, 1 Mechanical Machinist/year and 1 Hardware Technician/year represent an ‘in kind’ contribution of 150K US dollars/year to CDF.