Polarized RF Guns for Linear Colliders
An ICFA Workshop
Fermilab, April 18–20, 2001

1 Introduction

The ICFA Workshop on Polarized RF Guns for Linear Colliders was held at Fermilab during April 18-20, 2001. It was attended by 37 scientists from 14 institutions. A list of participants is appended.

An RF photoemission gun that delivers polarized electrons at low emittance would be an attractive electron source for a linear collider. Moreover, recently it has been demonstrated that an RF gun in conjunction with nearby injection system optics can deliver a beam with a high ratio of transverse emittances; a simplification of a linear collider's damping system could result.

However, at present RF electron gun technology has not developed sufficiently to assure that such a source is feasible. The purpose of the workshop was to review the status of polarized RF gun development with linear collider application in mind, and outline a possible program for the future. Tab. 1 lists the requirements for the electron injector for proposed linear colliders. The specifications are given for the beam before and after the electron damping ring.

The NLC and JLC are based on the use of DC polarized sources of the SLC type. For the TESLA and the CLIC designs, the injected emittance values shown (for the beam entering the damping ring) are for an RF gun. Both designs have damping rings which can accommodate the larger emittance coming from a DC polarized electron source, and both designs refer to the SLC polarized electron source as a possible option. In all cases the lower emittance of an RF gun would significantly ease the requirements on the damping rings; reducing the length of wiggler required and allowing a reduced ring aperture. In the extreme case, if the emittance from an RF gun system could be made low enough, the need for a damping ring would be eliminated. A significant *caveat* applies to the preceding two sentences, of course: is the additional desire for polarization achievable without degradation of the other virtues of RF guns?

In the following sections, we comment on the status of RF guns in general and as polarized sources in particular, list the R&D issues involved in bringing present status into compatibility with collider requirements, discuss a number of these issues in more detail, and finally put forward a parameter list for a Proof of Principle Demonstration with suggestions for next steps.

Table 1: Parameters of a variety of proposed linear colliders

	NLC	JLC	TESLA	CLIC
Number of bunches/train	95	95	2820	154
Bunch spacing (ns)	2.8	2.8	337	0.66
DR energy GeV	1.98	1.98	5	1.98
Charge per bunch (nC)	2.56	1.9	3.2	1.0
Injected emittance (mm-mrad)	100	100	10	7
Damped beam emittance (h)	3	2.6	8	.43
Damped beam emittance (v)	0.03	0.004	0.02	0.003
Damped beam bunch length (ps rms)	13.3	16.6	20	10
Damping time (ms)	5.2	3.9	50	21
Damping cycles	4.8	4.8	4	6
Bunch trains per ring	3	3	1	12
Repetition rate (Hz)	120	150	5	100

2 Current Architectures

2.1 RF Guns

A possible candidate for the production of spin polarized electrons is the 1.6 cell S-Band RF gun which was designed, manufactured, and tested by the BNL/SLAC/UCLA RF Gun collaboration. There are nine copies of the prototype 1.6 cell RF gun in operation throughout the world. In addition, there are three 1.6 cell RF guns in the manufacturing pipeline.

The 1.6 cell RF gun is a π-mode standing wave structure operating at 2856 MHz. The shunt impedance is 46 MΩ/m, with an unloaded Q of 11285.3, and the loaded Q is 5607. The RF gun was initially baked out at 450 C for 10 days. The base pressure after RF processing was 10^{-10} Torr without RF power. The RF guns operational pressure with 15 MW of RF power in 2 μs at 3 Hz rep rate was measured to be 10^{-9} Torr. Clearly the pumping speed needs to be improved upon by 2 orders of magnitude to make the 1.6 cell RF gun a viable RF structure for the production of spin polarized electrons. Vacuum pumping of the 1.6 cell RF gun is limited due to the use of the RF power coupling as the vacuum pumping ports. The strict vacuum requirements of a spin polarized DC gun is the driving parameter for the serious consideration of an L-Band PWT RF gun as a candidate as a polarized RF gun. Concerns related to high-gradient operation (e.g. dark current, GaAs energy band pulling) probably preclude the standard 1.6 cell photoinjector design at S-Band or shorter, and may pose difficulties at L-Band.

Cathode gradient concerns may be addressed by the split photoinjector design, e.g. lower field in the cathode cell than the full cell. The basic split photoinjector design also has potential problems from pumping speed concerns. This may in part be addressed by the use of a higher-order mode cavity to mimic the on-axis field profile while removing all internal obstructions.

2.2 Plane Wave Transformer

The Plane-Wave Transformer (PWT) design, in which accelerating cells consist of iris-loaded disks suspended by coolng pipes in a large cylindrical tank, provides a large vacuum conductance and strong cell-to-cell coupling. An S-band PWT photoelectron linac recently manufactured by DULY Research and installed at UCLA has an expected normalized emittance on the order of 1 μm for a 1 nC bunch charge with a peak field of only 60 MV/m. This 10+2/2 cell, 60 cm long, integrated PWT photoinjector provides an average accelerating gradient 30 MV/m with an input RF peak power of 20 MW. Because of its low peak field and good vacuum pumping, an S-band or L-band PWT gun may be suitable for polarized electrons. It may be possible to further improve the vacuum coating on the tank wall and vacuum ports with a thin film of getter material such as TiZrV. Separation of tank and accelerating cells for the standing wave structure allows a longer filling time which may mitigate RF breakdown. Diamond turning surfaces may be easier to accomplish with the open PWT structure. Use of Class-1 OFHC copper forged with the HIP method is recommended For a scaled L-band PWT with a long RF pulse and high repetition rate, adequate cooling must be provided. In addition, a load-lock is essential for GaAs photocathodes to avoid backfilling the gun once it is RF processed.

2.3 DC Guns and Hybrid Injectors

DC polarized guns, while a relatively mature technology, show promise of reaching significantly higher cathode field strengths and gun voltages in the near future. This is due to recent improvements in the reduction of field emission from the cathode electrode and its structure support, and to the development of ceramic insulators capable of draining off the small charge deposited by field emitted electrons. Cathode field strengths of 20 MV/m or higher and total gun voltages of 750 kV or higher appear possible.

If the above DC field strengths and gun voltages are demonstrated, a careful assessment of the utility of a DC gun for the present application should be done. The issue to be addressed is how best to produce the required bunch charge within the specified transverse and longitudinal phases space. Injector designs based on both technologies appear capable of meeting the required beam properties, the choice will rest with the technological risks and uncertainties of the two methods. It may be that a hybrid injector, based on a DC gun followed by RF acceleration is an optimum choice.

In existing DC guns, the operational lifetime of a negative electron affinity GaAs photoemission cathode is limited only by ion back bombardment. Thus the cathode lifetime is not sensibly expressed in terms of clock hours, but rather in terms of the number of coulombs delivered per unit illuminated area to reduce the quantum efficiency to $1/e$. In polarized guns in operation at the Jefferson Laboratory, this lifetime is above 2×10^5 coulombs/cm^2.

Bruce Dunham has carefully measured the thermal emittance provided by a GaAs photocathode as a function of illumination wavelength. The result is that the normalized emittance is given by:

$$\varepsilon_{n,rms} = \frac{r}{2}\sqrt{\frac{E_{thermal}}{mc^2}}$$

with $E_{thermal} = 35$ to 40 meV. This is equivalent to the electrons being emitted from a thermalized population of this energy, and a uniformly illuminated spot of radius r. Emittance compensation functions as well with a DC gun as with an RF gun.

2.4 Experimental Status of RF Guns as Polarized Electron Sources

RF guns have already demonstrated many advantages for producing intense electron beams with low emittance and high brightness. For some years it has been recognized that it would be very attractive to use such a source to produce polarized electrons. Using activated GaAs photocathodes it should be possible to produce electron beams with polarization up to 90%. But till now, very few experiments have been performed with a GaAs photocathode inside an RF cavity. These experiments have demonstrated that this type of photocathode needs particular attention.

First, in common with RF guns in general, the high electric field at the cathode increases the probability of damaging breakdown and increase of dark current which reduces the the lifetime of the photocathode. Second, it is not easy to obtain adequately good vacuum (in the range of 10^{-12} Torr) due to RF power induced gas desorption; this implies that high pumping speed be a design consideration.

The experiments demonstrated:

1. Activated photocathodes can perform in strong accelerating RF fields up to 100 MV/m without irreversible damage.

2. Dark current from an activated negative electron affinity (NEA) bulk GaAs photocathode exceeds by 2-3 orders of magnitude dark current of a positive electron affinity (PEA) photocathode. For instance, the dark current from an OFHC copper photocathode in the accelerating field E=45 MV/m, 1 ms pulse duration delivers Q=0.1 nC/pulse, whereas a bulk GaAs photocathode activated till PEA in an RF accelerating field of the same strength delivers 0.5 nC/pulse. A bulk GaAs photocathode activated till NEA in the RF accelerating field E=21 MV/m, 2 ms RF pulse duration delivers dark current Q=22 nC/pulse..

These early results, though encouraging, illustrate that an R&D program is required for further progress.

3 R&D Issues

3.1 Summary

- Charge output: Can sufficient charge be brought off of the semiconductor cathode in a small spot (emittance) in a short pulse, and in a pulse train? (unexplored territory)
  - Emission time
  - Impacts on Surface Charge Limit
  - Bulk charge depletion, is this any different than the case of Cu or CsTe photocathodes?
- Is there a better cathode/surface treatment
  - much effort has gone into higher DC polarization.
  - What about better vacuum integrity?
  - Does an NEA photocathode emit dark current at the high gradients?
  - Do we need to develop a stable PEA (other than III-V) photocathode?
- Cathode polarization
  - in a magnetic field
  - in the presence of the RF field, needs a working system?
- Dark current
  - Can a gun operate at sufficient gradient with low enough dark current - what is low enough?
  - Studies of clean structures, good materials
  - RF choke joint: is this a problem or are there solutions?
- RF Processing
  - How can a fresh cathode be brought into the gun without having to repeat RF processing -or- how high can one go without re-processing?
- Vacuum: baseline and pulsed pressure limits
  - Cleaner materials and processing (HIP Cu and di-ionized water rinsing
  - Open structures for high pumping conductance, the UCLA/DULY PWT gun is an example
  - Cryopumping
- Polarimetry at a few MeV (e.g., JLAB Mott, 5 MeV, 172 degrees backscatter)

- Lasers
    - Are there perceived limitations to laser performance?
    - How difficult are the proof of principle lasers (do not need stable performance)?
    - What are the basic concerns in this regard?

3.2 Charge Output

When the semiconductor photocathode is excited with high intensity light, the total emitted charge does not increase proportionally with the light intensity and saturates well below the space charge limit of the gun. This phenomenon, called the surface charge limit (SCL) effect, is attributed to the photovoltage that builds up in the band bending region when the photo-electrons are trapped at the surface. The photovoltage induces a rise in the electron affinity, resulting in a lower photoemission probability and thus less emitted charge at later times. The electron affinity can recover to the zero charge limit after the trapped electrons recombine with holes through the band bending region.

The problem of the SCL is important for operation of polarized electron cathodes in next generation linear colliders. For example, the present NLC design requires a train of 95 micro bunches each having 2.8×10^{10} particles in 0.7 ns with an interbunch spacing of 2.8 ns. While experience at the SLC has shown it is possible to generate 1.6×10^{11} in 2 ns with $\approx 80\%$ polarization, the required total charge for the NLC is two orders of nagnitude higher than the SLC case and the 266 ns-long buch trains may experience stong intensity damping.

There has been significant progress in understanding and mitigating the SCL. Recent measurements at SLAC have shown the photovoltage effect is strongly dependent on the doping concentration, diminshing to zero at $5 \times 10^{19}\mathrm{cm}^{-3}$. The Nagoya group has shown the superlattice structure has much improved charge performance. Charge enhancement is also observed when the GaAs surface is covered with a metallic grid which shunts the trapped surface charge. The SCL increases with both cathode QE and bias voltage. Due to the Schottky effect, the QE increases with cathode bias. Since RF guns operate with much higher extraction field, the SCL is expected to be higher.

While the emission time in Cu or CsTe photocathodes is sub-ps, the time response in semionductor photocathodes may be much longer. Recent measurements at Mainz of the electron emission time from a thin (100 nm) strained GaAsP photocathode show an emission time of 2.8 ns using a DC gun biased at 100 KV, indicating the response-time in semiconductor photocathodes is not an issue for RF guns.

3.3 Is there a Better Cathode/Surface Treatment?

The high polarization values already achieved in DC guns should be equally achievable in RF guns. However, the vacuum environment in operating RF guns is presently a serious problem. The vacuum is one of the principal indicators of what the quantum yield, Y, and yield decay rate, dY/dt, will be. A low Y and/or high dY/dt results in the need for higher laser energy, which requirement can quickly exceed existing technical capabilities. A low Y may also invoke the surface charge limit (SCL), although very likely this effect can be effectively supressed by appropriate cathode design. Improvement of the vacuum is discussed elsewhere, but the cathodes themselves can possibly be made more robust by operating them with near-zero electron affinity (PEA) mode or by developing a protective film (perhaps by substituting K for some of the Cs in the activation layer, or by developing and analog to the CsB coatings sometimes used for Cs_2Te cathodes). Both of these approaches will significantly decrease Y. A second indicator of cathode performance is degree of dark current. In an RF gun some fraction of the dark current is back accelerated into the cathode. Initial experiments with GaAs in RF guns have been accompanied by excessive dark current that in turn has led to a very rapid decrease in Y. The mechanism by which this dark current is generated needs to be understood. In particular, the question of whether a negative electron affinity (NEA) cathode emits excessive dark current needs investigation.

3.4 Spin Polarization and Polarization Preservation

There has been significant progress in generating electron beams of high polarization from DC photocathode guns at many laboratories around the world. Beam polarization greater than 80% has been produced and used in physics experiments. The preservation of the polarization through the accelerator and transport beamlines is calculable and understood. The polarization of electrons in very short pulses (as required by RF guns) has also been measured at high values. For the generation of a flat beam from an RF gun an axial magnetic field is required at the photocathode. This is contrary to the earlier convention in both RF and DC guns in which the axial magnetic field at the photocathode is deliberately cancelled. The polarization of an electron beam produced by a photocathode placed in an axial field needs to be measured to insure that no unanticipated effect exists.

3.5 Dark Current

Dark current is a vexing problem in RF guns as noted elsewhere in this report. The identification of the sources is incomplete and deserves continuing study. The L-band guns installed in the TESLA Test Facility at DESY and in the Fermilab/NICADD Photoinjector Laboratory (FNPL) at Fermilab are identical in construction. Yet observations concerning the sources of dark current differ at the two sites. At DESY, the spring that holds the cathode in place is suspect; at Fermilab, an experiment has identified sources in the emission region of the cathode. In the latter case, it is desirable that the cathode be removed soon and subjected to micorscopic exmination.

The variation of both dark current and quantum efficiency with time depending on axial field at the cathode observed at FNPL deserves study. Typically, these two quantities increase with running time in the normal (i.e., zero axial magnetostatic field at the cathode), while the reverse is the case when the axial field associated with flat beam generation is present. This behavior is not understood.

3.6 Vacuum

From the experience of DC guns for polarized electrons, the required operative pressure is in the 10^{-12} Torr range in a residual gas mainly composed of H_2, CH_4 and CO. These gases go not react with GaAs photocathodes but they are a source of ion back-bombardment during cathode operation. The pressure of reactive gases, like O_2, H_2O and CO_2, must be an order of magnitude lower. In these conditions, photocathode operative lifetime is very long.

The present status of RF gun technology provides operative pressure in the 10^{-9} Torr range, which is not compatible with GaAs photocathodes. To obtain similar vacuum conditions as in DC guns, efforts are necessary in different fields. "New" materials (as HIP Cu) and better cleaning processing must ensure lower field emission and better vacuum condition. Distributed NEG pumps (Zr-Ti thin films, activation at 200 C) can be sputtered on the gun inner surfaces to overcome the limited conductance of the pumping ports; NEG strips can be used in the pumping tube.

"Open" structures, like the Plane Wave Transformer (PWT) gun, allow a more efficient pumping (also with NEG films). A PWT, with slots in the outer tube, can be contained in a larger vacuum vessel that can be pumped more efficiently.

A separate GaAs cleaning/activation chamber is needed with a proper load/lock valve and manipulator for photocathode replacement to avoid any system venting.

3.7 Polarimetry

Two polarimetry methods appear adaptable for use at the beam energies and time structure anticipated from a polarized RF gun/injector - Mott scattering and Møller scattering. Mott scattering is elastic electron scattering from a heavy nucleus, typically gold. Møller scattering is from the polarized electrons in a magnetically saturated thin foil, typically supermendur.

Mott scattering has been measured to 8.2 MeV at JLab, and to 14 MeV at Mainz (MAMI) and is likely practical to about 20 MeV. The Mott analyzing power is large only at very backward scattering angles. At 5 MeV, the analyzing power maximum, 52%, is reached at 172.5 degrees. As the beam energy increases, the angle of maximum analyzing power movers closer to 180 degrees. It is not necessary to reach this angle, however. The MAMI measurements were made significantly away from the angle of maximum analyzing power. The short duration, low repetition rate beam pulses will require that an integrating technique be used for scattered electron detection.

The Møller analying power is maximum for electron-electron scattering at 90 degrees in the center of mass. Both the scattered electrons thus carry half the incident beam energy in the lab. Coincidence detection is impractical for high charge, short duration bunches, requiring an integrating detector. Magnetic separation will be necessary to isolate the Møller scattered electrons. The maximum Møller analyzing power is small, typically about 6%, principally because only about 7.5% of the target foil electrons are polarized. Møller polarimeters have typically been used at energies well above those of the RF gun/injector.

Careful simulation and detector design will be necessary to obtain reasonable precision from either type of polarimeter. A number of systematic effects will need to be carefully considered in the design of either type of polarimeter.

3.8 Laser

Basic design issues of a laser system for a polarized electron RF gun are much the same as those for the unpolarized variety: the wavelength, the pulse energy, pulse length, and requirements on synchronization with the RF of the gun. Independent of the specific use of the polarized source, the wavelength of the laser has to be chosen to maximize polarization. For a standard SLC type cathode, a 100 μm layer of strained GaAs, the wavelength required is 845 nm, where the bandwidth should not be more than 1 nm. It is desirable that the laser is tunable between 780 nm and 880 nm to adjust the polarization.

The quantum efficiency for highest polarization is 0.1%. As an example, 5 μJ of laser energy is required to produce a 3 nC electron bunch. The laser has to be synchronized with the RF to better than 1 degree in phase. For S- or L-band guns this translates to 1 or 2 ps respectively. The laser pulse length should not be much longer than several degrees in RF phase. A sigma of 10 ps is a reasonable choice in terms of beam properties.

Actively mode-locked solid state lasers are naturally synchronized, since they are locked to an external RF source. A commercially available solid state laser material, which can be mode-locked and is tunable in the wavelength range around 850 nm is Ti:Sapphire. Other candidates are Cr:LiCAF or Cr:LiSAF, and some other materials which are less common. Ti:Sapphire is the prime choice, since lasers based on this material are well developed and commercially easily available.

For a polarized RF gun test stand, a single pulse laser may be sufficient. Such lasers are commercially available. In addition, pulsed diode lasers tuned to the correct wavelength may be sufficient for certain experiments. Laboratories which run RF guns may have a laser system based on Nd doped materials like Nd:YLF or Nd:glass. A conversion of their second harmonics (523 nm) to 850 nm using optical parametric methods with, for instance, an optical parametric oscillators (OPO) is possible and has to be considered.

However, for linear collider applications, long pulse trains are required, which makes their specification to be so demanding that these laser systems require a considerable R&D effort. For instance, TESLA requires 3000 pulses in a train of 1 ms length at a repetition rate of 5 Hz. For 5 μJ per pulse, the average power within the pulse train sums up to 15 W; the overall average power is 75 mW. These numbers are demanding, but well within the reach of present technology.

3.9 Two-Photon-Excitation

A new type of polarized electron source using a two-photon excitation process was proposed by the Nagoya group to solve the NEA lifetime problem observed in RF-guns. This method has two advantages, 1) two photon adsorption can give enough energy to conduction electrons to escape into vacuum through the PEA surface, and 2) the bulk-materials can give the highest polarization.

The high electron polarization inside the GaAs crystal was already confirmed by the circular polarization measurement of photoluminescence, where the average polarization was about 60% and the initial polarization was estimated to be about 95%. The preliminary experiment to produce the polarized electron beam by a DC-gun also gave hopeful results.

Further studies are required to enhance the probability of the two photon absorption process for high intensity and high polarization. The development of laser system with an ultra-short pulse width and an appropriate wavelength is indispensable for application to the polarized RF-gun. A semiconductor material search with LEA would also be required.

4 Proof of Principle Demonstration

4.1 RF Gun Parameters

Tab. 2 lists the beam output parameters which constitute the minimum performance for an R&D polarized RF gun system which could be adapted for use as the primary electron source of a linear collider. Once achieved, the demonstration system would serve as a platform from which further development could be based. This additional required development includes the generation of full bunch trains, full repetition rate, proper bunchlengths, and charge populations required by the specific linear collider projects, CLIC, JLC, NLC, and TESLA. For the demonstration, a single, polarized electron pulse per RF cycle is required. Laser pulse splitting techniques can be used to explore whether or not a pulse train can be constructed.

A load locked cathode preparation chamber attached to the gun system is required. Gun solenoids are necessary to test the effect of magnetic fields on polarization and cathode performance. A polarimeter is required. Beam diagnostics are required to measure the charge, emittance, bunch length, and energy and the stability of these parameters.

A laser system needs to be developed which has sufficient intensity and timing stability for the beam demonstration. The case of two photon generation of polarized beams is of significant interest because of the promise of high polar-

Table 2: Minimum performance specifications for an R&D polarized RF gun.

Parameter	Symbol	Value	Units
Single Bunch Charge	Q_b	2	nC
Number of Bunches	Nb	1	
Bunch length (FW)	Δt	10	ps
Emittance, normalized	$\gamma\varepsilon$	10	mm-mrad
Energy	E	≈ 5	MeV
Polarization	P	> 80	%
Quantum Efficiency	QE	0.1	%
Repetition Rate	f_{rep}	10	Hertz
Operation Lifetime	τ_{ops}	> 4	Hours

ization and improved cathode robustness. For the two-photon demonstration a second laser system of roughly twice the wavelength is required; the QE is expected to be significantly lower than the case of single photon photoemission.

4.2 Next Steps

There was a general recognition among the participants in the workshop that institutional support for polarized RF gun R&D would be very limited, and that discussion should be continued in the format of an informal collaboration. A Collaboration Board was identified, basically the Organizing Committee for this workshop with some additions. The list appears in the Appendix. An email connection and a web site is to be established. Future meetings will be organized at the time and locations of the periodic accelerator conferences.

A Participants

Name	Affiliation	Email address
Aune, Bernard*	Saclay	b.aune@cea.fr
Bähr, Jürgen	DESY-Zeuthen	baehr@ifh.de
Bohn, Courtlandt L.	FNAL	clbohn@fnal.gov
Bohnet, Ilja	DESY-Zeuthen	bohnet@ifh.de
Clendenin, Jym	SLAC	clen@slac.stanford.edu
Champion, Mark	FNAL	champion@fnal.gov
Desler, Kai	DESY	Kai.Desler@desy.de
Dombeck, Tom	FNAL	tdombeck@fnal.gov
Edwards, Don*	FNAL/DESY	edwards@fnal.gov
Edwards, Helen T.*	FNAL/DESY	hedwards@fnal.gov
Finley, David	FNAL	finley@fnal.gov
Flöttmann, Klaus*	FNAL	klaus.floettmann@desy.de
Gromov, Roman*	INP	gromov@inp.nsk.su
Kuchnir, Moyses	FNAL	kuchnir@fnal.gov
Lewellen, John	APS/ANL	Lewellen@aps.anl.gov
Maruyama, Takashi	SLAC	tvm@slac.stanford.edu
Michelator, Paolo	INFN-Milano	paolo.Michelato@mi.infn.it
Milton, Stephen	APS/ANL	milton@aps.anl.gov
Nagaitsev, Sergei	FNAL	nsergei@fnal.gov
Nakanishi, Tsutomu*	Nagoya Univ.	nakanisi@spin.phys.nagoya-u.ac.jp
Nezrick, Frank	FNAL	nezrick@fnal.gov
Pagani, Carlo*	INFN-Milano	carlo.pagani@mi.infn.it
Palmer, Dennis T.	SLAC	DTP@slac.stanford.edu
Piot, Philippe	DESY	piot@mail.desy.de
Prescott, Charles	SLAC	prescott@slac.stanford.edu
Rosenzweig, James B.*	UCLA	rosen@physics.ucla.edu
Schreiber, Siegfried*	DESY	siegfried.schreiber@desy.de
Schultz, David*	SLAC	dcs@slac.stanford.edu
Sertore, Daniele	DESY	daniele.sertore@desy.de
Sheppard, John C.	SLAC	jcs@slac.stanford.edu
Sinclair, Charles*	JLAB	sinclair@jlab.org
Stephan, Frank	DESY-Zeuthen	Frank.Stephan@desy.de
Suberlucq, Guy*	CERN	Guy.Suberlucq@cern.ch
Suzuki, Chihiro	Nagoya Univ.	chihiro@spin.phys.nagoya-u.ac.jp
Travier, Christian	Saclay	ctravier@cea.fr
Umstadter, Donald P.	U. Michigan	dpu@engin.umich.edu
Yu, David	DULY Research	davidyu@pacbell.net

*Collaboration Board