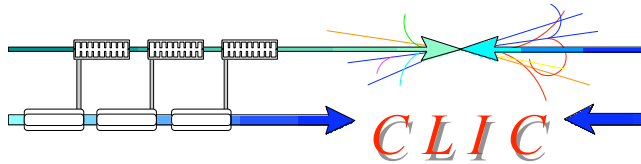


# CLIC 09 workshop summary for the Injector Complex working group

Louis Rinolfi

for the CLIC Collaboration



# The workshop in numbers

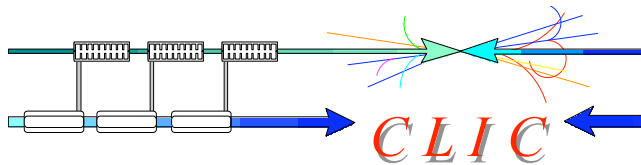


## Complete workshop

250	Participants
21	Countries
62	Institutes
20	Plenary talks
142	Parallel talks
5	Working groups

<http://indico.cern.ch/conferenceDisplay.py?confId=45580>

Here only the working group 2 on Injectors will be summarized



# Outline



as presented by M. Palmer for the Summary of the working group 2

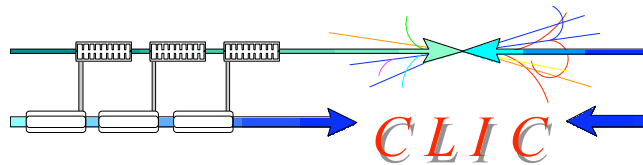
## • Injectors

- Conveners:
  - Louis Rinolfi
  - Jim Clarke
  - Alessandro Variola

## • Damping Rings

- Conveners:
  - Ioannis Papaphilippou
  - Susanna Guiducci
  - Mark Palmer

**Most of the slides below have been prepared by the Injectors conveners**



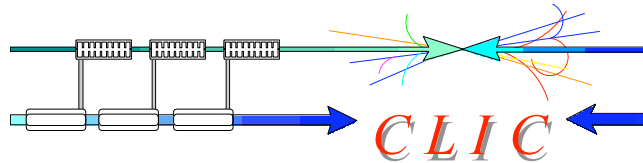
## Updated mandate

For polarized electron sources, ILC and CLIC studies are based on photo-injectors using a DC gun with different parameters.

For polarized positron sources, the ILC study considers the Undulator option as the base line while the Compton schemes are alternative options. The CLIC study considers the Compton schemes as the base line while the Undulator is an alternative option. Additionally, both projects are interested in the development of conventional sources (ILC as an alternative option and CLIC as the baseline for the CDR).

The working group should:

- Develop the synergy between the ILC and CLIC  $e^+$  and  $e^-$  studies.
- Evaluate the common technical issues related to production of unpolarized and polarized positrons.
- Prioritize R&D.
- Review the existing tests facilities where further tests could be performed.
- Invite experts from different institutes to contribute to the studies.
- Evaluate where cost savings could be obtained.
- Promote common meetings and workshops.



# CLIC Main Beam generation

CLIC Main Beams generation: 4 studies are ongoing to produce  $e^+/e^-$  with the requested parameters at the **entrance of the Pre-Damping Ring (PDR)**:

## 1) Baseline configuration:

3 TeV (c.m.) - polarized electrons ( $5 \times 10^9$   $e^-$ /bunch) and unpolarized positrons ( $7.6 \times 10^9$   $e^+$ /bunch). Pulse of 156 ns long with 312 bunches

## 2) Double charge configuration:

500 GeV (c.m.) - polarized electrons ( $10 \times 10^9$   $e^-$ /bunch) and unpolarized positrons ( $15.2 \times 10^9$   $e^+$ /bunch) with same pulse length as above

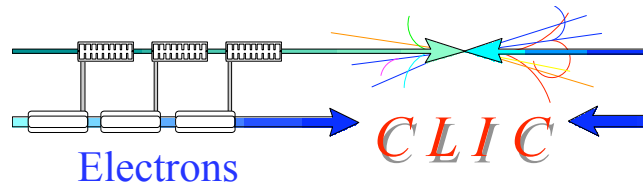
## 3) Polarized positron configuration:

3 TeV (c.m.) - polarized  $e^-$  and  $e^+$  with same parameters as for the baseline

## 4) Low energy configuration (< 3 TeV):

4.1) Polarized  $e^-$  and unpolarized  $e^+$  but with the highest repetition frequency

4.2) Polarized  $e^-$  and unpolarized  $e^+$  with half the baseline charge but 800 bunches



# Challenges for the $e^-/e^+$ source

Reliable load locked gun, High voltage; Ultra-high vacuum requirements; Cathode/anode optics

Production of the full current with space charge and surface charge limits

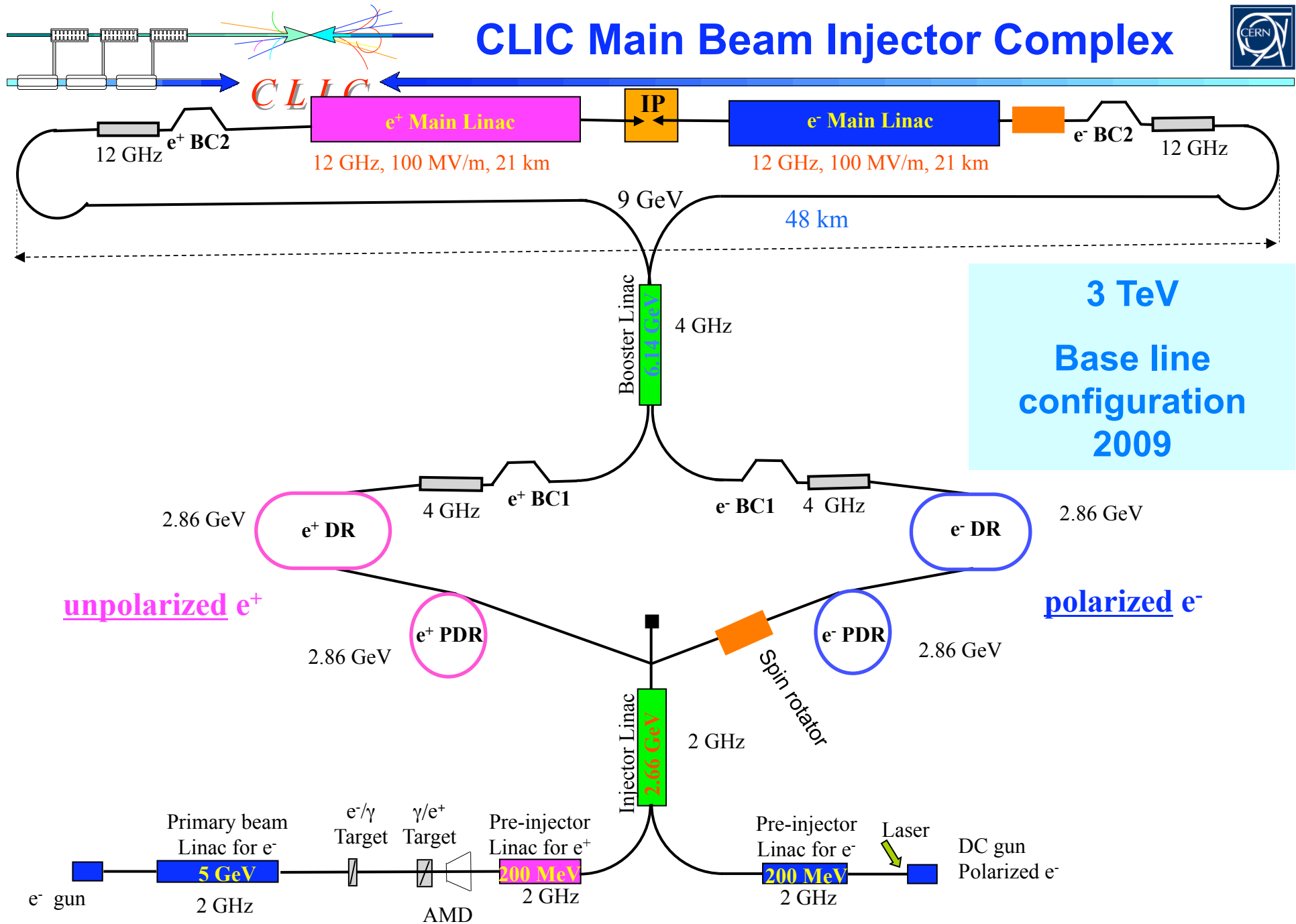
Photocathode high polarization; High Quantum Efficiency and Long life time

Laser frequency, Pulse length and Pulse energy.

## Positrons

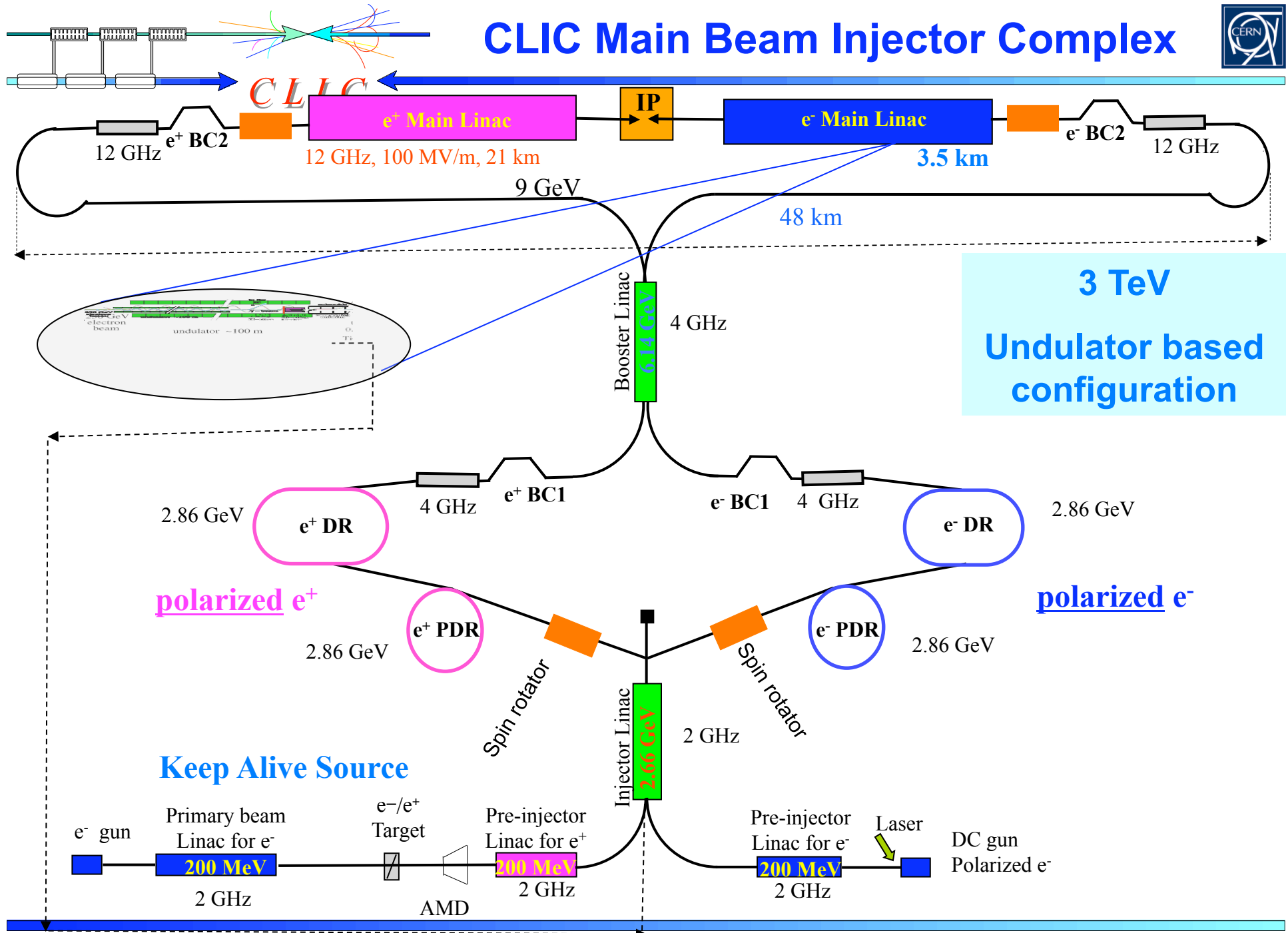
- A single hybrid targets station or several stations to cover all the CLIC needs
- Devices for Undulator scheme (Helical undulator, collimators, dumps,...)
- Devices for Compton schemes (Optical cavities at IP, powerful laser systems,...)
- Targets issues (Heat load dynamics, beam energy deposition, shock waves, breakdown limits, activation, ....)
- Adiabatic Matching Device (AMD)
- Capture sections (Transport and collimation of large emittances, high beam loading)
- Trade off between yield, polarization and emittances
- Design and implementation of the spin rotators
- Polarization issues (Analyze systematic errors of polarization measurements)
- Efficient use of existing codes (EGS4, FLUKA, Geant4, PPS-Sim, Parmela, ...)
- Integration issues for the target station (remote handling in radioactive area)
- Radioactivity issue.

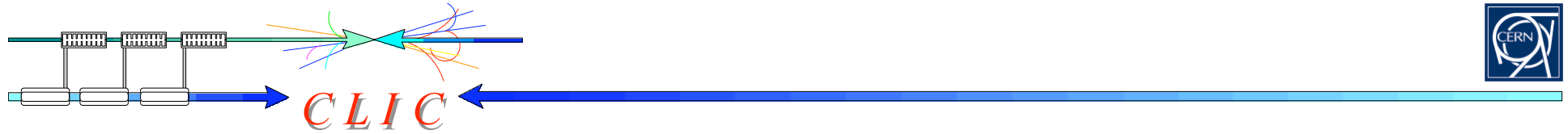
# CLIC Main Beam Injector Complex



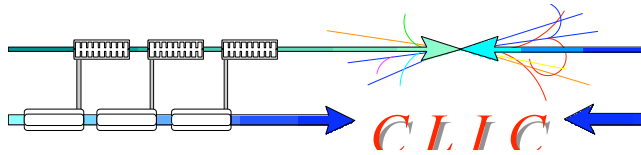


# CLIC Main Beam Injector Complex





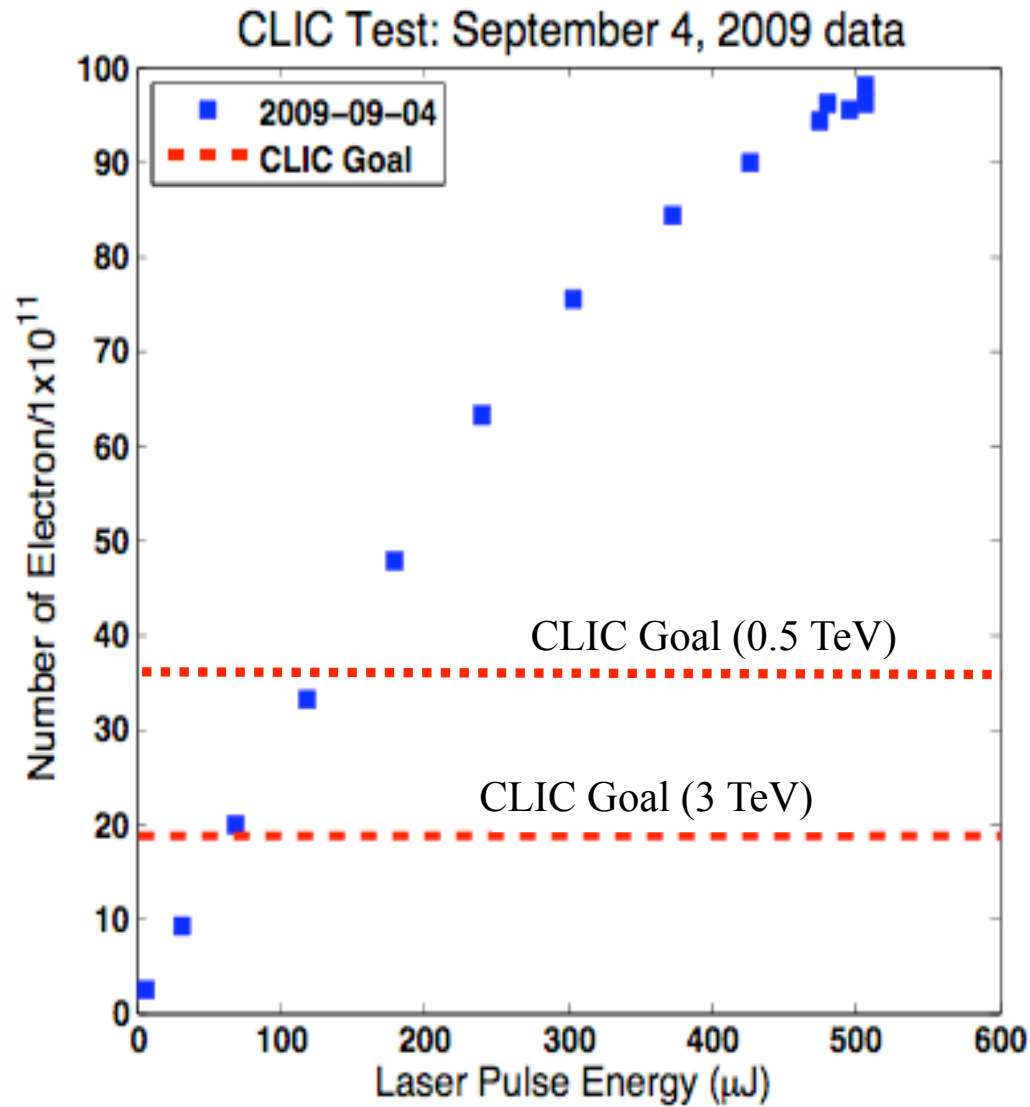
# Polarized electrons



# Polarized e<sup>-</sup> produced at SLAC



J. Sheppard

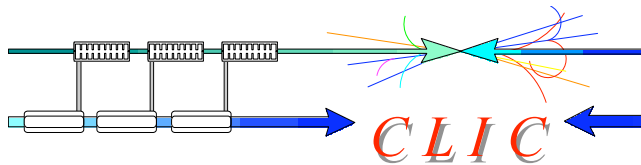


The total charge produced is a:  
**factor 3** above the CLIC requirement for 0.5 TeV and  
**factor 5** above the CLIC requirements for 3 TeV

QE  $\sim 0.5 - 0.7 \%$

The measured polarization is  
 $\sim 82 \%$

Major milestone



# Polarized e<sup>-</sup> at JLAB

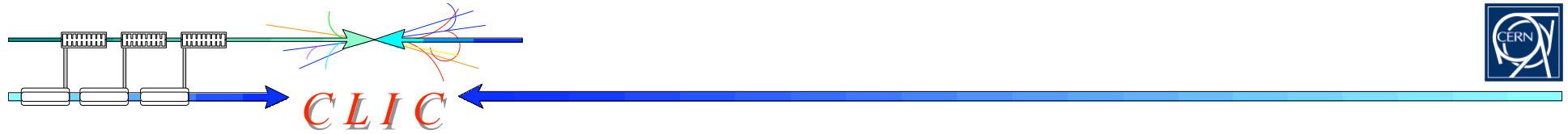


M. Poelker

## To-do List for CLIC, ILC and JLab

- **Demonstrate Higher Voltage > 100kV with new inverted gun**
  - 200kV for CEBAF, 350kV for ILC
  - Field emission measurements, materials and polishing techniques
  - New gun design if necessary: reduce gradient where possible, symmetric design
- **Cathode/Anode Design for large laser beam**
  - Uniform emittance across beam profile
  - No beam loss
- **Improve Vacuum**
  - NEG/ion pump limitations
  - Gauges at 10<sup>-13</sup> Torr
  - Cryopumping

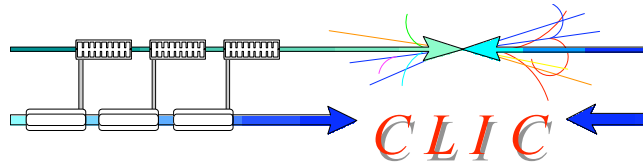




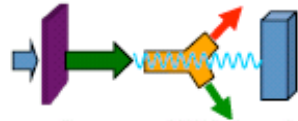
# Unpolarized positrons

# KEKB hybrid source experiment

T. Takahashi

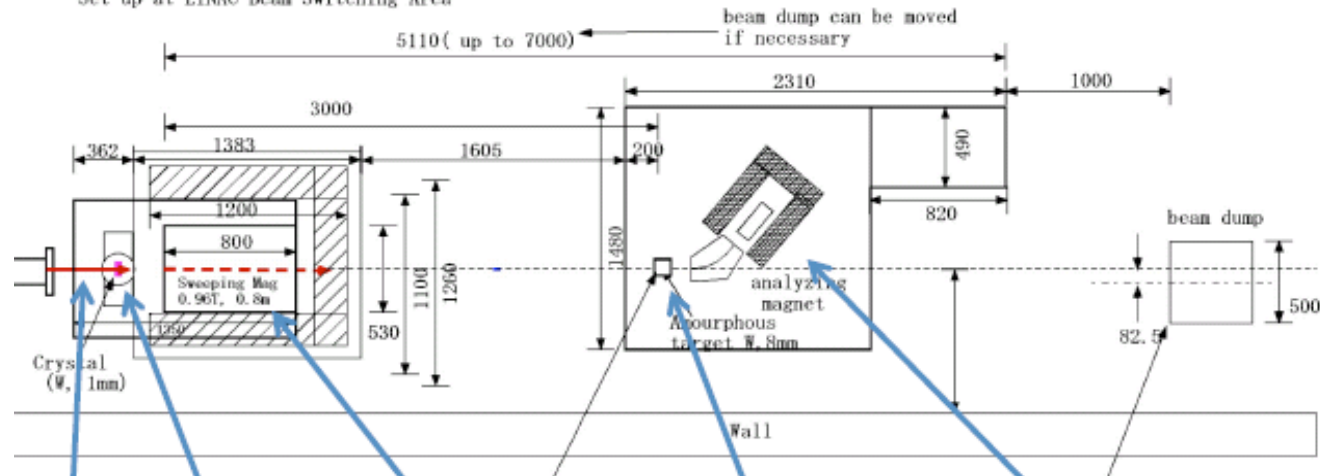


CLIC



## Setup

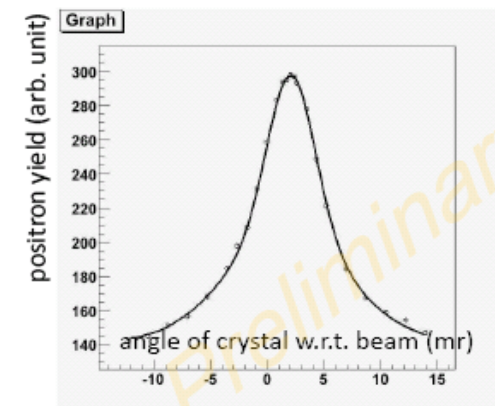
Set up at LINAC Beam Switching Area



- 8GeV e-
- 1mm W crystal
- Sweeping Magnet 0.96T 0.75m
- amorphous W 0.4 mm 8 mm
- Analyzing magnet 5 ~ 20MeV

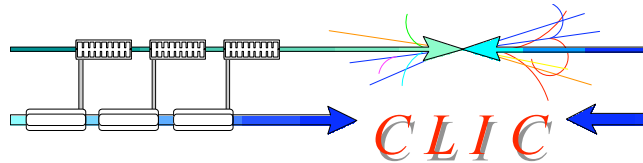
1<sup>st</sup> result

Rocking Curve

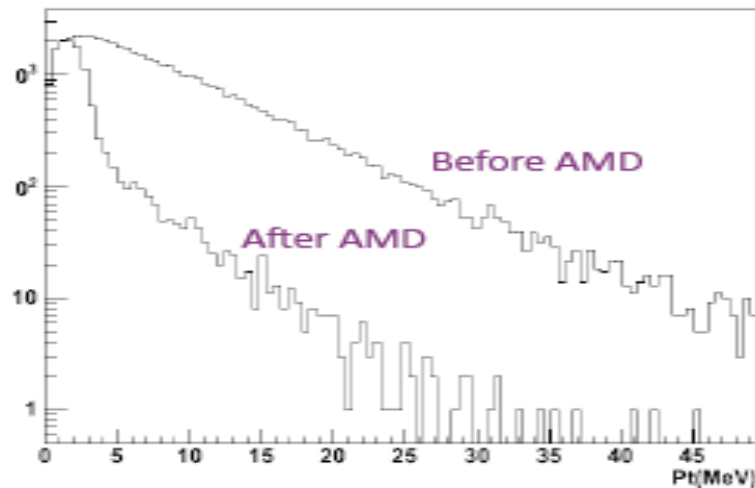


# Hybrid source optimization

O. Dadoun



## Simulation results

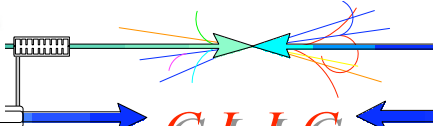


$a$ (mm)	$d$ (m)	Yield	P(kW)	Pedd (GeV/cm <sup>3</sup> /e <sup>-</sup> )	Pedd(J/g/train)
0.6	1.5	1.83	3.90	0.95	18.45
0.6	2.0	1.76	3.85	0.83	16.12
0.6	2.5	1.70	3.70	0.71	13.80
0.6	3.0	1.66	3.65	0.64	12.43
0.8	1.5	1.91	6.55	1.00	19.42
0.8	2.0	1.87	6.40	0.87	16.90
0.8	3.0	1.81	6.20	0.78	15.15
1.0	1.5	2.01	10.05	1.37	26.60
1.0	2.0	1.97	9.80	1.14	22.14
1.0	2.5	1.91	9.60	1.00	19.42
1.0	3.0	1.83	9.25	0.89	17.29
1.2	1.5	2.04	13.70	1.41	27.38
1.2	2.0	1.96	13.45	1.25	24.27
1.2	2.5	1.92	13.05	1.05	20.40
1.2	3.0	1.86	12.65	0.96	18.65

Table 5: 5 GeV incident electron beam energy.

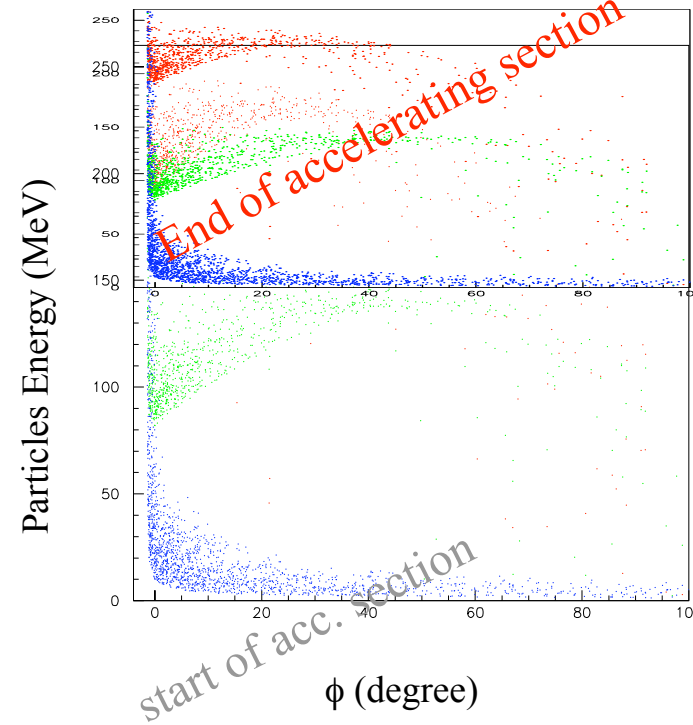
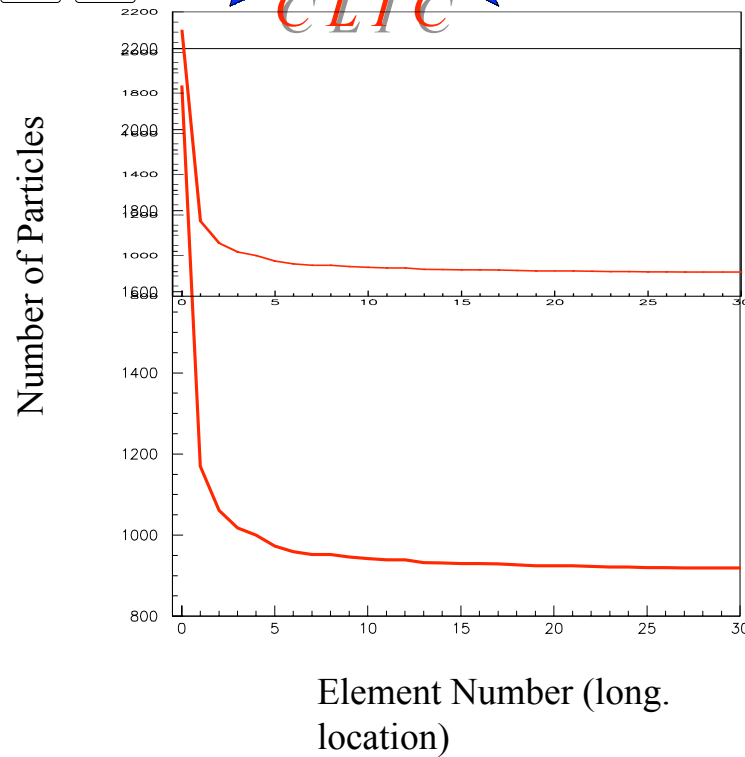
If we are looking at the optimisation of the produced yield and take into account a safety factor of 50% on the PEDD limit

1. an incident electron energy of 5 GeV
2. a distance radiator-converter of 2 – 3 meters
3. a converter thickness of 6 – 9 mm



# Pre-accelerator results at 200 MeV

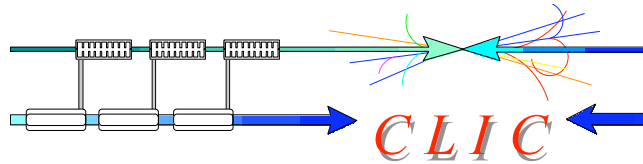
F. Poirier



Start to end results:

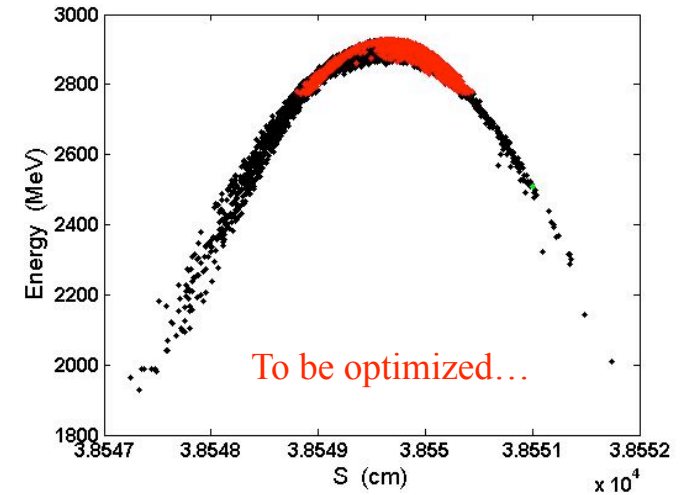
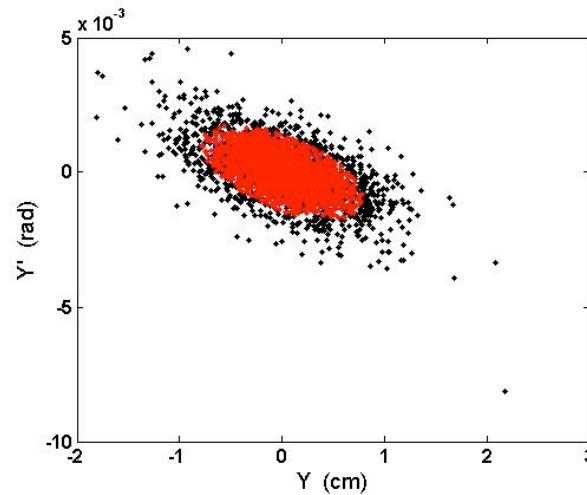
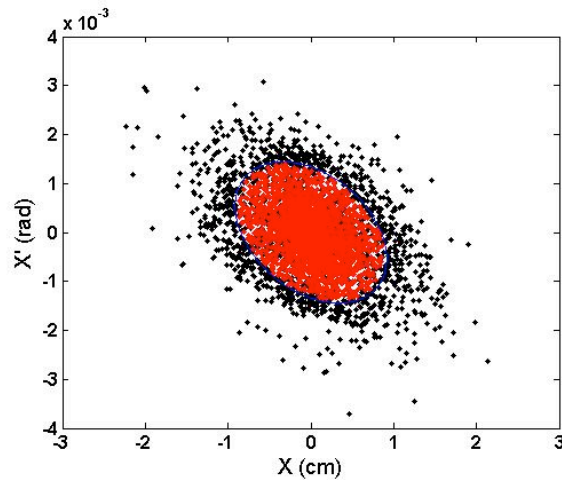
e+/e- yield	AMD yield	ACS yield	Total yield
~8.15	0.23	0.42	~ 0.8

Yield e+/e- = 0.8 (at 200 MeV) with Parmela i.e. with  $7.5 \cdot 10^9$  e- / bunch in front of crystal we get  $\sim 6 \cdot 10^9$  e+ / bunch at exit of accelerating section



# Injector linac results at 2.8 GeV

A. Vivoli



s cm	N. e <sup>+</sup>	Yield e <sup>+</sup> /e <sup>-</sup>	$\gamma\epsilon_x$ $\pi$ mm mrad	$\gamma\epsilon_y$ $\pi$ mm mrad	$\langle E \rangle$ MeV	$\sigma_E$ MeV	$\sigma_z$ mm	$\epsilon_z$ $\pi$ cm MeV
38550	4558	0.76	19804	14729	2825.1	129.5	6.2	69.5

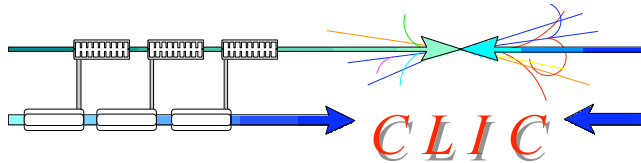
e<sup>+</sup> in PDR: 2747

Yield e<sup>+</sup>/e<sup>-</sup> = 0.458

For e<sup>+</sup> capture into the PDR

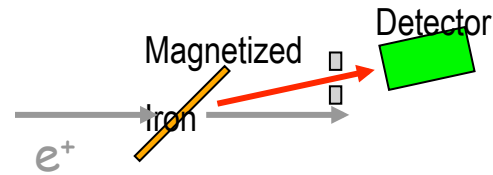
# Bhabha polarimeter at 200 MeV

S. Riemann



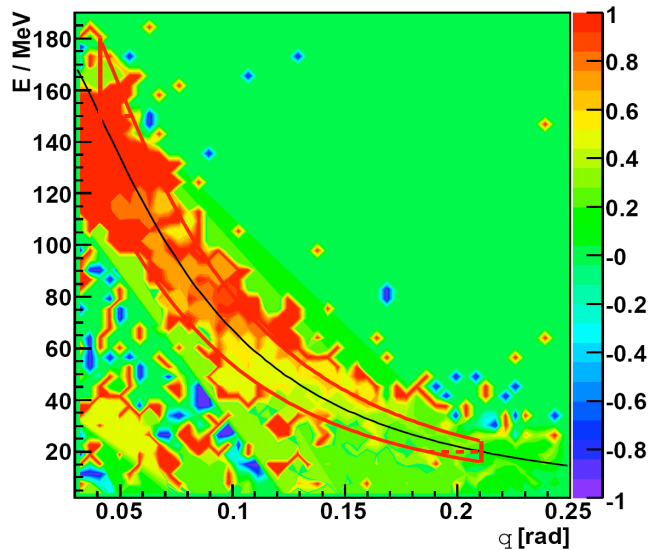
## • G4 Simulation

- $E_{e^+}$  200 MeV
- Target 30  $\mu\text{m}$  Fe

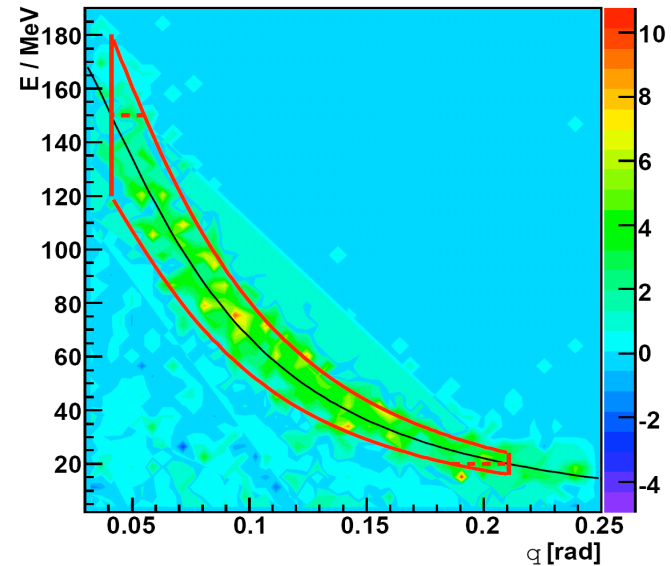


$$S = \frac{A}{\Delta A} \approx \frac{n-p}{2} \sqrt{\frac{n+p}{(n+1)(p+1)}}$$

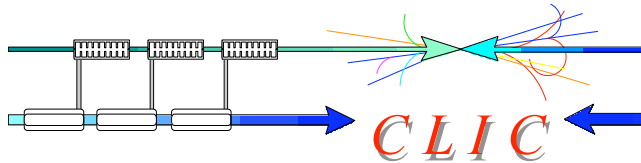
electron asymmetry distribution



electron significance distribution



asymmetry measurement with scattered electrons  
 Energy range: 30 - 150 MeV

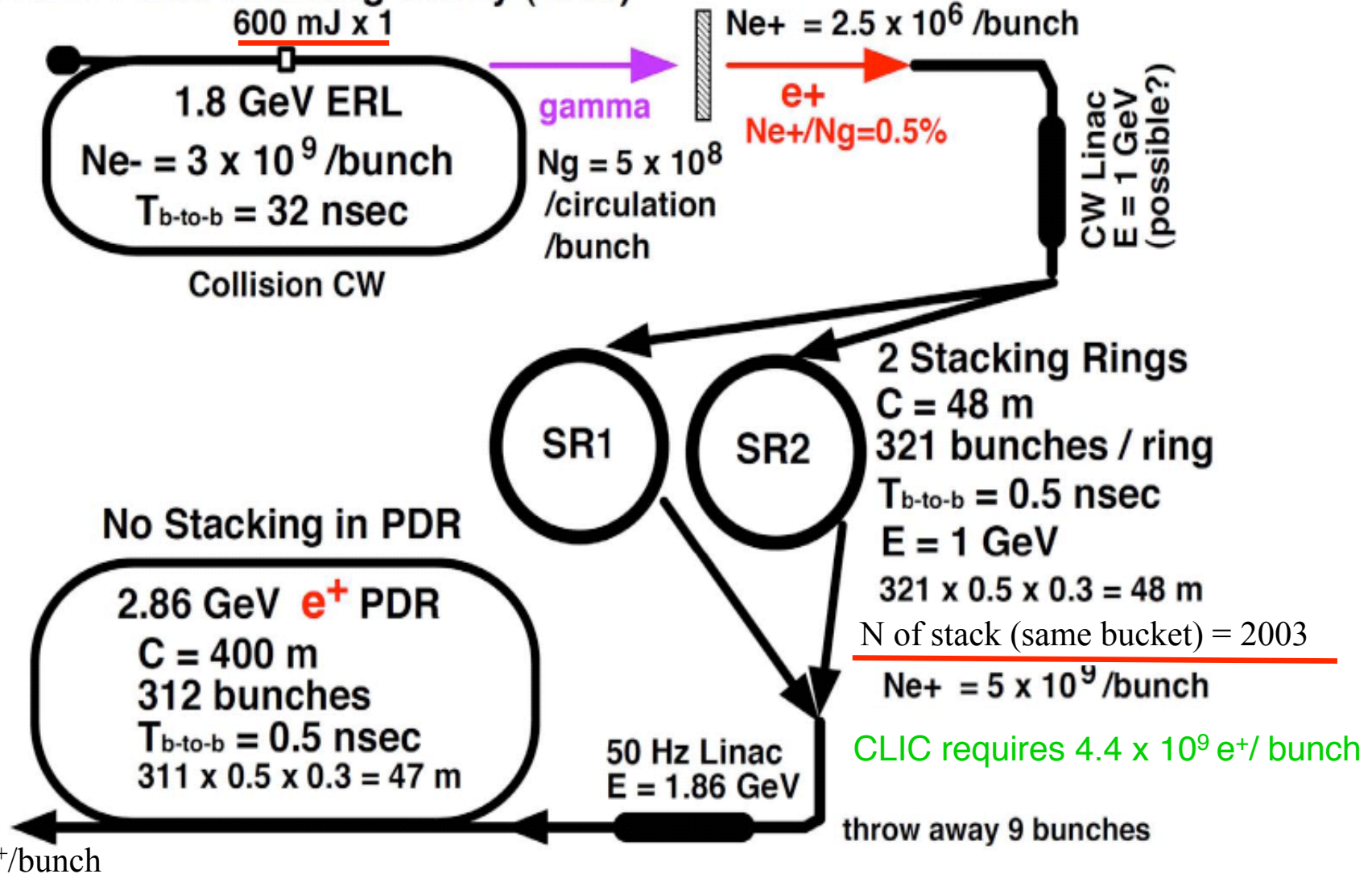


# CLIC Compton ERL



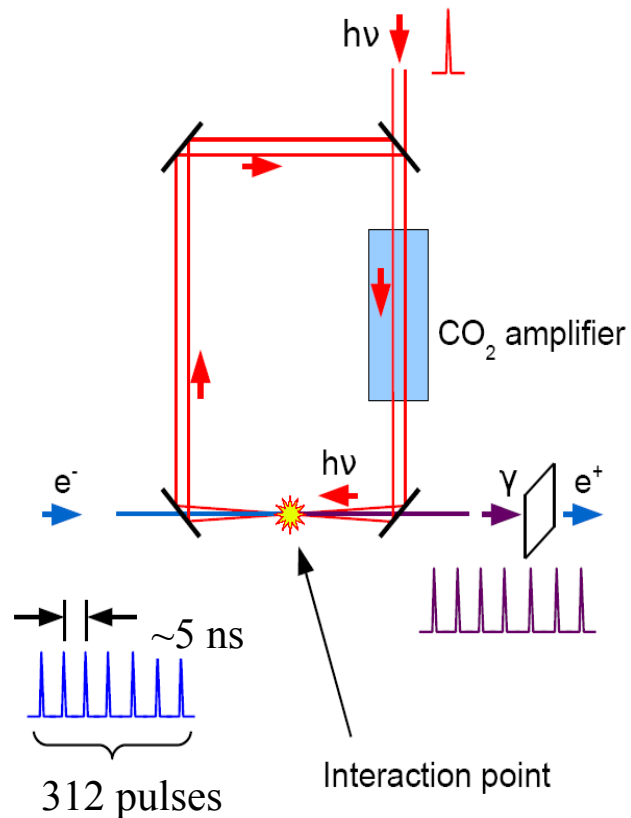
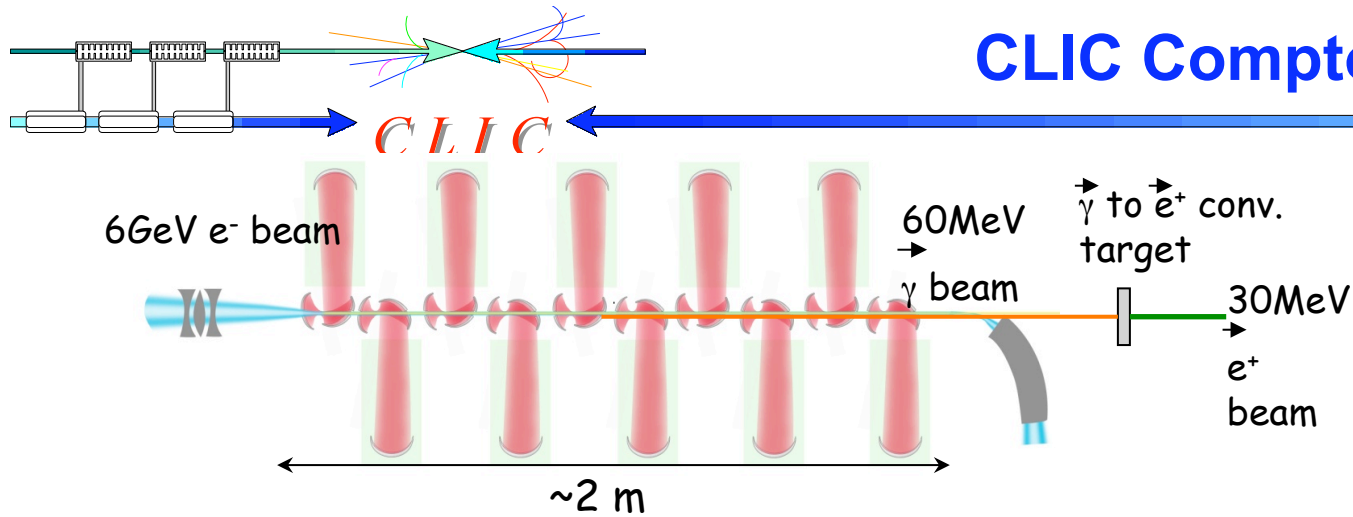
T. Omori

## Laser Pulse Stacking Cavity (YAG)



# CLIC Compton Linac

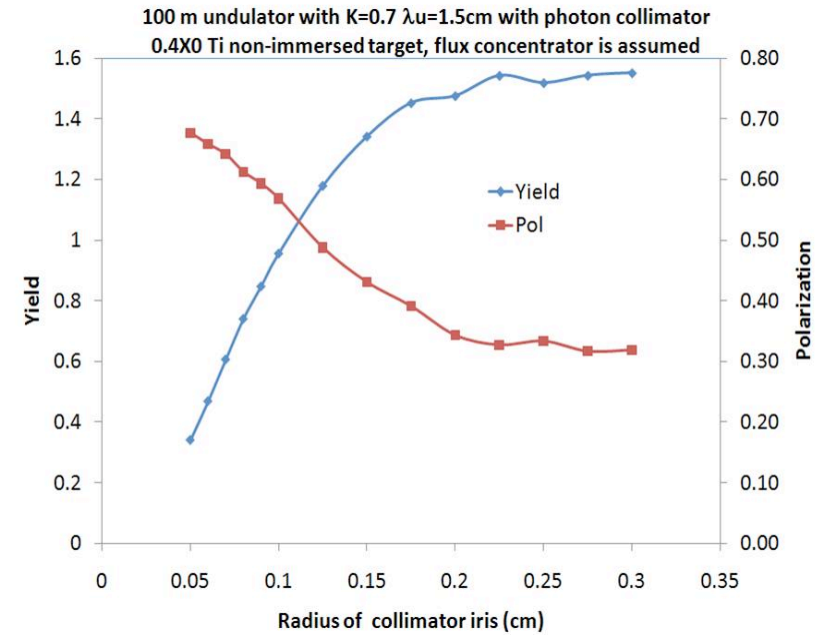
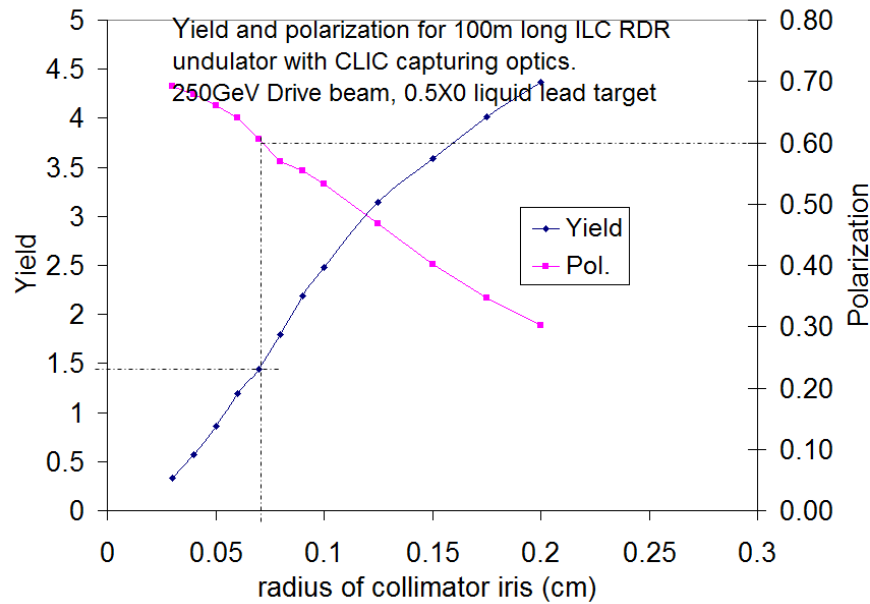
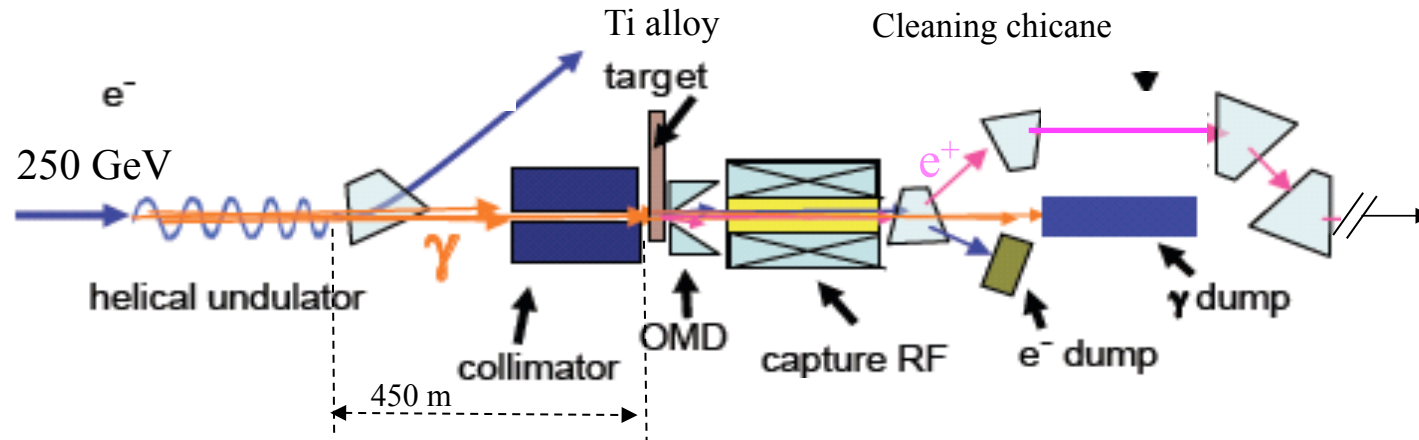
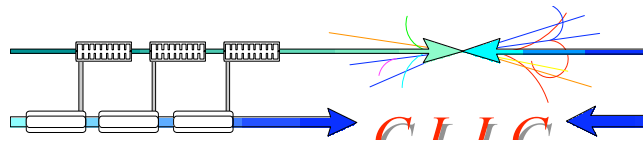
V. Yakimenko



- No stacking in the PDR
- Laser system and recirculating cavity should be built and tested
- Demonstration with a test beam is required

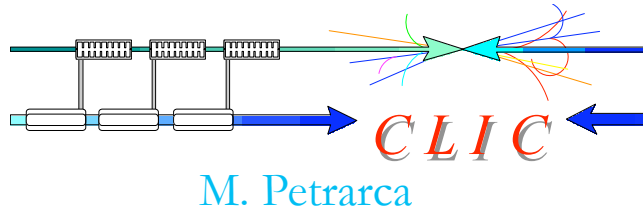
# CLIC Undulator scheme

W. Gai



ANL simulations

# PHIN results at CERN



M. Petrarca

PHIN = PHoto-INjector

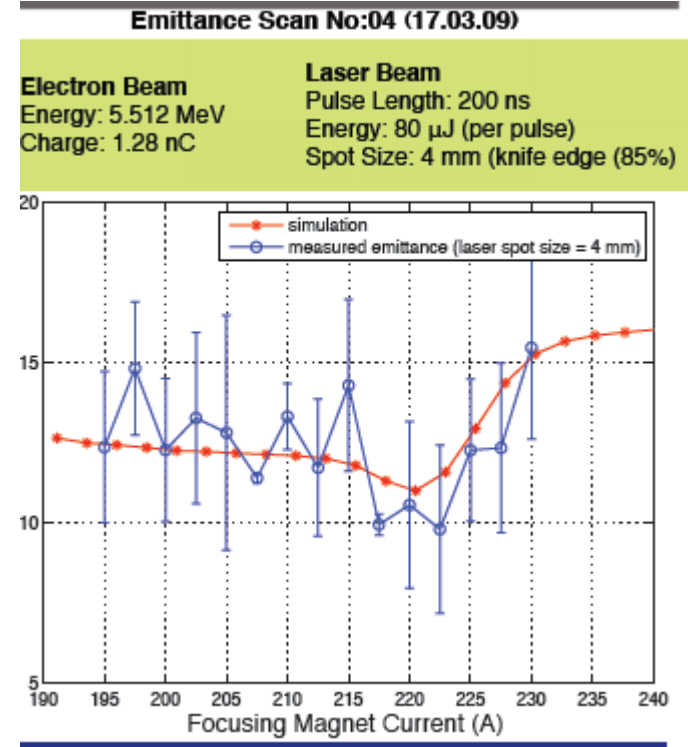
O. Mete

## Sur la route pour CLIC

	Unit	DRIVE BEAM			MAIN BEAM
		CTF3 / PHIN [17]	CLIC 3 TeV	CLIC Compton ring	CLIC 3 TeV
$\mu$ pulse charge	nC	2.33	8.6	9.3	0.96
$\mu$ pulse width (FWHH)	ps	16	12	100	100
peak current	A	233	716	93	9.6
number of $\mu$ pulses	-	1908	92664	312	312
distance between $\mu$ pulses	ns	0.667	1.49	0.5	0.5
Macro pulse duration	ns	1272	140000	156	156
Macro pulse charge	nC	4446	796900	3120	300

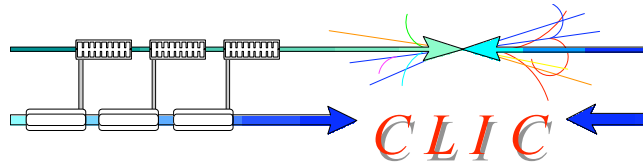
For CTF3 drive beam more powerful amplifiers can be added to the laser

For the Compton Ring 2 GHz oscillator is feasible – More powerful amplifiers to be designed



Transverse emittance scales with the laser spot size as expected from the PARMELA simulations. Values are  $\sim 6, 7$  and  $12$  mm mrad for 2, 3 and 4 mm laser spots, at the energies of 5.7, 5.2 and 5.5 MeV, respectively.

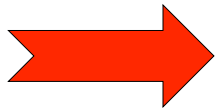
# Highlights for the CDR



For polarized  $e^-$ , the SLAC major milestone confirms that the desired charge can be produced



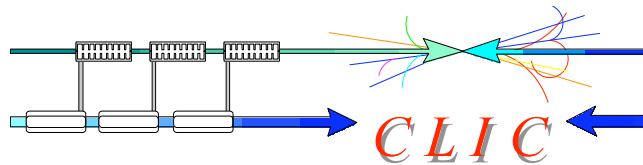
For unpolarized  $e^+$ , the present simulations based on hybrid targets and the KEKB experiment provide great confidence that we can reach the requested performance with a single target station



For polarized  $e^+$ , all schemes (Compton Ring, Compton Linac, ERL, Undulator) a possible solution has been proposed but all schemes need strong R&D developments



**The work performed by the international collaboration working on the CLIC Injector Complex has produced important progress and should be greatly acknowledged.**



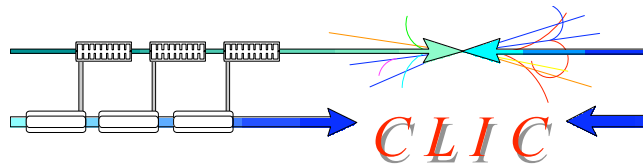
# Collaborations



## for the CLIC Main Beam Generation studies

Alphabetic order for countries

Countries	Institutes	Collaborators	Subject
France	LAL	I. Chaikovska, O. Dadoun, F. Poirier, A. Variola	e <sup>+</sup> studies
France	IPNL	X. Artru, R. Chehab, M. Chevallier, V. Stakhovenko	Channeling studies
Germany	FZR Rossendorf	J. Teichert	Compton sources
Japan	Hiroshima Uni.	M. Kuriki, T. Takahashi	Experiments at KEKB
Japan	KEK	T. Kamitani, T. Omori, J. Urakawa	e <sup>+</sup> studies
Turkey	Uludag University	E. Eroglu, A. Kenan Çiftçi, E. Pilicer, I. Tapan	FLUKA simulations
Ukraine	Kharkov Institute	E. Bulyak, P. Gladkikh	Compton Rings
United Kingdom	Cockcroft Institute	I. Bailey, J. Clarke, L. Zang	Undulator e <sup>+</sup> studies
USA	ANL	W. Gai, W. Liu	Undulator e <sup>+</sup> studies
USA	BNL	I. Pogorelski, V. Yakimenko	Compton Linac
USA	JLAB	M. Poelker	DC gun for polarized e-
USA	SLAC	A. Brachmann, T. Maryama, J. Sheppard, F. Zhou	Polarized e- sources



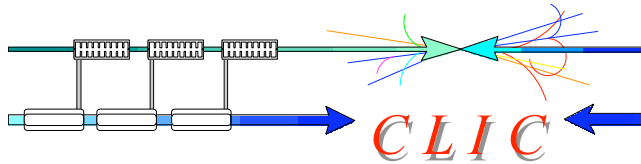
## Final Remarks



B. Barish

- The central frontier of particle physics is and will continue to be the energy frontier!
- The LHC will open a new era at that frontier and its discoveries will motivate the next machine --- a lepton collider.
- That machine could be the ILC or CLIC (or maybe a muon collider). Science must dictate the choice of machines, informed by the realities of technical performance, readiness, risk and cost for each option
- It is our jobs (ILC and CLIC design teams) to make sure our R&D and design work will enable the best informed decision for our field.

Global Design Effort



# Summary of a Summary



K. Peach

1. An excellent workshop
  2. Good technical progress
  3. Clear short and medium term goals
- but
- need the LHC to show the way
    - Energy range!!!
    - and we need
    - the technology to meet the challenge

We were born to succeed,  
not to fail

Henry Thoreau (1817-1862)

We will either find a way,  
or make one

Hannibal (248-183 BC)

*inveniemus viam aut faciemus*