John Adams Institute for Accelerator Science

Imperial College London

Royal Holloway University of London

UNIVERSITY OF OXFORD

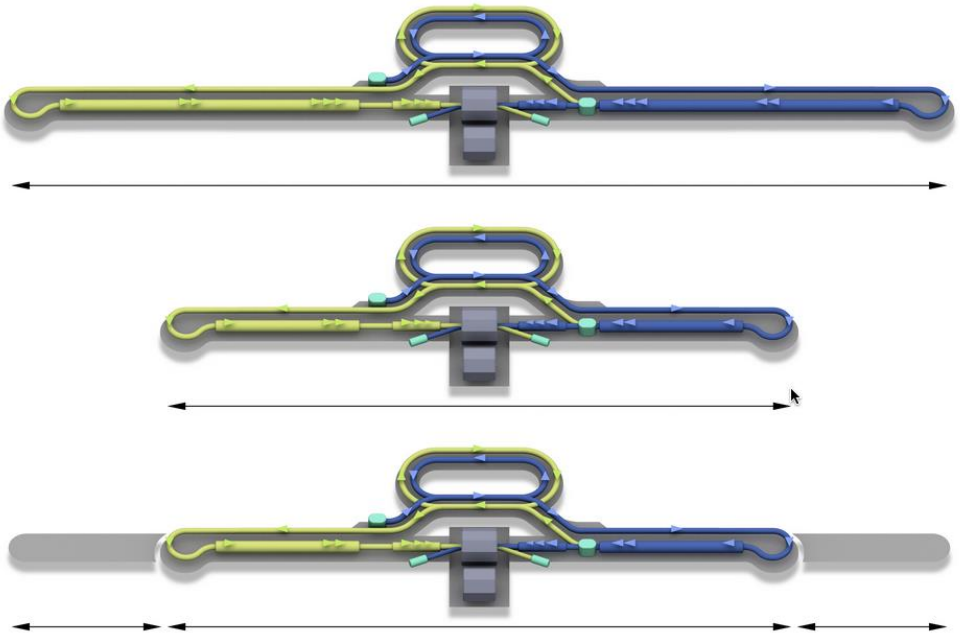
Upgrade of 250 GeV CM ILC to 1-2 TeV CM using plasma acceleration driven by auxiliary proton beam - concepts

Andrei Seryi

27 March 2018

Motivation

- **The International Linear Collider (ILC) team has recently suggested a cost-cutting scenario where the 250 GeV CM Higgs Factory could be constructed first, giving the possibility of reducing the cost by up to 40%, and leaving open the possibility of upgrading the machine to higher energy (500 GeV CM) in the future**



- **However, taking into account the rate of the progress of advanced acceleration research, it would be advantageous, in line with ALEGRO team approach, to explore the strategy of upgrading ILC to 500 GeV CM and even to 1 TeV CM using plasma acceleration, keeping the same footprint of the Higgs Factory, and re-using its hardware**

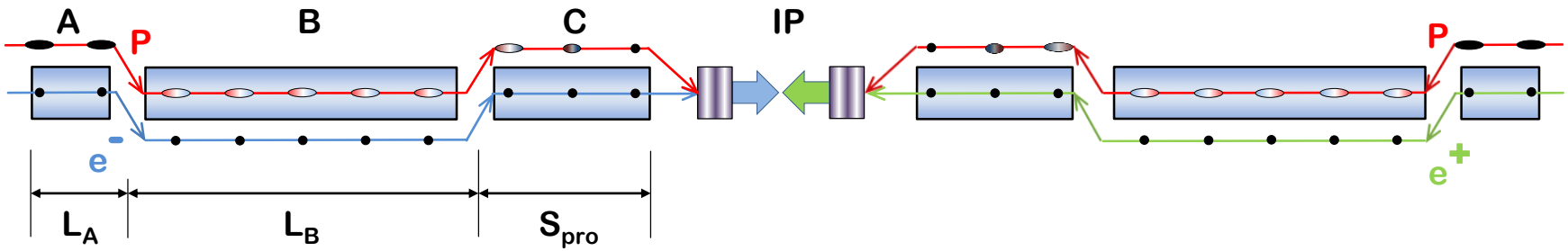
Upgrade options considered

- **Upgrade ILC to ~TeV CM using plasma acceleration driven by auxiliary proton beam**
  - **(upgrade with e-beam driver also possible – not discussed here)**

  – **Version 1: proton beam is accelerated in the middle part of the re-phased ILC linacs, while e+ and e- bunches are accelerated in the beginning and end sections of ILC linacs**
    - **Proton bunches ballistically compressed while they travel along the final section of ILC linac**
    - **Main challenge – protons too low energy, and they dephase in plasma => too many plasma stages needed => very challenging concept**
    - **This version is unlikely better than the e-beam driven version**
  – **Version 2: proton beam is accelerated in the beginning 100 GeV part of the linac in several passes to the energy 0.5-1 TeV**
    - **Different set of challenges. Perhaps overall this version is more promising**

- **Concepts have many issues – shown to stimulate discussion**

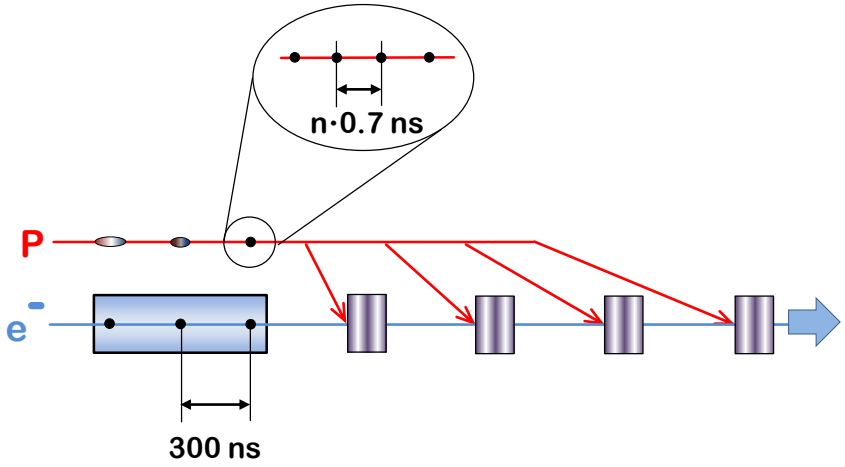
ILC upgrade concept 1-st version



ILC upgrade using plasma acceleration driven by ballistically compressed proton beam
(this figure does not yet take into account the need for multiple plasma stages)

- Middle part (B) is re-phased for proton beam acceleration
- Proton bunch is placed off-crest of RF to create energy chirp
- Accelerated p-bunch extracted and ballistically compressed

ILC upgrade concept 1-st version



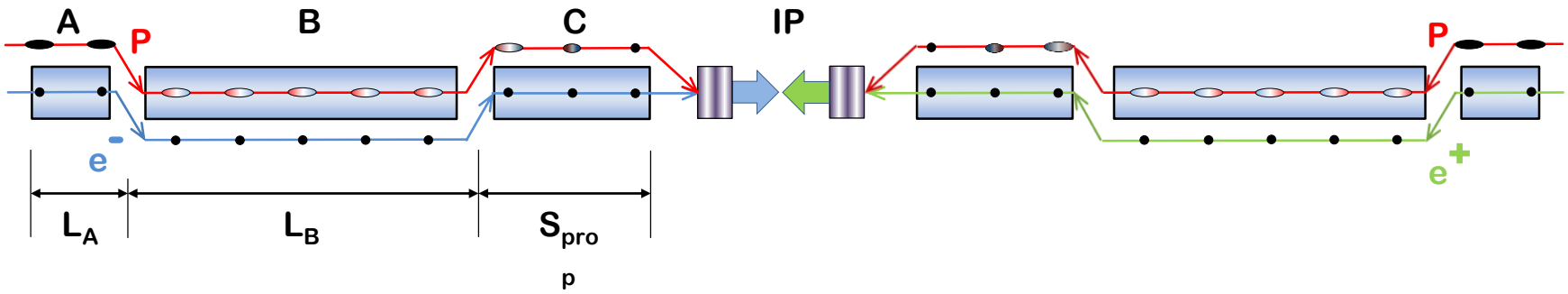
Distribution of proton bunches into multiple plasma acceleration sections in the 1-st version of ILC upgrade

- Proton beam is weakly relativistic and will dephase from e- or e+ in plasma
- Thus, multiple plasma cells needed (approximately 20 or so cells for 1TeV CM)
- Proton beam distribution system needs to ensure proper timing
- 20 p-bunches needed for each e+ or e- bunch, n defined by min kicker rise time

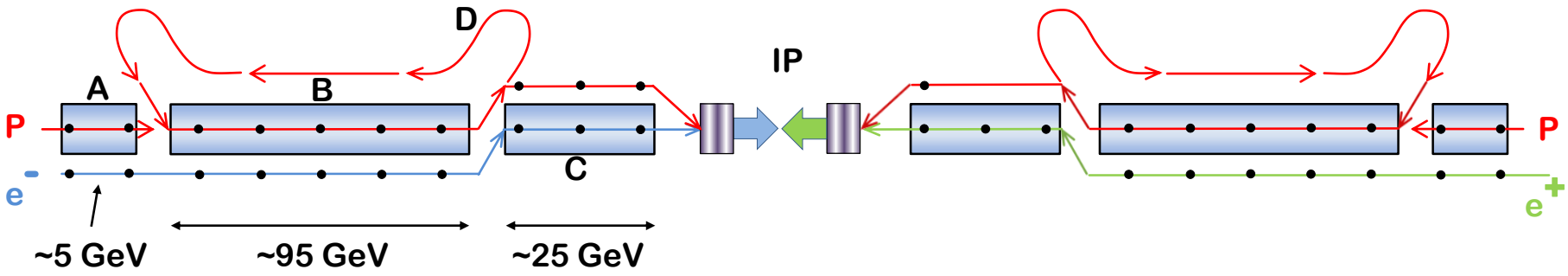
ILC upgrade concept 1-st version

Parameters of 250 GeV ILC Higgs Factory upgraded to 1 TeV CM using plasma acceleration with ballistically compressed proton drive, first version

Parameter	Value
Final E, CM TeV	1.0
Total length, km	Same as ILC Higgs Factory
Repetition rate, Hz	Same as ILC Higgs Factory
Initial E of e+ e- bunches, GeV	50
Energy of driver bunches, GeV	75
Number of plasma acc. stages	20



ILC upgrade concept 2-nd version



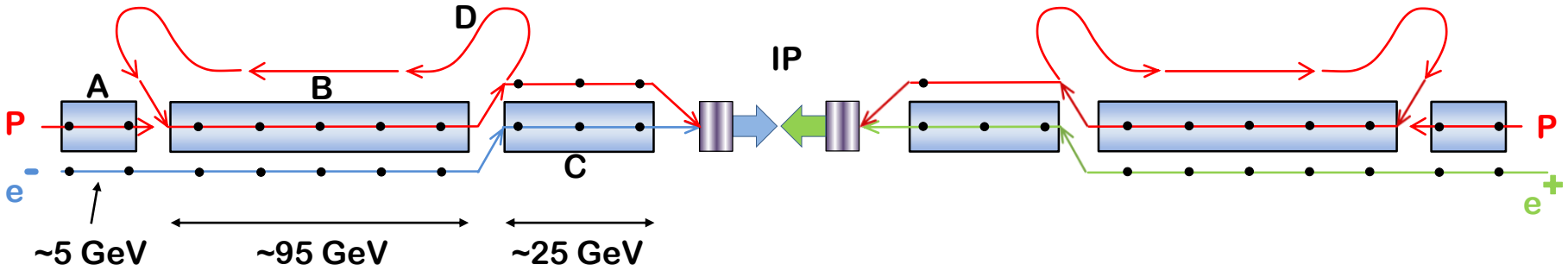
Second version of ILC upgrade using plasma acceleration driven by proton beam

- First part (A) – low beta acceleration of protons
- Middle part (B) – multi pass acceleration of protons
- (ILC train which is 200-km long needs to be chopped into shorter trains)
- Turn-arounds are R=300m with up to 16T magnets and multiple orbits
- Proton beam sufficiently relativistic – single plasma acceleration stage is used
- Injection E of p-beam such that beam-RF dephasing in part B tolerable

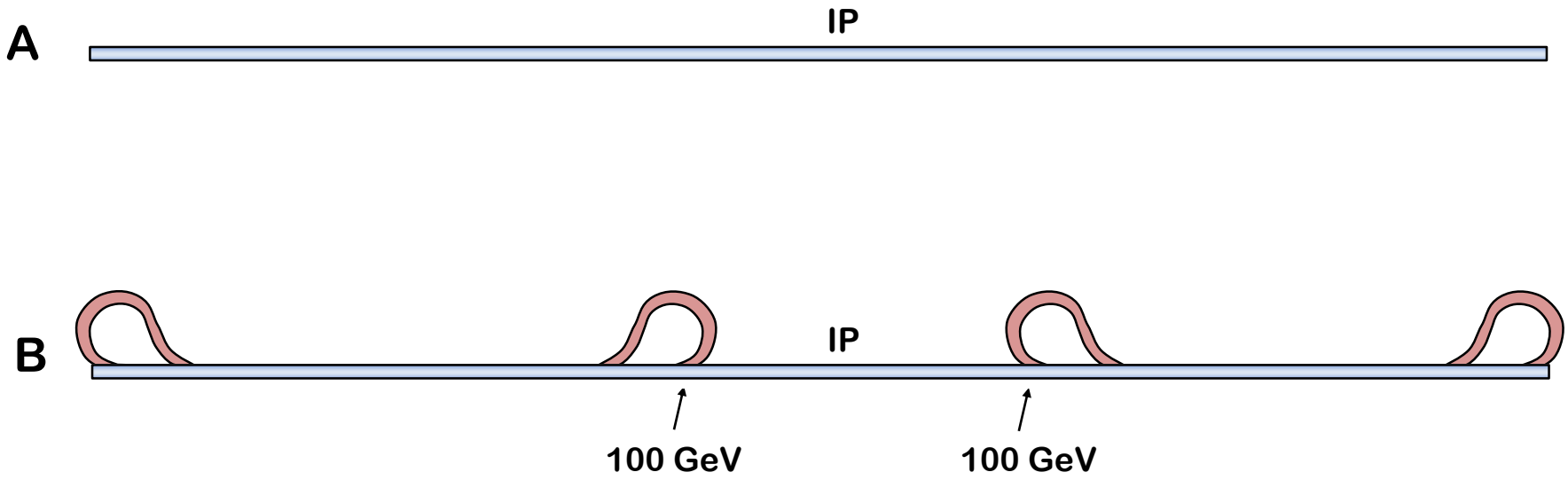
ILC upgrade concept 2-nd version

Parameters of 250 GeV ILC Higgs Factory upgraded to 2 TeV CM using plasma acceleration with proton drive beam, second version

Parameter	Value
Final E, CM TeV	2.0
Total length, km	Same as ILC Higgs Factory
Repetition rate, Hz	Same as ILC Higgs Factory
Initial E of e+ e- bunches, GeV	25
Energy of driver bunches, GeV	1000
Number of plasma acc. stages	1



ILC upgrade concept 2-nd version



Possible Civil Construction provisions for 250 GeV ILC Higgs factory tunnel layout that enable 1-2 TeV CM upgrade in the future (if this concept will be proven viable).

Here A – present layout of ILC Higgs factory tunnel, and B – modified tunnel layout where turn-around with 300 m radius are added at 100 GeV point of the initial linac, and at the beginning of the tunnels

Conclusions

- We discussed here a concept of the upgrade of ILC Higgs factory from 250 GeV CM to 1 TeV CM using an auxiliary proton beam that drives plasma acceleration of e+ and e- bunches of ILC
  - It was shown that such upgrade is in principle conceptually possible
  - We discussed two version of the upgrade concepts
  - Some challenges of the first version has been identified
  - The second version needs to be critically reviewed too
  - The 2-nd version of the ILC upgrade may exhibit advantages over electron-drive schemes, as it may reach (in the fixed size of ILC Higgs factory) a much higher energy of 1-2 TeV CM
- If concept will be shown viable, enabling, in future, the possibility of 250 GeV CM ILC Higgs factory upgrade to 1-2 TeV CM requires, at this moment of design stage, to foresee including into ILC Conventional Facilities construction plan, provisions for the 300 m turn-around tunnels at 100 GeV point of the linac
- Further detailed comparison of the merits of this concept in comparison with other schemes require detailed considerations of many different design aspects
- Hope that discussion of these concepts can stimulate development of other possible advanced collider concepts

Acknowledgment

- I would like to thank Alexander Pukhov (University of Duesseldorf) and Konstantin Lotov (Budker Institute) for pointing out some conceptual issues in the 1-st version of the concept and for discussion of possible merit of this scheme in comparison with the electron beam driven collider