Fermilab

Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

“Integrated” Accelerator R&D at FNAL

1. Brief overview of Accelerator R&D at AD
2. Synergy between R&D at TD and AD
3. Are our efforts aligned well enough to address Fermilab and US HEP community goals? Where can we improve our communications, efforts, etc.?

Vladimir Shiltsev, APC

TD Accelerator R&D Retreat

Fermilab, January 26, 2016

US HEP Community Goals: P5

	Intensity Frontier Accelerators	Hadron Colliders	e^+e^- Colliders
Current Efforts 0-10 yrs	PIP	LHC	
	PIP-II	HL-LHC	ILC
Next Steps 10-20 yrs	Multi-MW proton beam	Very high-energy *pp* collider	1 TeV class energy upgrade of ILC*
Further Future Goals 20+ yrs	Neutrino Factory*	Higher-energy upgrade	Multi-TeV collider*

***dependent on how physics unfolds**

- Key R&D elements:
  - PIP-III (2.5 MW FNAL complex upgrade)
  - IOTA Research on Space-Charge
  - High Power Targetry R&D
  - Low cost SC RF (in TD)

Present & Future HEP IF Accelerators

300+ kW JPARC (Japan)

400+ kW CNGS (CERN)

500+ kW Fermilab's Main Injector (2015)

EVOLUTION OF INTENSITY FRONTIER ACCELERATORS

700+ kW Proton Improvement Plan (PIP, 2016)

1.2+ MW Proton Improvement Plan-II (ca 2025)

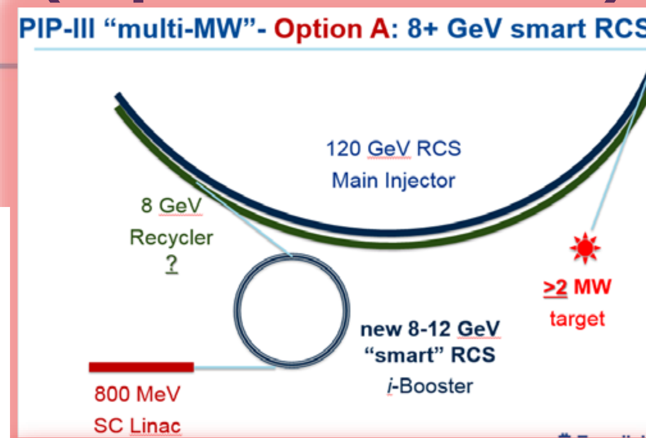
2.5 MW → 5 MW?

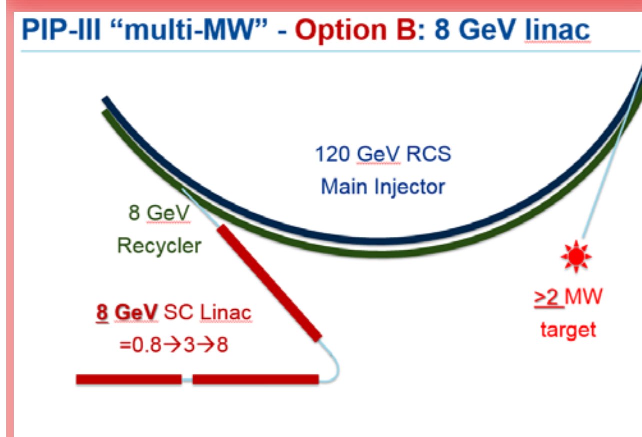
Proton Improvement Plan-III (under study)

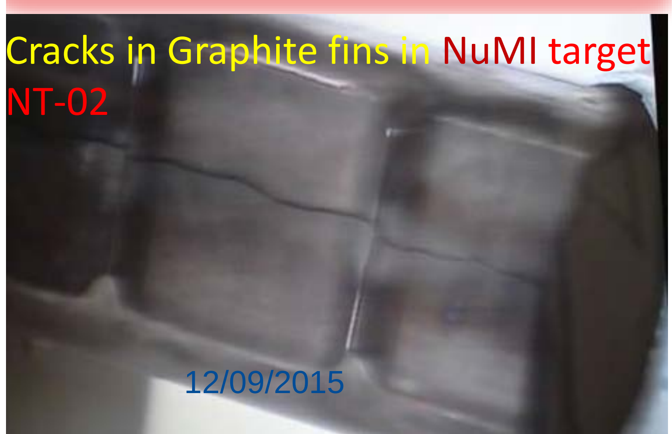
How to Double Power Beyond PIP-II (replace Booster)

So far , just at the beginning, formation of R&D Program to consider **two options**:

- **Either** increase performance of the synchrotrons by a **factor of 2-4**:
  - e.g. ***dQ_sc >1 (now 0.3)***→ **need R&D**
  - Instabilities/losses/RF/vacuum/collimation
  - *IOTA/FAST* to be built to study new methods
- **Or** reduce cost of the **SRF / GeV** by a **factor of 3-4**:
  - Several opportunities → **need R&D**
- **And** – in any scenario – develop **multi-MW** targets:
  - do not exist now → extensive **R&D needed**
- **Finally** – in any scenario – understand **multi-MW facility design** concept:
  - Integration in accel.complex&DUNE **needed**





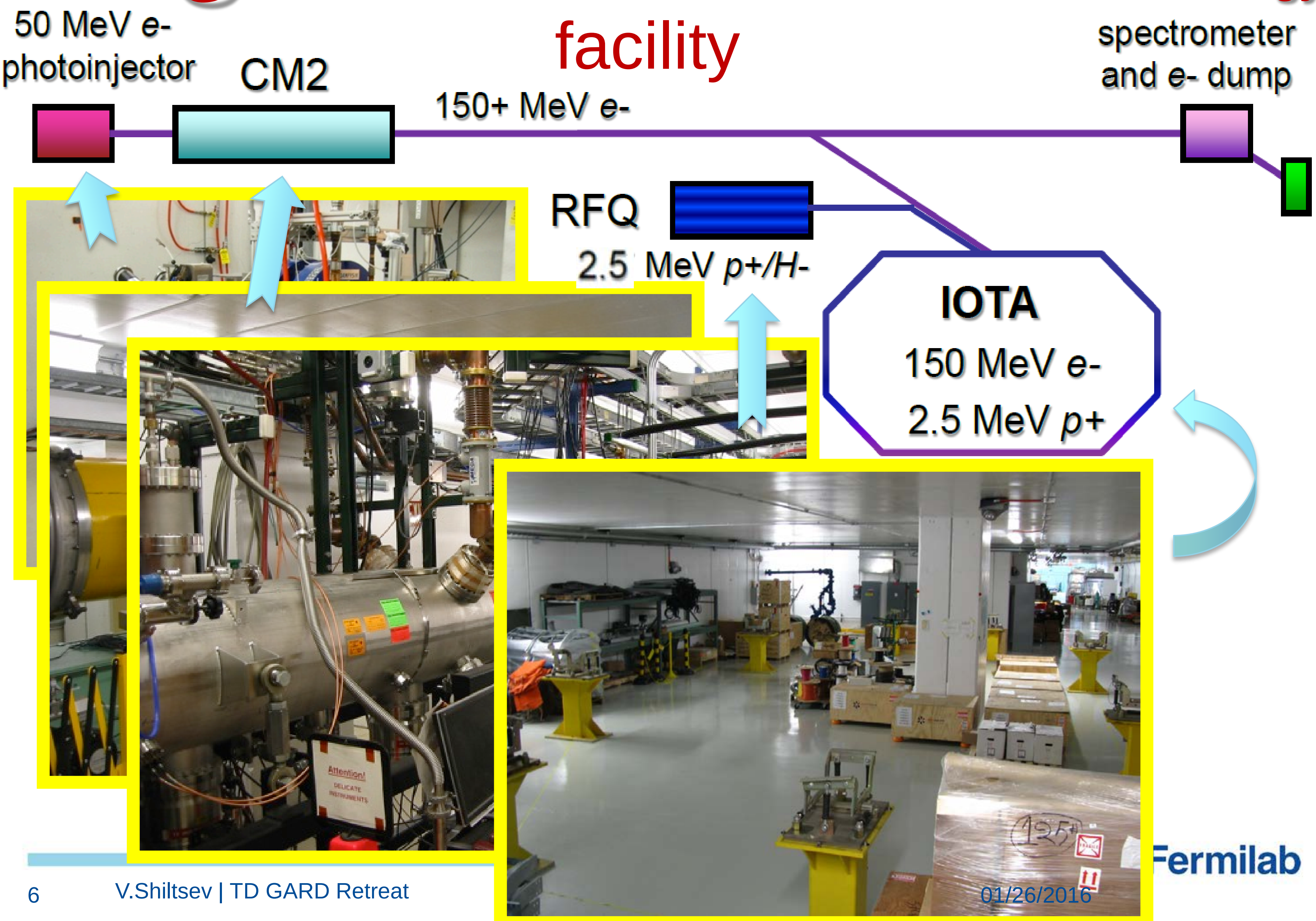


12/09/2015

IOTA Physics Motivation

- To explore two **innovative ideas**:
  - *Integrable Optics*
    - *With strongly nonlinear magnets*
    - *With specially shaped electron beams in electron lenses*
  - *Space Charge Compensation*
    - *With ~"Gaussian" electron lenses*
    - *With neutralizing "electron columns"*
- Both work in simulations→ to test them experimentally, we are building the **Integrable Optics Test Accelerator (IOTA)**
  - a machine for proof-of-principle R&D
  - can operate with either *e*- or *p*+ up to 150 MeV/c momentum
  - large aperture,
  - significant flexibility of the beam optics lattice
  - precise control of the optics quality and stability
  - set up for very high intensity operation (with protons)

IOTA @ Fermilab Accelerator Science and Technology facility

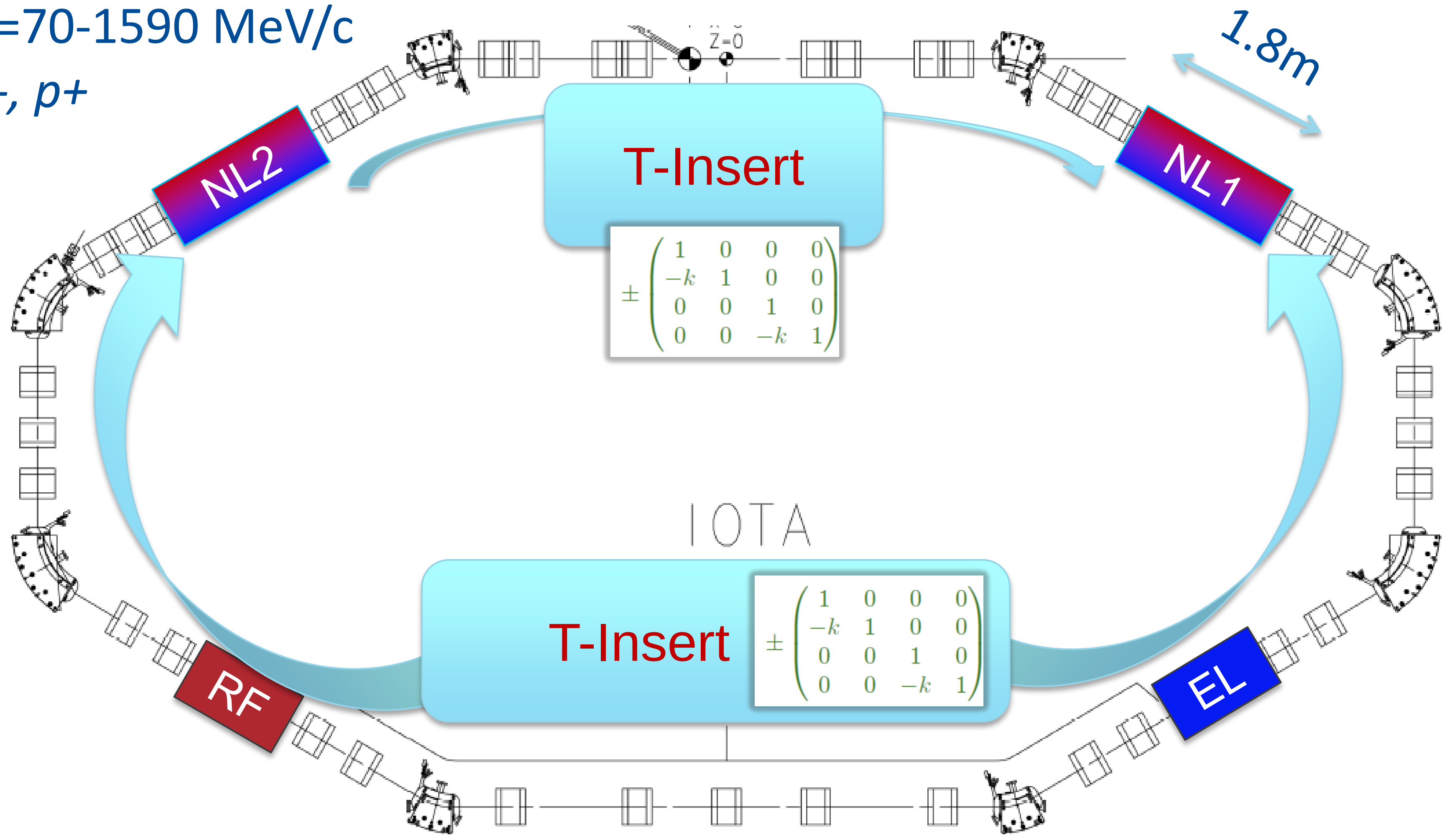


IOTA with Two Nonlinear Lenses and E-Lens

C=40m

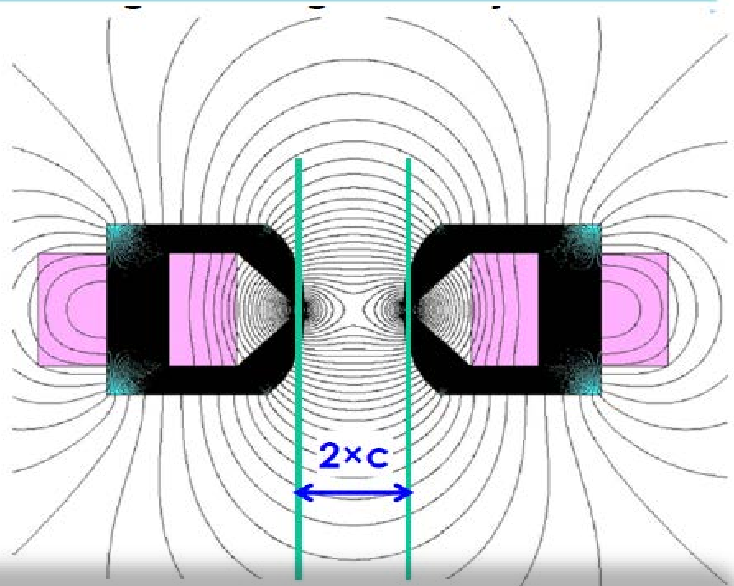
P=70-1590 MeV/c

e-, p+

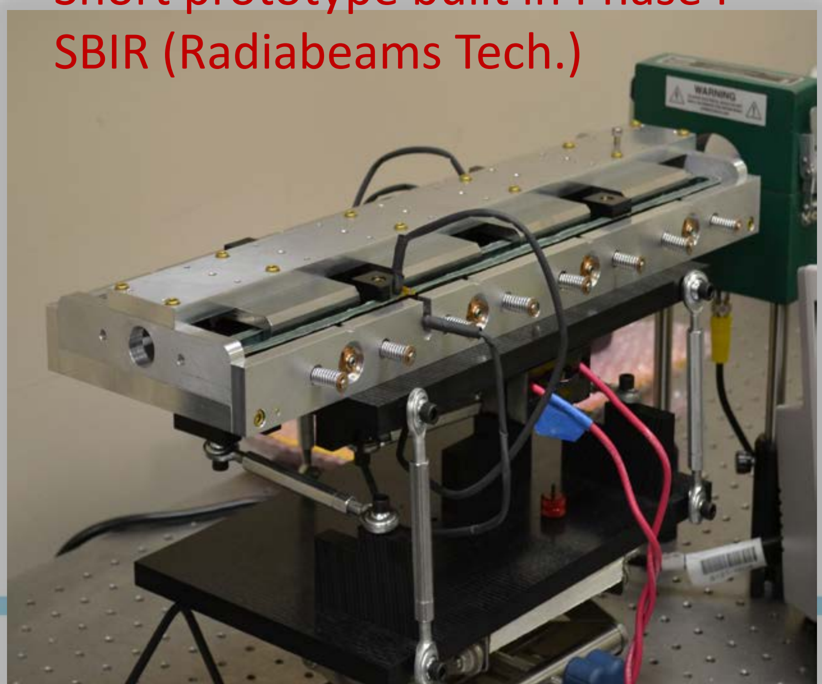


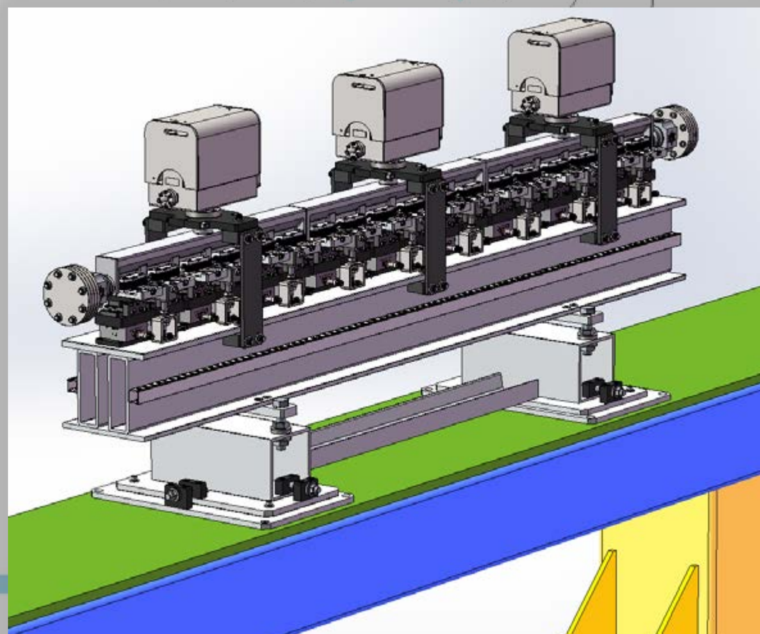
Integrable Optics with Non-linear Magnets

- Additional integrals of transverse motion possible:
  - Special NL magnets →
  - Makes particle dynamics stable with very large tune-spread



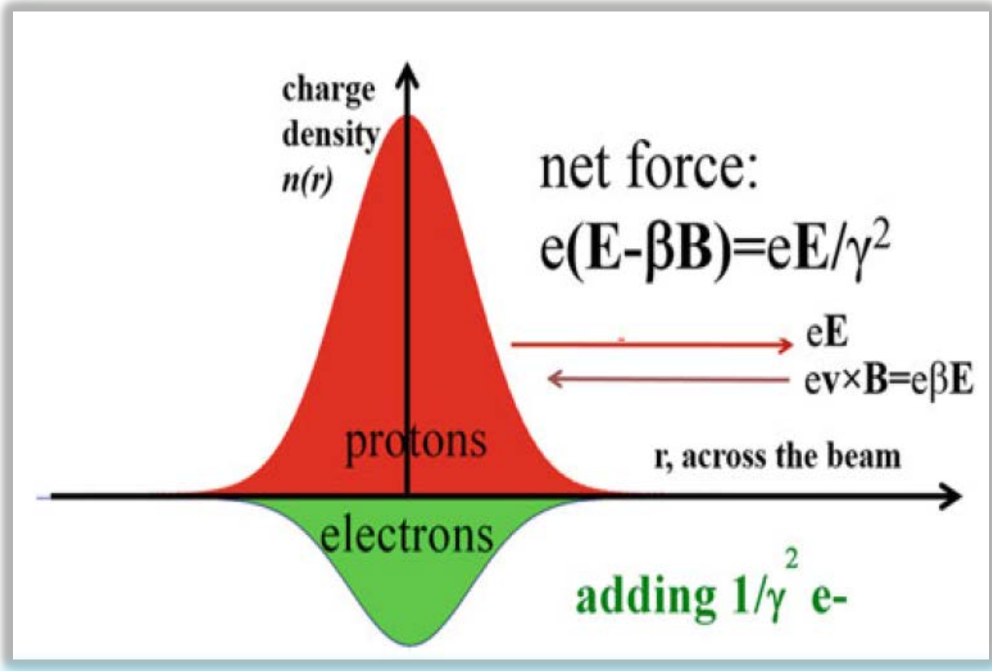
Short prototype built in Phase I SBIR (Radiabeams Tech.)

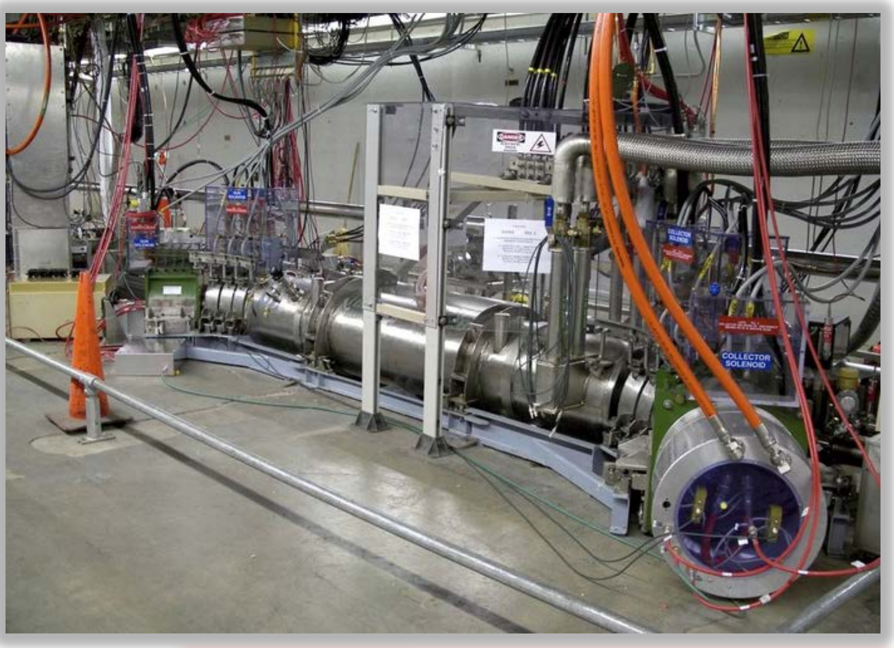


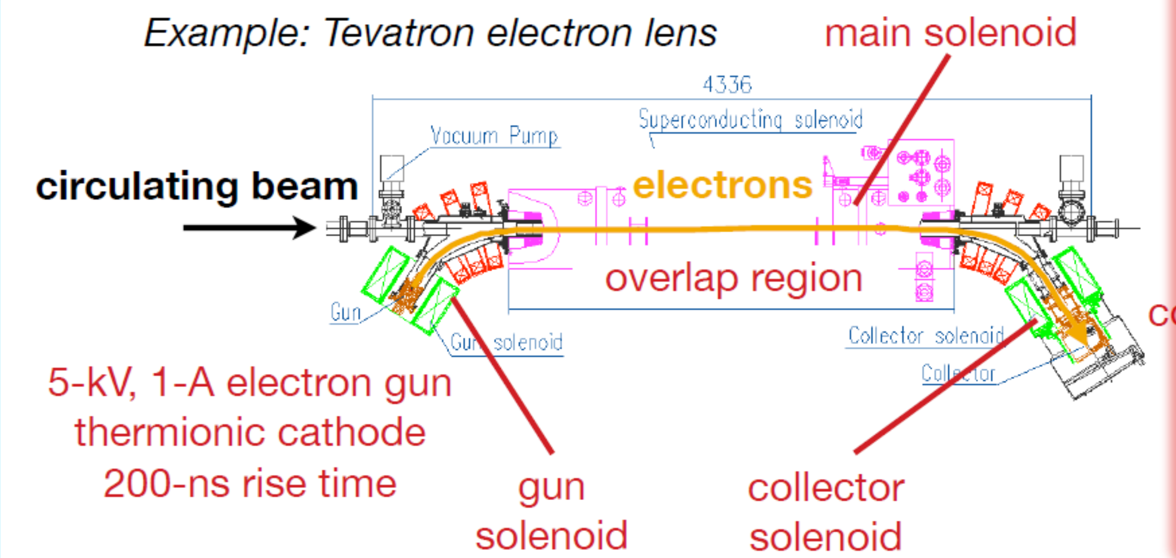


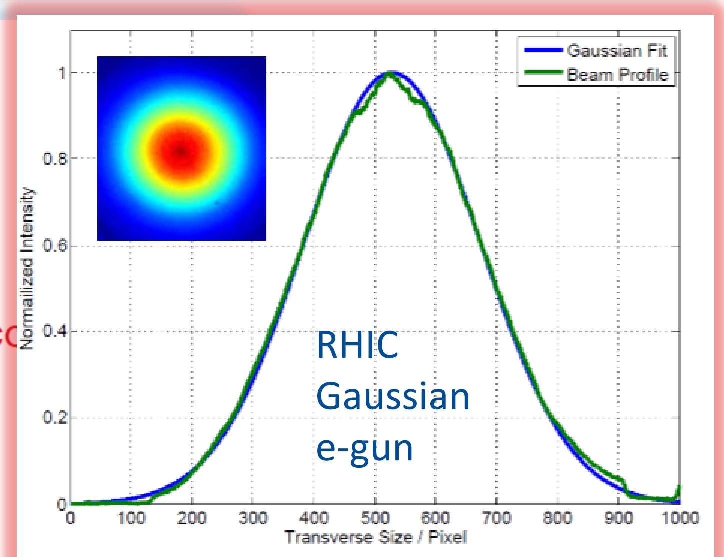
1.8-m long magnet to be delivered in 2016

Electron Lenses: Space-Charge Compensation



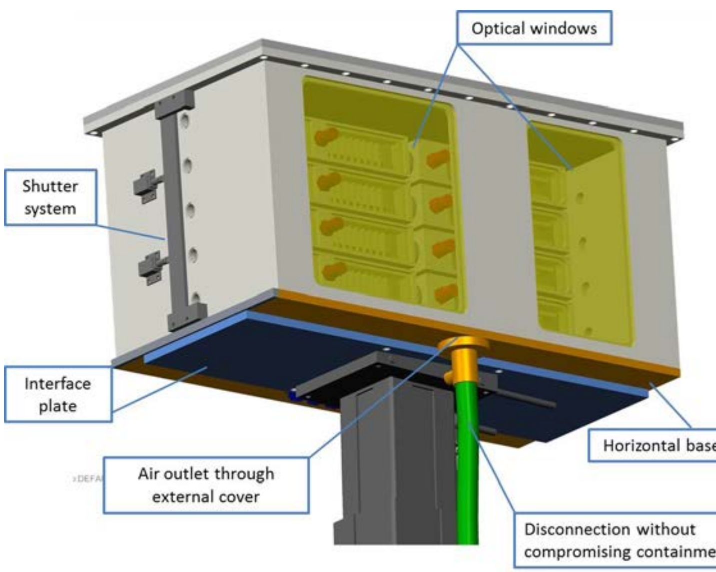


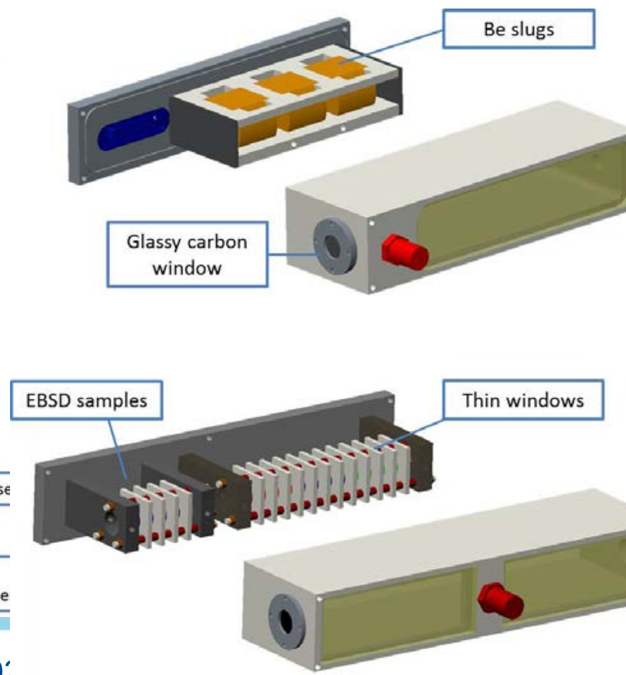


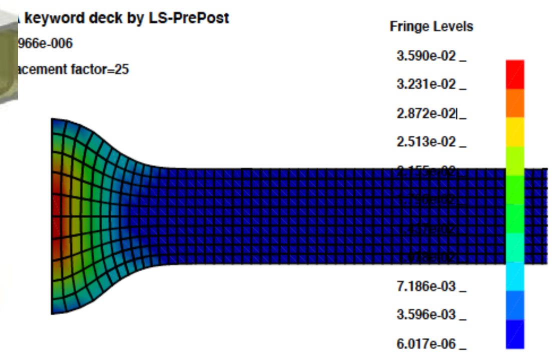


High Power Targetry : New R&D Thrust

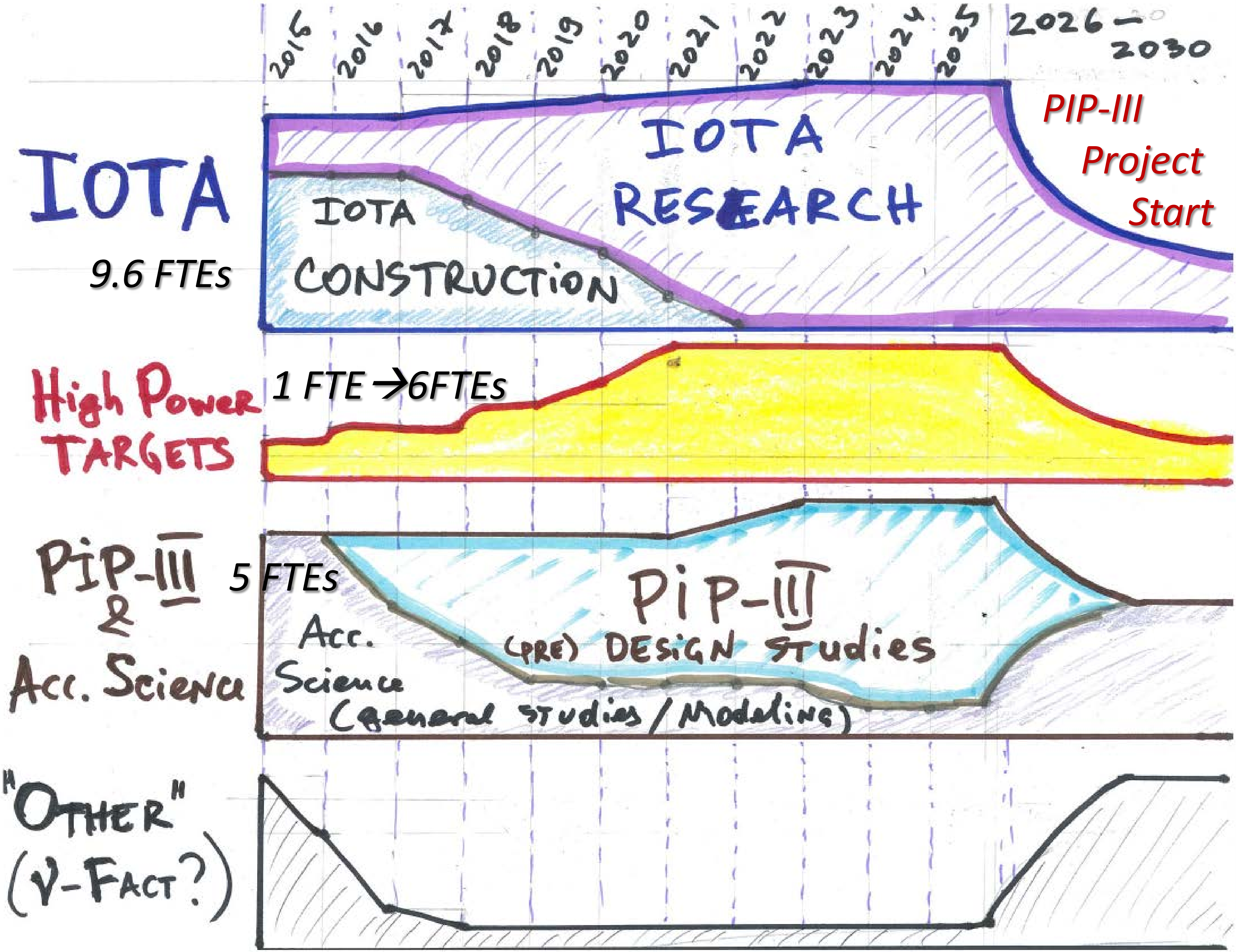
- Int'l **RADIATE** collaboration: Thermal Shock R&D activities
  - Approval of BeGrid experiment at CERN's HiRadMat beamline
  - Test 4 grades of beryllium to varying intensity HE proton beam
  - Objectives of the 4 institution study (FNAL, RAL-STFC, Oxford, CERN):
    - Study the initiation of small scale damage from high intensity, single pulses
    - Explore failure limits of Be
    - Compare response of various grades/forms of Be
    - Validate simulation techniques and strength/damage material models







$t = 7.2\mu s, T_{max} \sim 1050^{\circ}C$
End of pulse



2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026 — 2030
IOTA
9.6 FTEs
IOTA CONSTRUCTION
IOTA RESEARCH
PIP-III Project Start
High Power TARGETS
1 FTE → 6FTEs
PIP-III & Acc. Science
5 FTEs
PIP-III (PRE) DESIGN STUDIES
Acc. Science (General studies / Modeling)
"OTHER" (ν-FACT?)

Things Which Are Important (1)

- (when we consider Accelerator R&D opportunities)
- Relevance:
  - Don’t expect blue sky research will have much traction in the budget-limited world “just because…”
  - For any R&D direction a clearly spelled relevance needed
    - Convincing rationale… may not necessary true
  - In our world it means:
    - P5
    - Fermilab
    - Accelerator Division

Things Which Are Important (2)

- (when we consider Accelerator R&D opportunities)
- **Relevance:**
  - Don’t expect blue sky research will have much traction in the budget-limited world “just because…”
  - For any R&D direction a clearly spelled relevance needed
    - Convincing rationale… may not necessary true
  - In our world it means:
    - P5
    - Fermilab
    - Accelerator Division

    (since reorganization of the Lab, integration weakened)

Fermilab

Things Which Are Important (2)

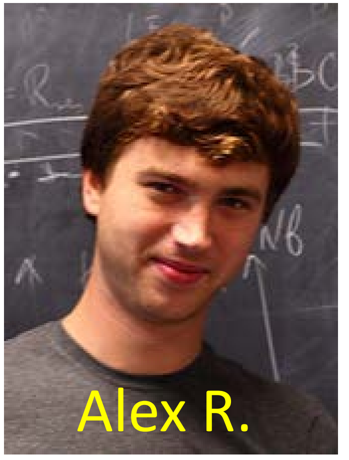
- (it might make it hard to start, but also hard to kill)
- **Collaborations:**
  - AD, SCD, PPD, ND
  - Other Labs
  - Universities
    - Joint Appointments
    - Adjunct Proffesorships
  - International
  - Users (incl. non-HEP)
- Those who will

stand by you

participants of the **2nd IOTA / FAST Collaboration Meeting**, June 2014

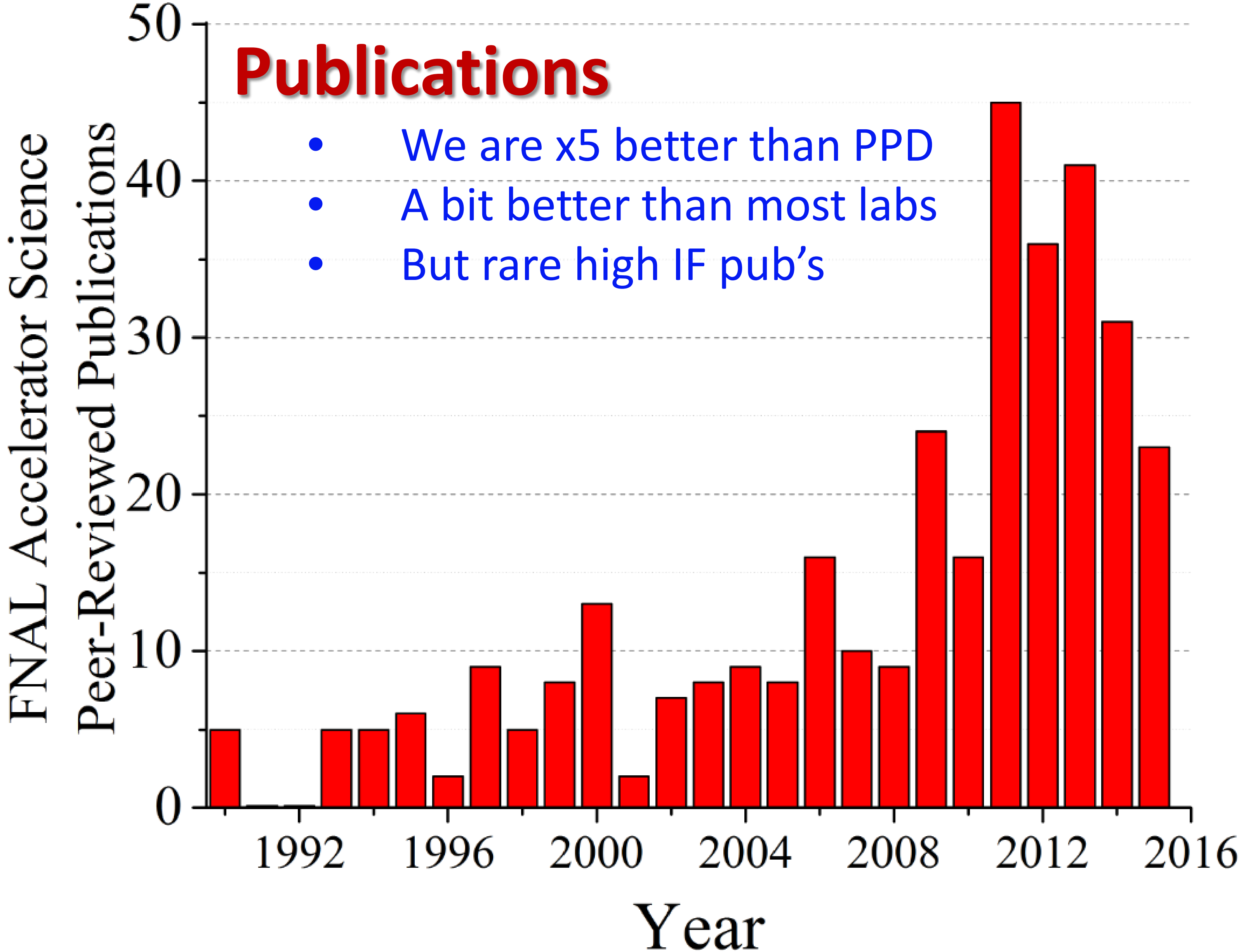
Things Which Are Important (3)

- (easy to get on board, will make it hard to kill)
- **Junior Researchers:**
  - Get PhD students
  - Post Docs
    - Huge problem in AD
  - Peoples Fellows
  - Bardeen Fellows
  - Toohig Fellows
- LDRD program is VERY helpful / important :
  - Just do not propose "usual" stuff and "things we must do but have no $$"



Peoples Fellows – leaders at FNAL

Things Which Are Important (4)



Things Which Are Important (5)

- (very important to position the lab)
- **Connections and positioning:**
  - With DOE OHEP
    - So far limited to Chiefs, annual briefings of PIs very useful
  - With accelerator and HEP community
    - Membership in program committees, etc
    - Review other labs/universities
    - Professional organizations:
      - APS DPB better
      - IEEE very weak
    - Accolades (Prizes, Awards, Fellows, etc)
      - Very weak record for the Lab our size and importance

Things Which Might Be Interesting

- (my own list… after being invited to "think out of the box"… mostly reflects needs of particle accelerators)

1. **Large aperture magnets… SC… 20-100 K**
2. **Fast cycling magnets… cheap … SC .. HTS**
3. **Fast tuneable SC RF**
4. **Graphene/borophene conductors/coats**
5. **High rad-resistant materials SC RF (HTS?)**
6. **Low freq (53 MHz) high power amplifiers**
7. **High grad SC RF (90 MV/m Nb3Sn)**
8. **High Q SC RF (N2)**
9. **Low cost SC RF (Nb on Cu , etc)**

Thanks for your attention!