Fermilab

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"Integrated" Accelerator R&D at FNAL: Goals, Scope, People, Junior Scientists

Vladimir Shiltsev, Accelerator Physics Center / AD

Vice-Chair APS DPB (2016-), Chair of NA-PAC'16 SPC, PAC OC (2008-), APS Wilson Prize Committee chair (2011), CERN MAC (2008-16), RHIC CAD MAC (2010-13), CLIC-ACE (2007-10), DOE OHEP and FES R&D and NSF AS panels, BELLA/FACET/SNS/NS/eRHIC/MEIC reviews, OHEP CoV (2013), MAP IB, EPS Accelerator Prize (2004), APS R.H.Siemann Award (2015), APS Fellow, IEEE Senior Member, Wilson Fellow (1996-2000), Editor Springer PAD and IoP JINST, PRSTAB EB (2009-15), Adjunct Professor NIU

Fermilab SAC, February 22, 2016

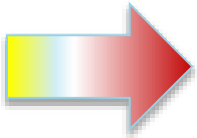
US HEP Community Goals: P5

	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*

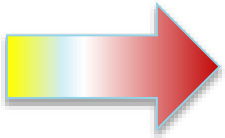
**dependent on how physics unfolds*

- **Key R&D thrusts:**
  - Accelerator and Beam Physics
    - IOTA Research on Space-Charge AD-SCD
    - PIP-III (2.5 MW FNAL upgrade) AD-TD-SCD
  - High Power Targetry R&D - AD
  - High field 16T magnets - TD
  - Low cost SC RF - in TD
  - Advanced Acceleration – (small, in AD)

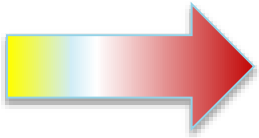
Present & Future HEP IF Accelerators



300+ kW JPARC (Japan)

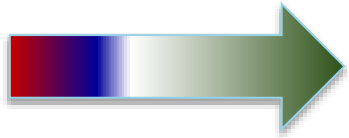


400+ kW CNGS (CERN)



500+ kW Fermilab's Main Injector (2015)

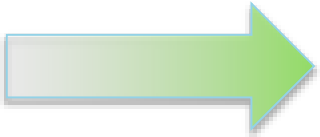
EVOLUTION OF INTENSITY FRONTIER ACCELERATORS



700+ kW Proton Improvement Plan (PIP, 2016)

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

2.5 MW

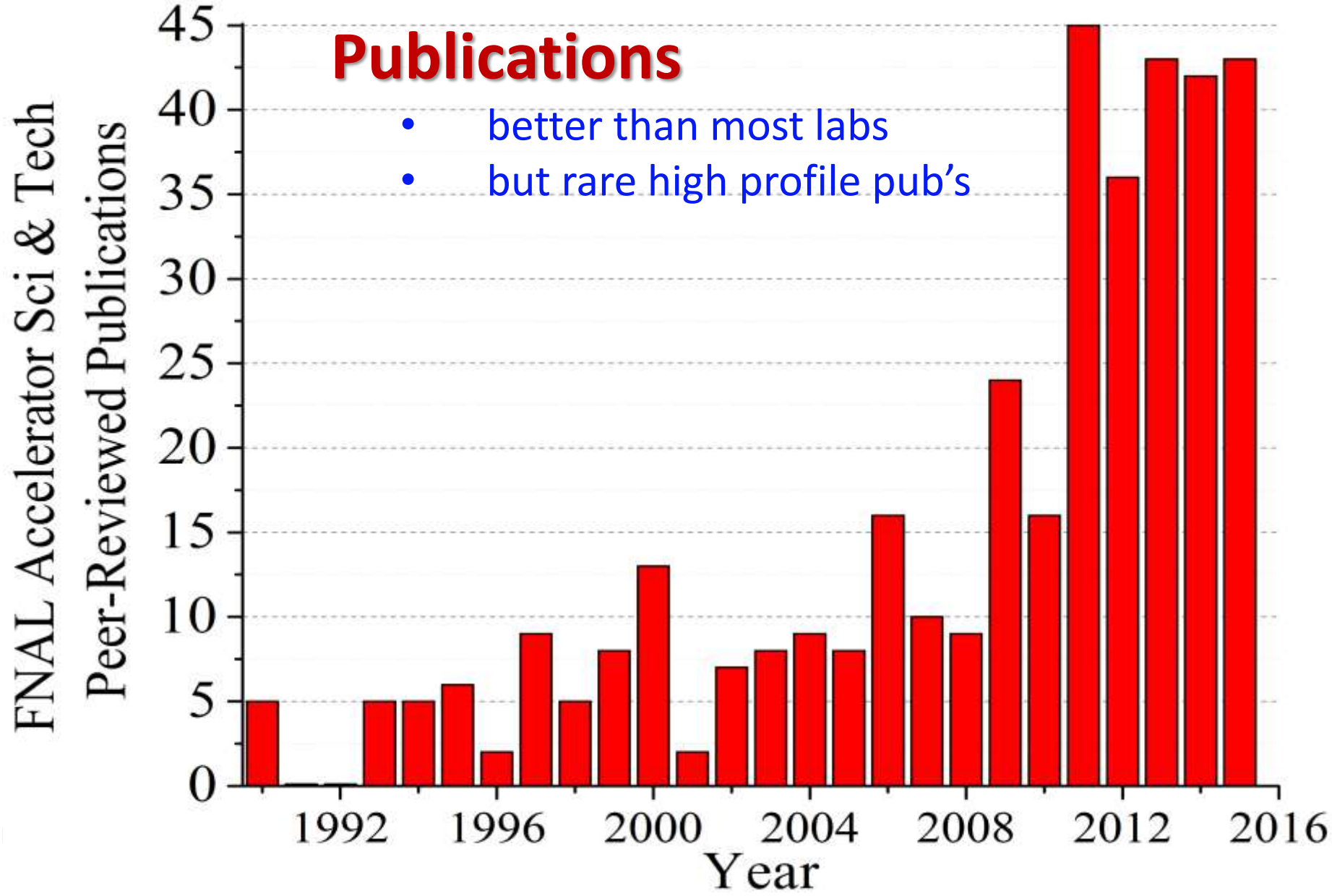


5 MW?

Proton Improvement Plan-III (under study)

Fermilab

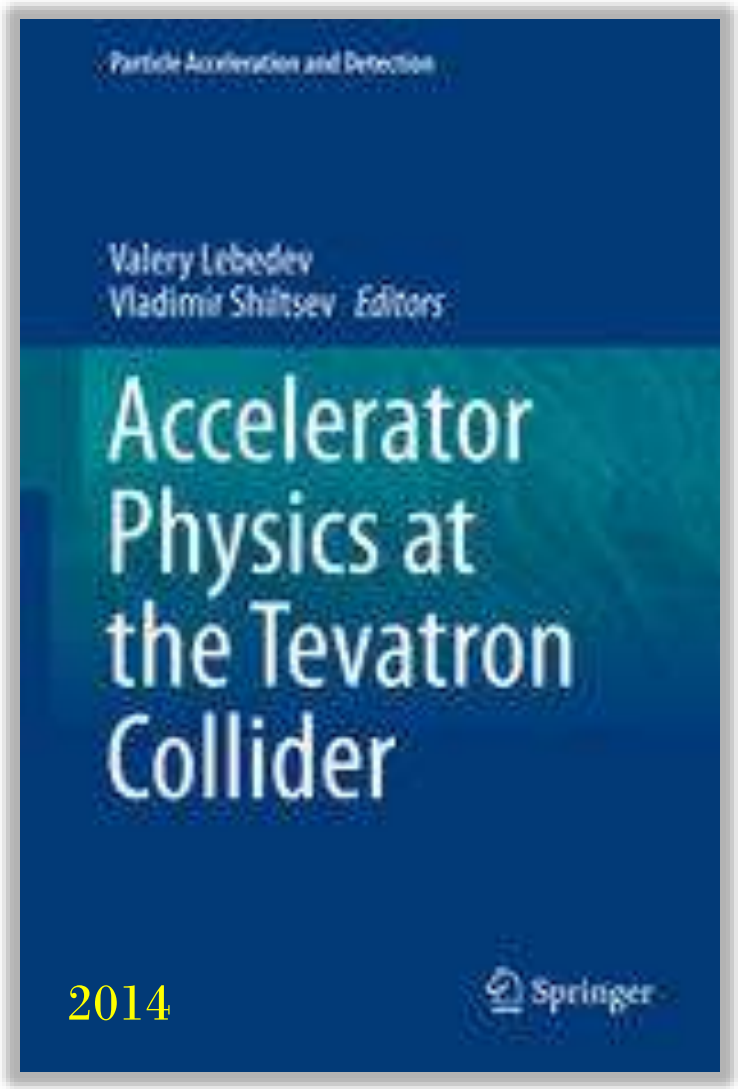
Accelerator R&D Outcome (1)

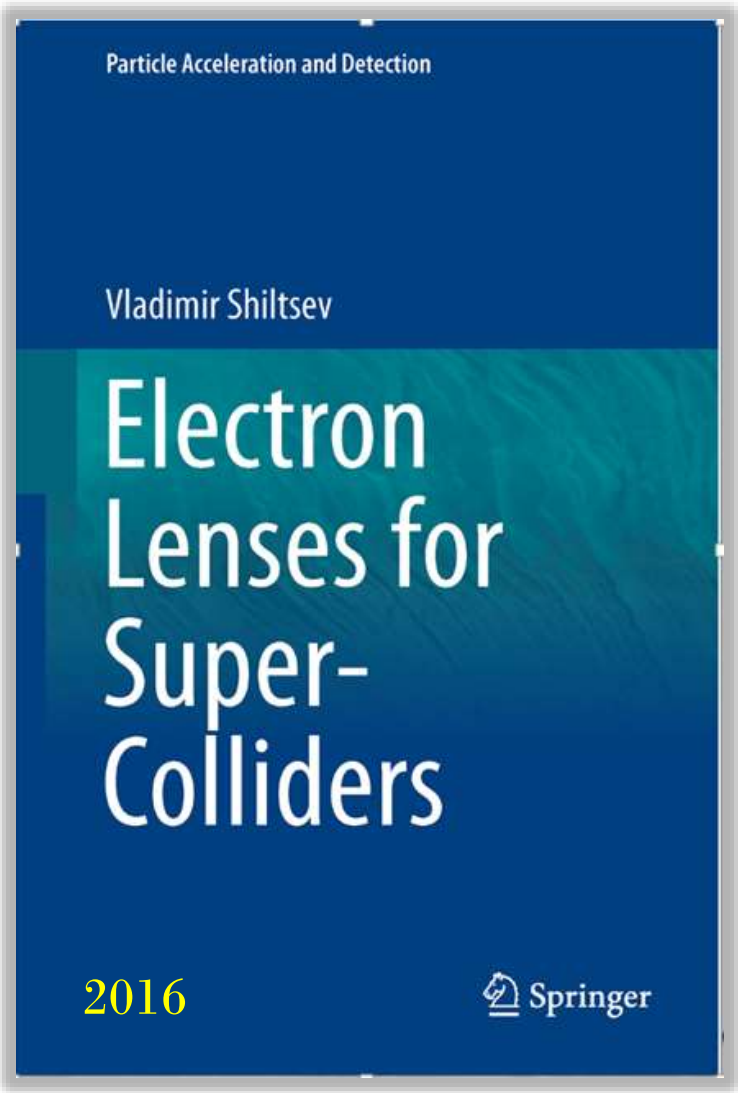


Our 10 Highest Impact Papers/Breakthroughs

Yr.	PI's	Magazine	Subject	Comments
1984	Tollestrup, R.Palmer	*Ann. Rev. Nucl. Sci.*	SC magnets	paved the way for HEP ~40 years
1985 2013	H.Edwards Holmes, Shiltsev	*Ann. Rev. Nucl. Sci.*	Tevatron collider	lessons, followed by HERA, RHIC, LHC
1993	Church, Marriner	*Ann. Rev. Nucl. Sci.*	record p-bar source	95% of man-made nuclear antimatter
2006	Nagaitsev, et al	*PRL*	rel. e-cool	now for eRHIC, NICA, FAIR
2006 2011	Piot, et al Ruan, et al	*PRSTAB* *PRL*	emmittace exchange	was for ILC, now for G4 light sources
2007	Shiltsev, et al	*PRL*	e-lens BBC	TeV, RHIC, now LHC
2011	Stancari, Shiltsev, et al	*PRL*	hollow TEL	Collim'n TeV, HL-LHC
2012	Lebedev, Shishlo, et al	*PRL*	H^- IBS strip	fundamental H- limit SNS, ESS, etc
2012	Johnstone, Machida, et al	*Nature Phys*	FFAG	now for medical ?
2013	Yonehara, et al	*PRL*	HP-gas RF	x4 higher gradient

Recent books





Nature/Science -type Topics for the Next ~ 6 Years

1. **MICE 4 D Muon Cooling Demonstrated (2018?)**
2. **N2 Doping Q-effect Theory beyond BCS (?)**
3. **Integrable Optics in IOTA (2019?)**
4. **Optical Stochastic Cooling in IOTA (2020?)**
5. **Space Charge Compensation in IOTA (2021?)**
6. **Super-acceleration in Crystals (?)**
7. **Single e- Quantum Wave Function in IOTA (2022?)**
8. **… hope smth else will come**

… e.g. out of collaborations with plasma wake-field community: AWAKE, BELLA, FACET-II (though none of these ideas stands even a simple ***collider-reality*** check now)

AD Junior Scientific Personnel : 7(9) out of 76 (445 total AD)

- Research Associates - 5(6):
  - Robert Ainsworth - Main Injector
  - Alejandro Garcia Sosa - Proton Source
  - Sujit Bidhar – High Power Targetry
  - Jeffrey Eldred – PIP-I, II, III / IOTA/FAST
  - Aleksandr Romanov - IOTA/FAST
  - (Ao Liu , to start 04/2016) - MICE
- Toohig Fellow (btw RA and AS)
  - (Miriam Fitterer, to start 03/07/16) – Hollow E-Lens Collim.
- Assoc. Scientists - 2:
  - Daniel Bowring (Peoples Fellow) – MTA/MICE
  - Alessandro Vivoli – PIP-II Project

TD Junior Scientific Personnel : 8(9) out of 32 (245 total TD)

- Research Associates – 3(4):
  - Julia Trenikhina – SRF new materials
  - Arun Saini – PIP-II SRF project work
  - Sebastian Aderhold – SRF R&D
  - (RA opening in SC mag R&D)
- Associate Scientists - 5:
  - Jeremniah Olzbauer– LCLS-II tests and SRF R&D
  - Alex Melnychuk – SRF cavity tests for LCLS-II and R&D
  - Sam Posen – SRF R&D, Nb3Sn
  - Stoyan Stoynev – SC MAG for LARP and R&D
  - Thomas Strauss – SC MAG for LARP and R&D
- + One RA (Accel. Sci) in SCD
  - Tim Zolkin – Integrable Optics theory/modeling

Where do we get them? Staged system of Accelerator Workforce Search and Development

- **Educ. programs** as entry points:
  - Lee Teng Intenship, PARTI, Italian
    - Supercompetitive (eg 105 appl for 5)
  - US PAS
- **Junior Researchers:**
  - PhD students – 7 (competitive)
  - Post Docs
    - Low % in AD – see below - $$, ops
    - Supercompetitive (recent : 29 for 1)
  - Peoples Fellows →
  - Bardeen Fellows
  - Toohig Fellows
- **LDRD program** is VERY helpful / important

Peoples Fellows – leaders at FNA

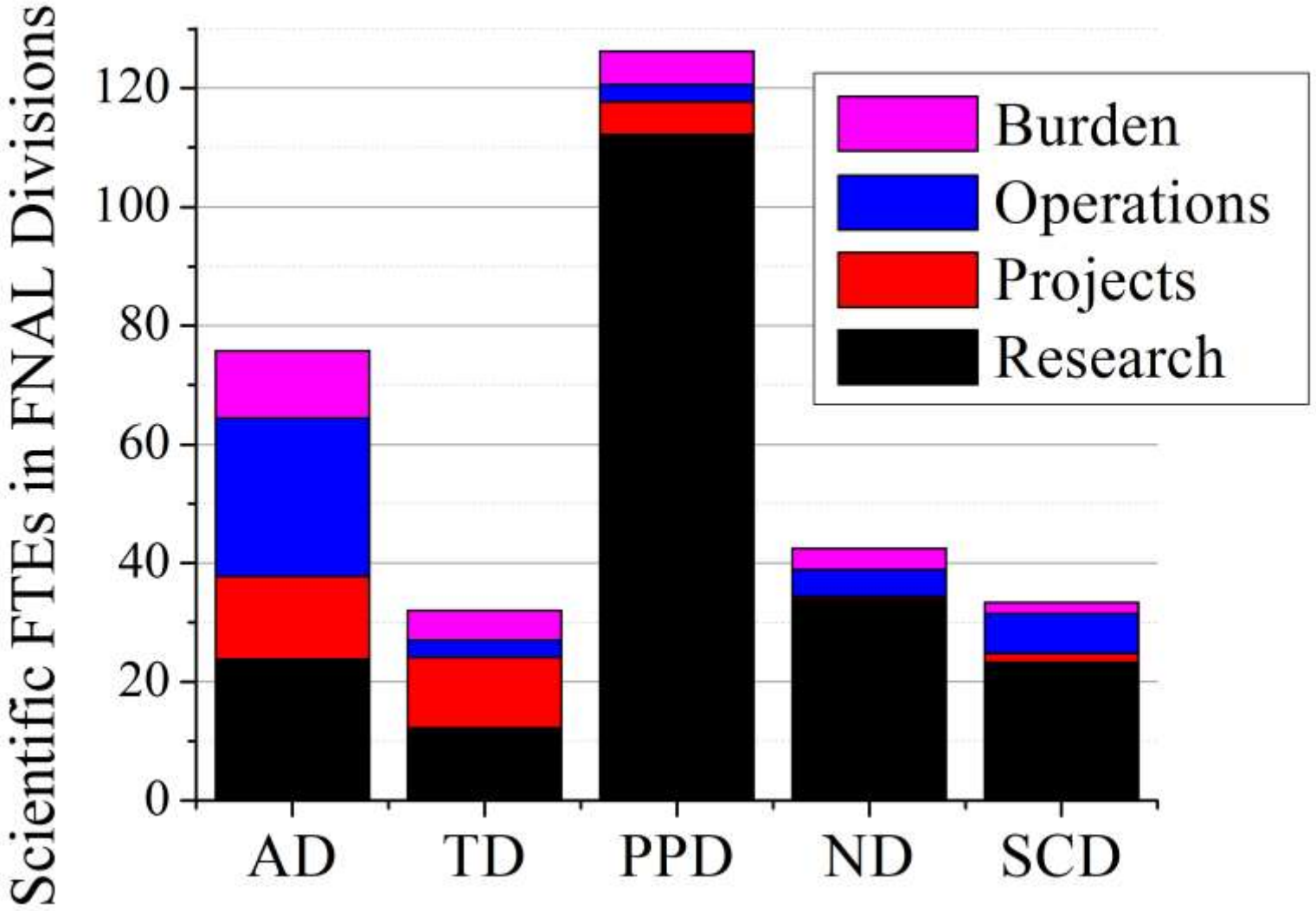
Collaborators: Source of People & Ideas

- **IOTA Collaboration:**
  - AD, SCD, PPD, ND
  - Other Labs
  - Universities
    - Joint Appointments
    - Adjunct Professors
  - International
  - Users (incl. non-HEP)
- **Strategic Partnership with NIU**
  - led by Swapan C.
  - Now 3 JAs, other Profs and students
  - many experiements

Attracted by FACILITIES (SRF, SCMag, IOTA)

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

Specifics : Scientists in Accelerator Sector



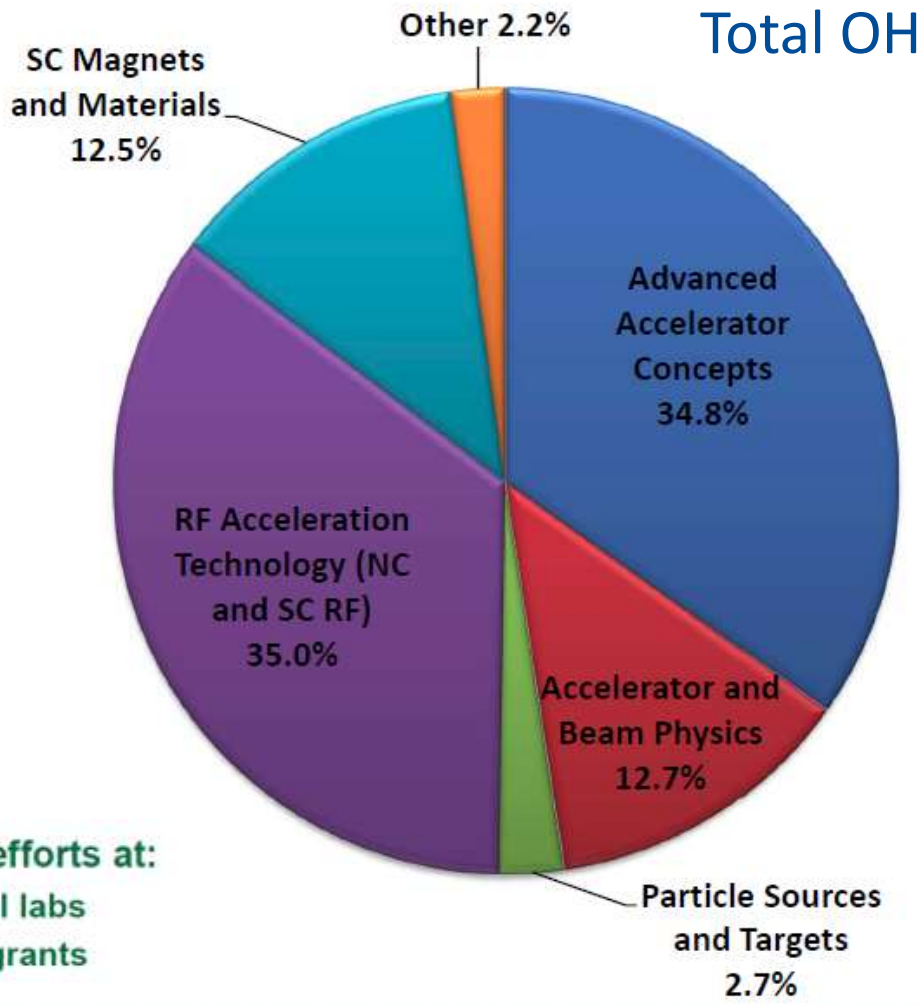
Summary:

- Fermilab has a lot of experience in accelerator science, with great record of ideas, accomplishments and publications
- At present, we are concentrated on a) Accelerator Physics (IOTA and PIP-III studies); b) Multi-MW targetry; c) SRF; d) SC magnets - and the Lab seems to be best aligned with P5 and HEPAP GARD subpanel goals/recommendations
- Specifics of accelerator scientists is mission-related:
  - scientist time covered by research B&R codes is ~30% in AD/TD, while >90% in PPD/ND/SCD
- Such a burden (to operate and carry out projects) together with limited funding for R&D affects the ability of AD+TD to attract larger number younger talent
  - that's critical for the future of the accelerator laboratory
  - Universities and collaborators (only) partly help resolve the issue

Thanks for your attention!

Back up slides

FY 2015 GARD Funding – % By Thrusts



Total OHEP GARD ~ 50M$
Fermilab ~11M$
(30 FTEs)

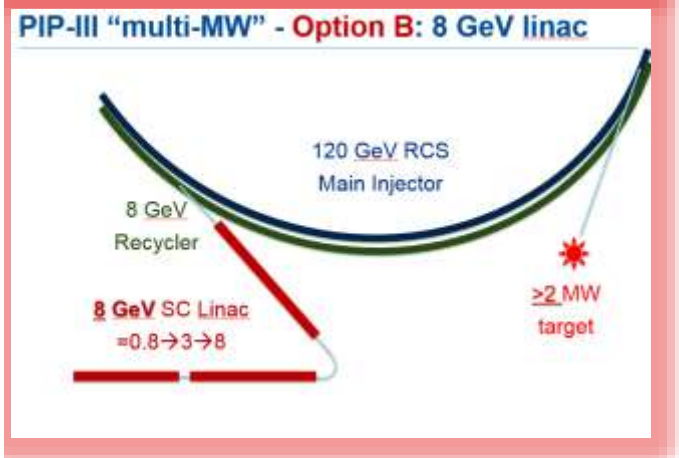
Support research efforts at:

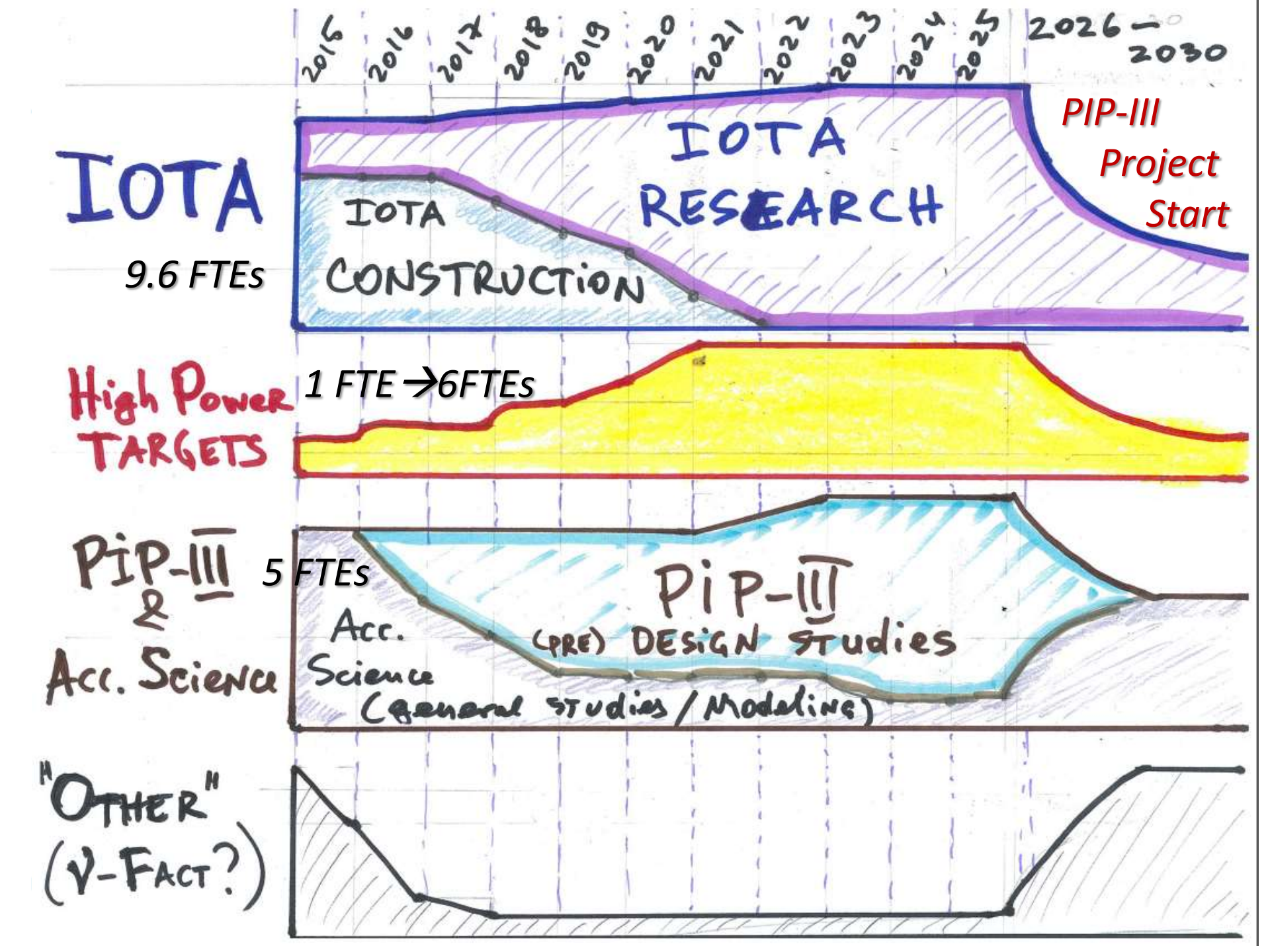
- 7 DOE national labs
- 30 university grants

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

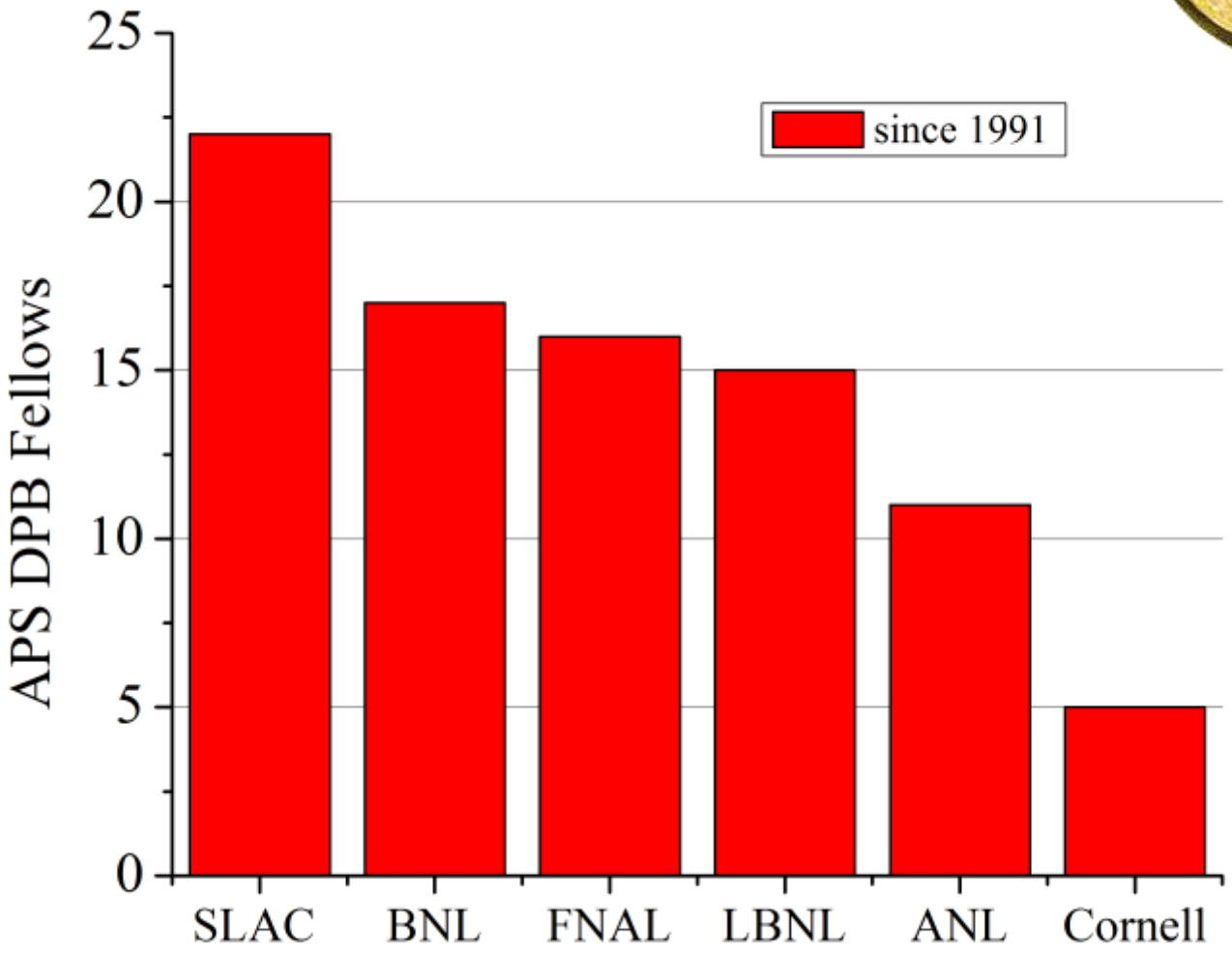
So far , just at the beginning, formation of R&D Program to consider two options:

- **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**




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
Acc. Science
PIP-III (PRE) DESIGN STUDIES
(General studies / Modeling)
"OTHER" (V-FACT?)

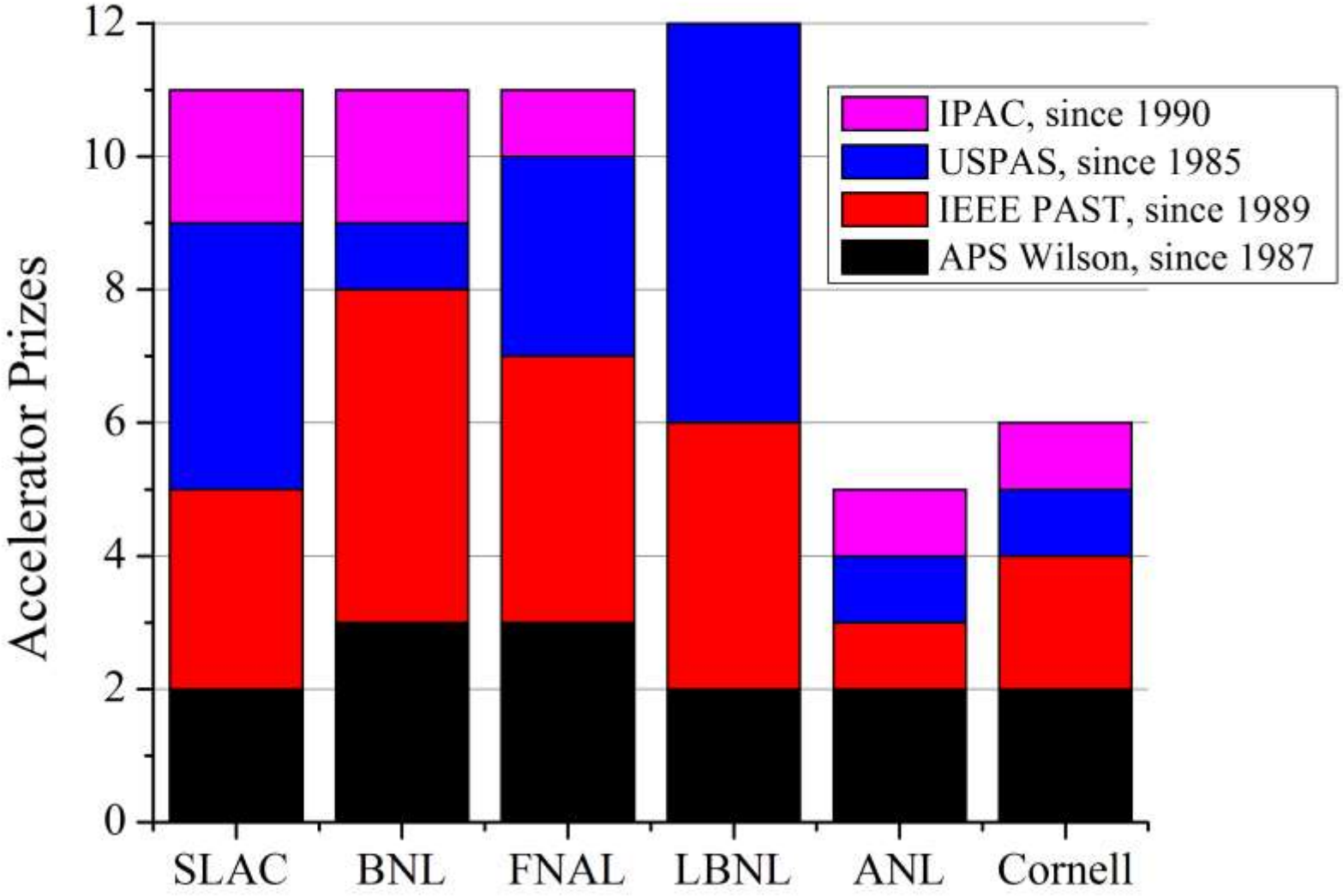
Accolades (1)


APS DPB Fellows
25
20
15
10
5
0
since 1991
SLAC
BNL
FNAL
LBNL
ANL
Cornell

Accolades (2)

Prizes

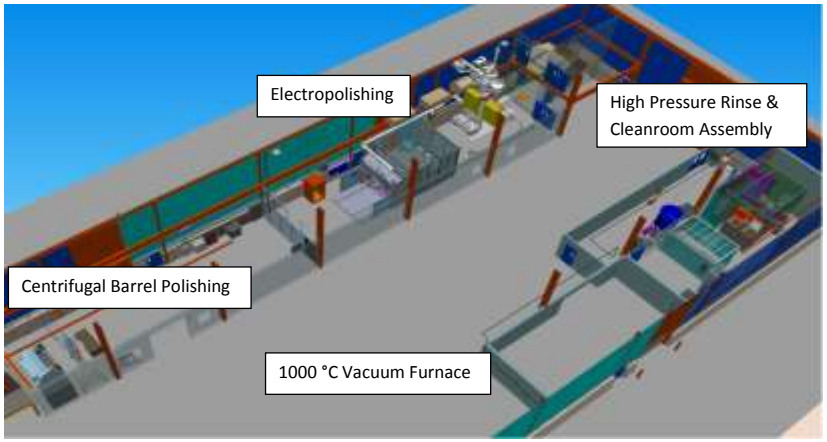
Robert R. Wilson Prize for Achievement in the Physics of Particle Accelerators



Three Ingredients of Successful Research:

PEOPLE (with ideas)
MONEY
FACILITIES

Very Successfully Used SRF Facilities in TD (many)




1300 MHz EP tool in SCSPF


Loading 1300 MHz cavity into HPR


325 and 650 MHz EP/BCP tool in SCSPF

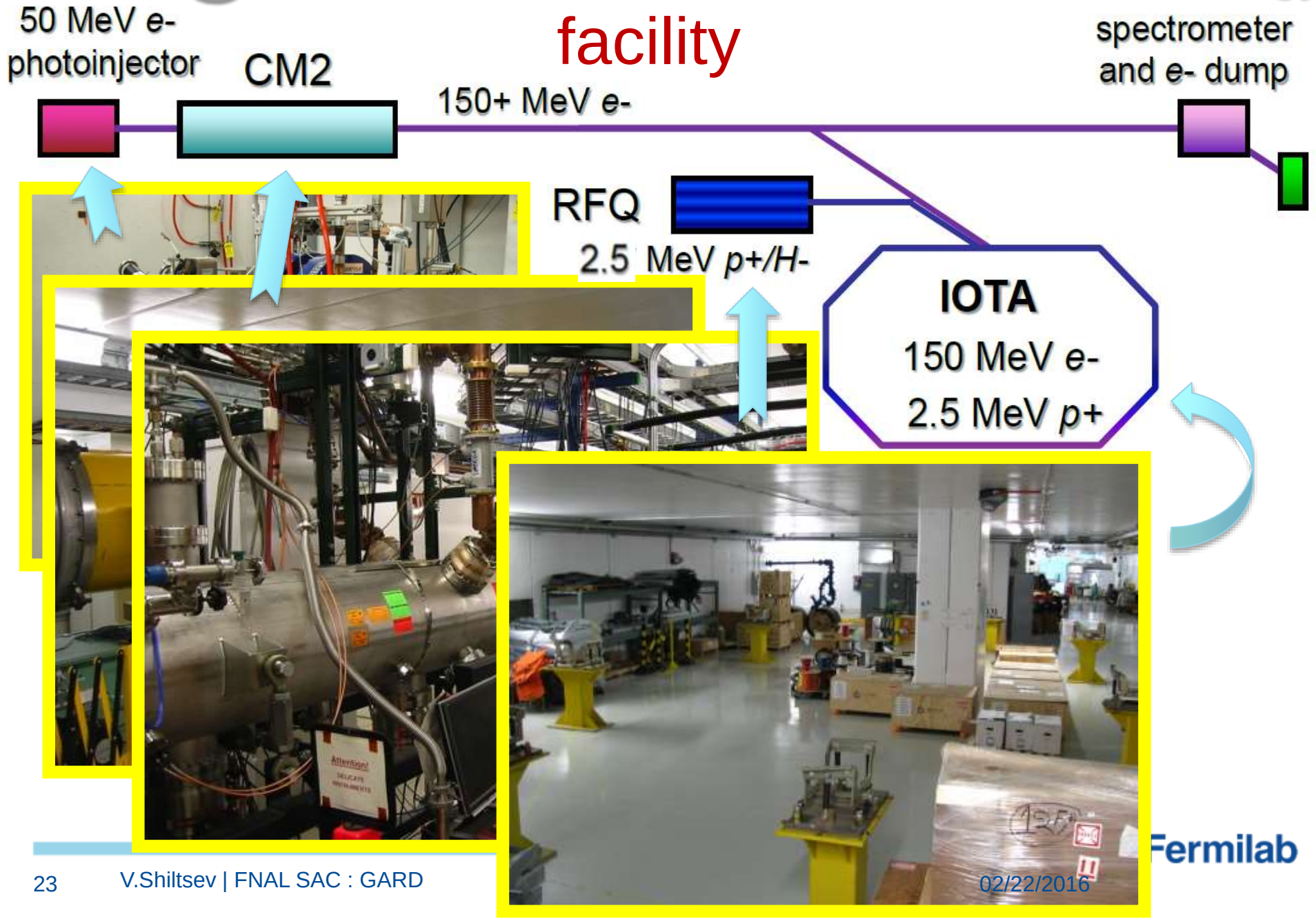

CBP machine


EP cabinet in CPL


SSR1 cavity on HPR system


Setting up for BCP in G150

IOTA @ Fermilab Accelerator Science and Technology facility



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)