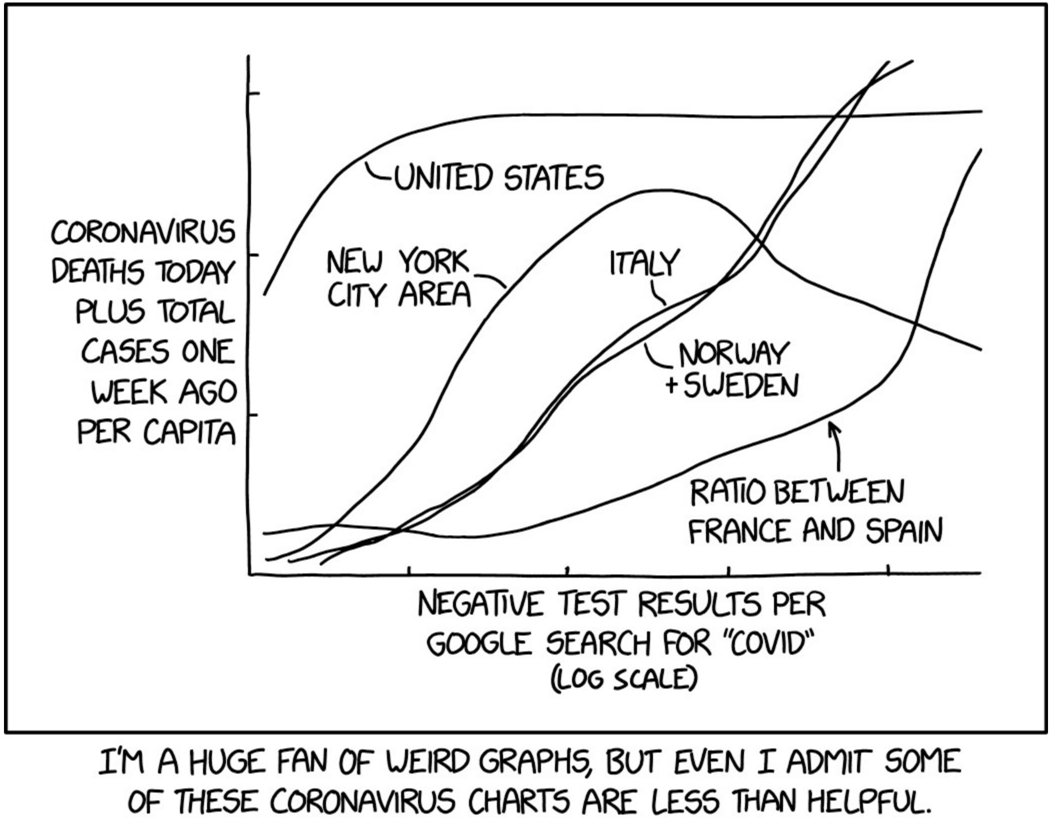
T. Cartier-Michaud

(virtual) IPAC2020

- IRL canceled due to Covid19
  => no poster
  => proceedings only for talks
  => no visit of facilities
  => no banquet...
- Recorded talks (available 2 weeks)
  ==> high quality of talks
  ==> time for wikipedia :-D
  ==> time for some meetings
- Chat/forum for Q&A
  ==> higher quality of answers ?
- Free of charge !



https://xkcd.com/2294/

Program (link / PDF link)

- Opening Session
- MC1 Circular and Linear Colliders
- MC2 Photon Sources and Electron Accelerators
- MC3 Novel Particle Sources and Acceleration Techniques
- MC4 Hadron Accelerators
- MC5 Beam Dynamics and EM Fields
- MC6 Beam Instrumentation, Controls, Feedback and Operational Aspects
- MC7 Accelerator Technology
- MC8 Applications of Accelerators, Technology Transfer and Industrial Relations
- LIVE Prize Award Session (https://indico.cern.ch/event/914436/)

Selected talks

1) Navin Alahari, GANIL
New Horizons in Nuclear Science: GANIL and Beyond

2) Fabiola Gianotti, CERN
Status of the European Strategy for Particle Physics update

3) Jerry Hastings, SLAC
Developments in Photon Science Accelerators and Competitive Technologies

4) Ben Shepherd, STFC/DL/ASTEC
Permanent Magnets for Accelerators

5) Anke-Susanne Müller, KIT
The Future Circular Collider Study

6) Sébastien Corde, LOA
Progress in Plasma-Based Accelerators Driven by Particle Beams

7) Adrian Fabich, SCK-CEN
Accelerators for Applications in Energy and Nuclear Waste Transmutation

8) Simon Leemann, LBNL
Applying Machine Learning to Stabilize the Source Size in the ALS Storage Ring

9) Alexander Scheinker, LANL
Adaptive Feedback Control and Machine Learning for Particle Accelerators

Navin Alahari, GANIL
New Horizons in Nuclear Science: GANIL and Beyond

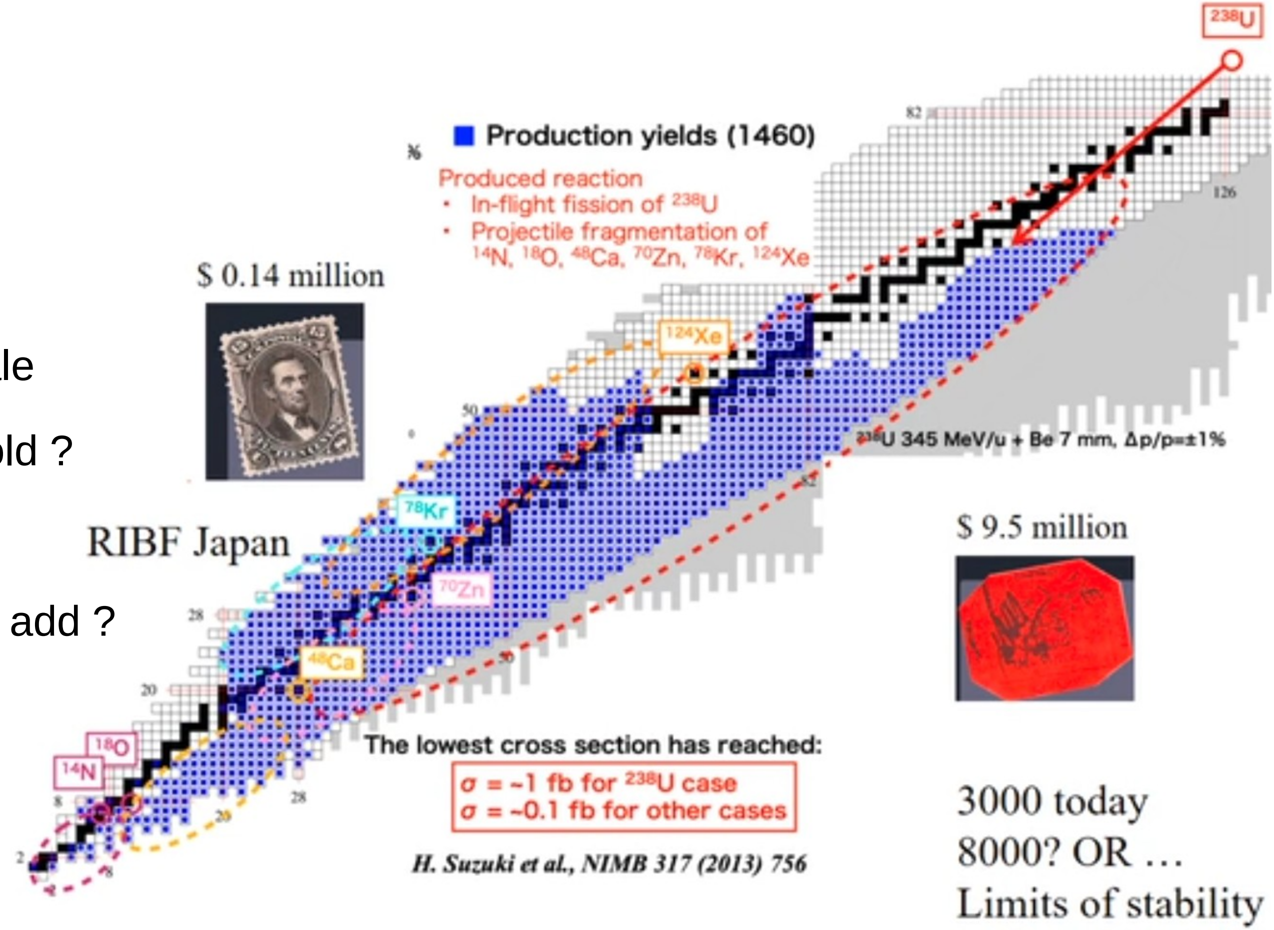
30 min talk

Very pedagogical / good overview

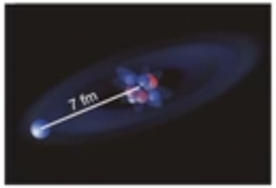
Objectives:
Study of the physics at the femtoscale
to understand physics at infinitely large scale

- How many protons can the nucleus hold ?
- How many isotopes are possible ?
- How many neutrons can you remove / add ?
- What are the properties of isotopes ?

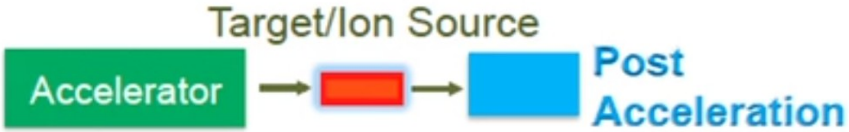
=> Limit of stability
=> Search for the island of stability

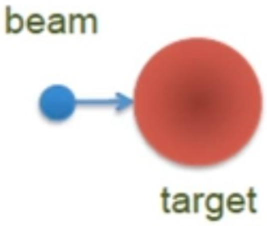


Production techniques Jargon ISOL /Inflight Fragmentation: **Short lived Exotic beams**



- Target spallation and fragmentation by light ions (ISOLDE/I …… TRIUMF)

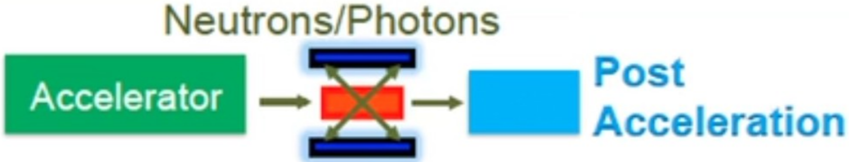




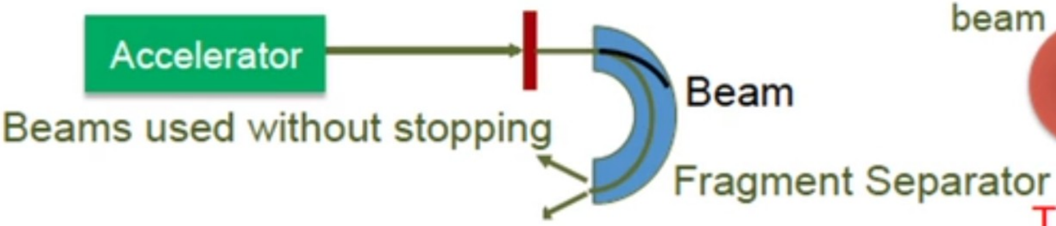
1 MeV/n to ..

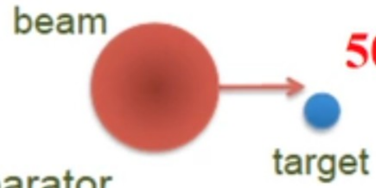
- Neutron induced fission (2-step target) (SPIRAL2/TRIUMF)

$T_{1/2}$ msecs
Pure beams,
well defined energy



- In-flight Separation following projectile fragmentation/fission (RIKEN,FAIR,FRIB)

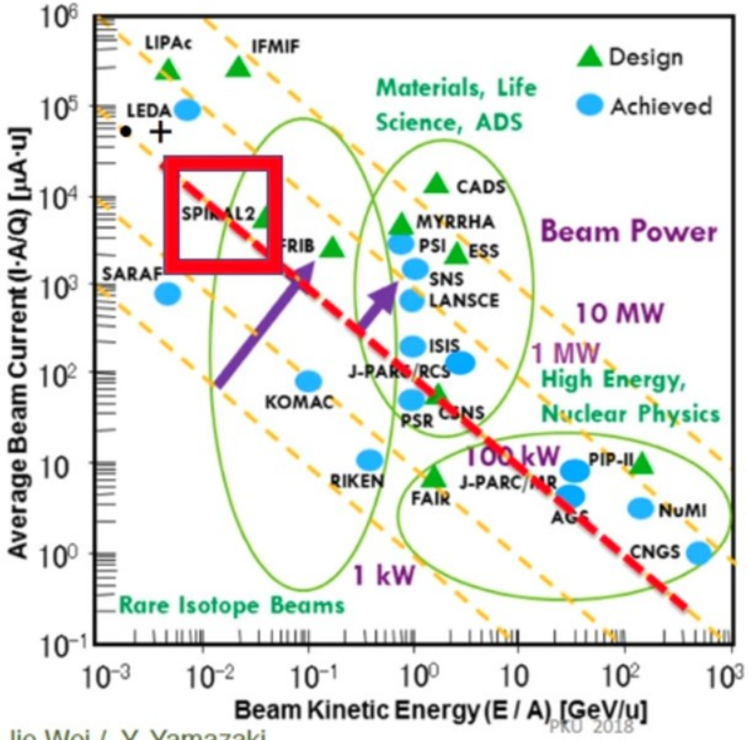




50 MeV/n to ..

$T_{1/2}$ μsecs
Many species simultaneously

Navin Alahari, GANIL
New Horizons in Nuclear Science: GANIL and



Jie Wei / Y. Yamazaki

High Intensity

↓

High Statistics

↓

- More Precision
- More Rare Searches
- More Materials

↓

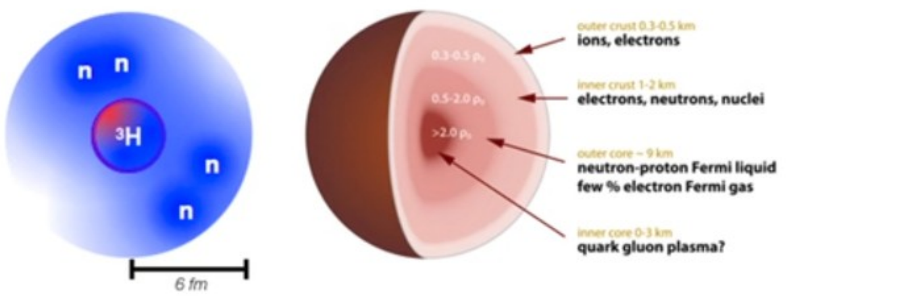
Discovery!

m = 516 T = 516 000 000 g ≈ $5 \cdot 10^8$ g

Courtesy Klaus Blaum

More fun stuff

^{1}H, ^{2}H ^{3}H..........^{7}H



Fabiola Gianotti, CERN
Status of the European Strategy for Particle Physics update

Higgs boson is a guaranteed deliverable: related to the most obscure and problematic sector of the Standard Model; it carries special quantum numbers and a new type of interaction
→ unique door into new physics, which can only be studied at colliders

"*When theorists are more confused, it's time for more, not less, experiments*", Nima Arkani-Hamed.

	2020-2040	2040-2060 1st gen technology	2060-2080 2nd gen technology
CLIC	HL-LHC	CLIC380-1500	CLIC3000
CLIC-FCC-mixed	HL-LHC	CLIC380	FCC-h/e/A (Adv HF magnets)
FCC	HL-LHC	FCC-ee (90-365)	FCC-h/e/A (Adv HF magnets)
LE-to-HE-FCC-h/e/A	HL-LHC	LE-FCC-h/e/A (LF magnets)	FCC-h/e/A (Adv HF magnets)
LHeC+FCC-h/e/A	HL-LHC + LHeC	LHeC	FCC-h/e/A (Adv HF magnets)

Main challenges of a post-LHC collider at CERN

Financial feasibility

Cost of tunnel + first-stage machine (CLIC at 380 GeV, FCC-ee): ~ 6-10 BCHF

→ cannot be funded only from CERN's (constant) budget + additional (voluntary) contributions of Member and other States

→ need innovative mechanisms: contributions from EC (potential interest e.g. in HTS development and industrialisation; tunneling technologies)? private funds? donations?

Governance model for an unprecedented, global project

To be developed from the beginning with the international partners.

Technical and administrative feasibility of a new tunnel

- highly-populated area; two countries with different legislative frameworks
- land expropriation and reclassification
- need to gain support of local populations
- environmental aspects

Technologies of machine and experiments

- huge challenges, but under control of our scientific community → "easier"
- environmental aspects (aim at "green collider"): power, energy, cooling, gases, etc.

Gathering political and societal support

→ requires "political work" and vast communication campaign for "consensus building" with governments and other authorities, scientists from other fields, general public

In conclusion: very exciting times for particle physics

Main results from LHC so far:
- ❑ discovery of the Higgs boson → Standard Model completed, it works beautifully
- ❑ no sign of physics beyond the Standard Model (yet!)

PUZZLING: the SM is not a complete theory of particle physics, as several outstanding questions remain that cannot be explained within the SM

What is the composition of dark matter (~25% of the Universe) ?
What is the origin of neutrino masses and oscillations ?
Why 3 fermion families ? Why do neutral leptons, charged leptons and quarks behave differently?
What is the origin of the matter-antimatter asymmetry in the Universe ?
Why is the Higgs boson so light (so-called "naturalness" or "hierarchy" problem) ?
Why is Gravity so weak ? Etc. etc.

These questions require NEW PHYSICS → E-scale?? Couplings to SM?

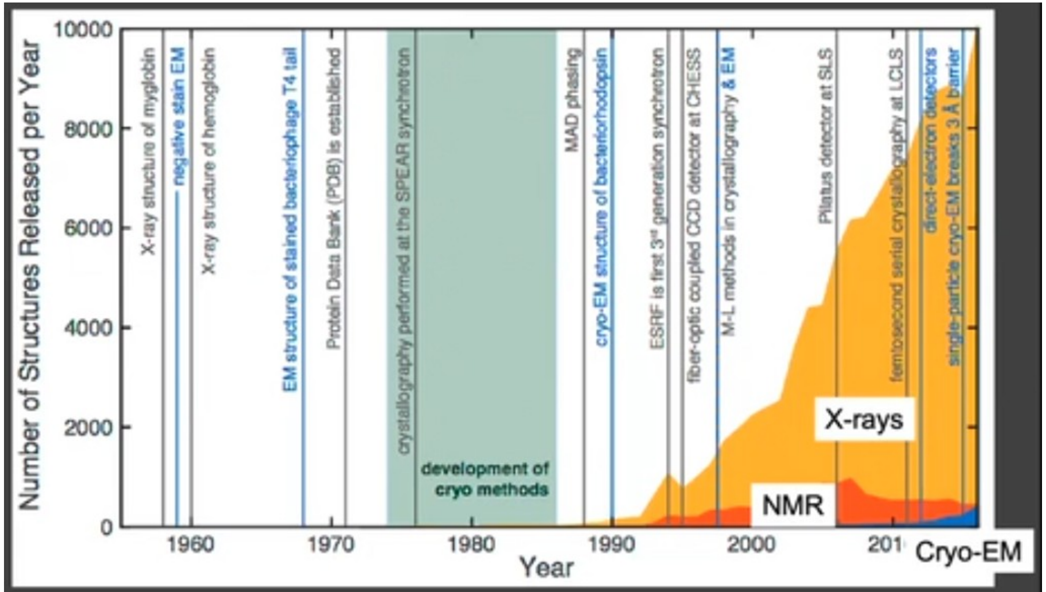
The breadth and complexity of the outstanding questions, and **the lack of clear indications of where new physics might be,** require a variety of approaches: **particle colliders**, neutrino experiments, dark matter direct and indirect searches, **measurements of rare processes, dedicated searches,** cosmic surveys → **scientific diversity** is crucial.

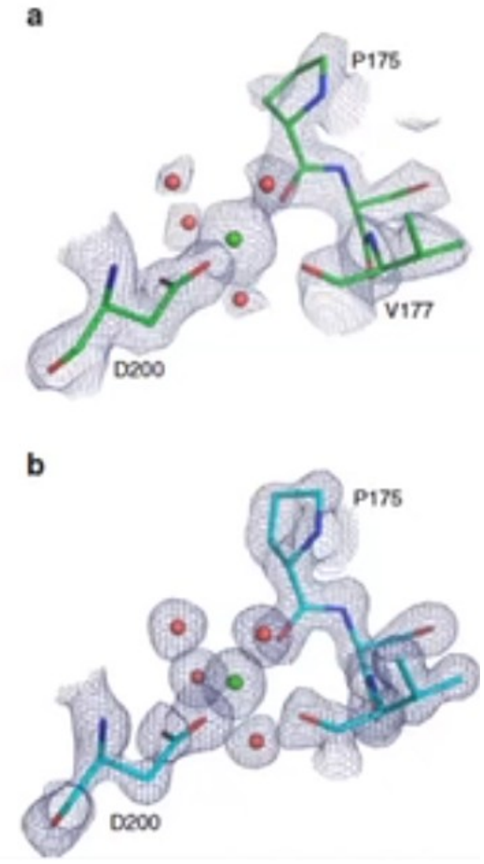
Historically: **accelerators have been our main tool of exploration in particle physics and we can expect them to continue to play a crucial role also in the future**

Jerry Hastings, SLAC
Developments in Photon Science
Accelerators and Competitive Technologies

Source / Optics / Detectors...

Reciprocal space imaging of macro molecules
==> room temperature
==> possibility to see motions of molecules

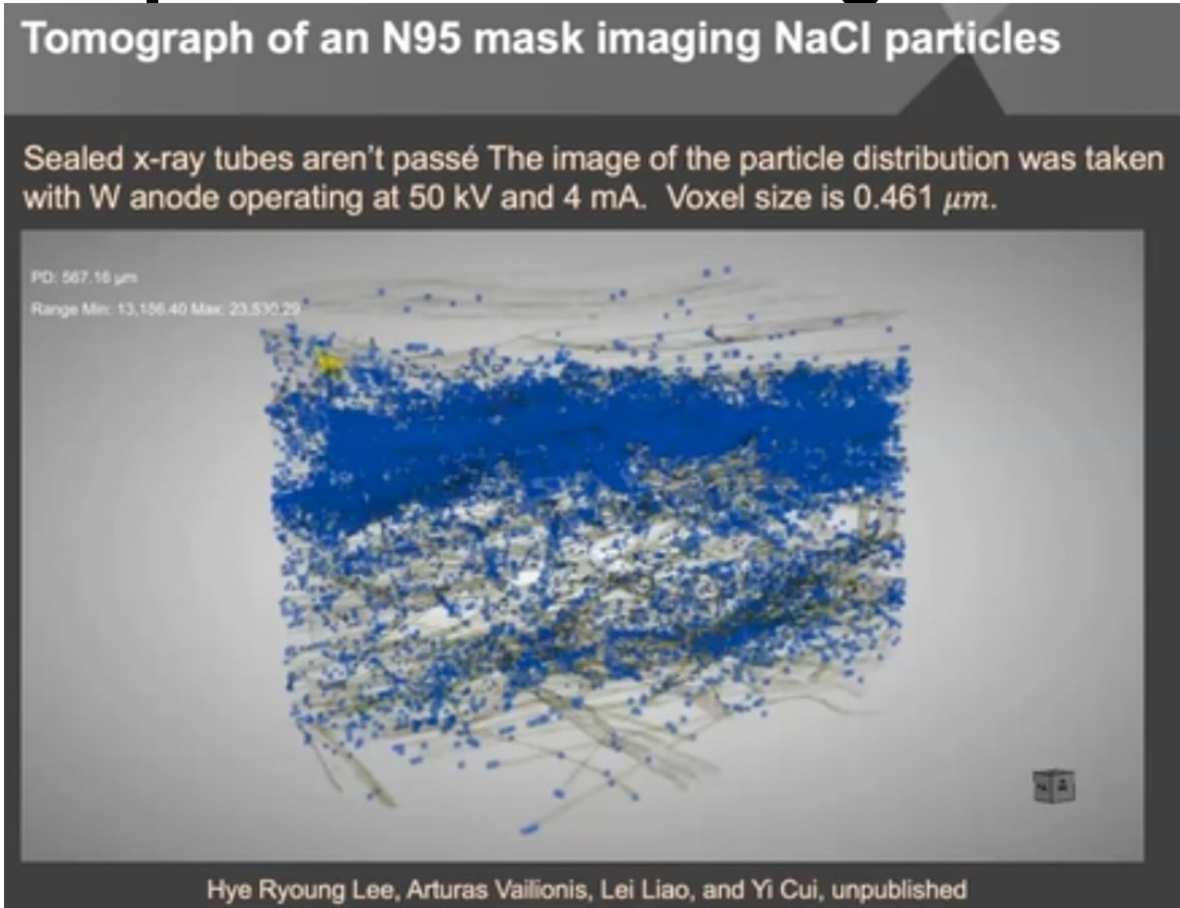




Jerry Hastings, SLAC
Developments in Photon Science
Accelerators and Competitive Technologies

Many Covid19
applications / contributions

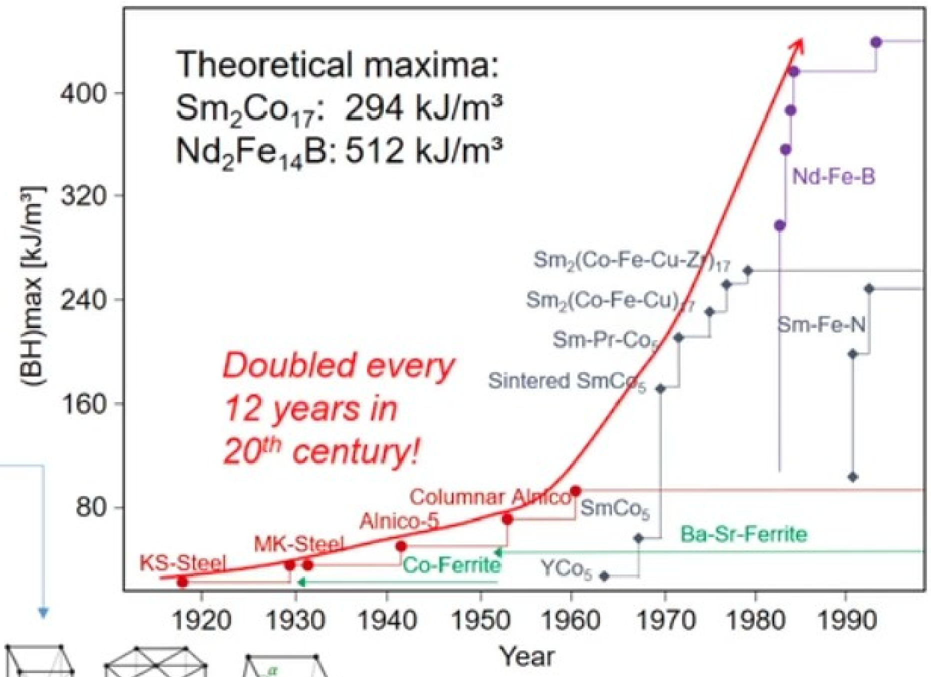
=> study of a mask
=> particles << size of fiber
=> particles are stopped by
electrostatic fields
=> when cleaning it, need to keep the electrostatic fields as strong as possible

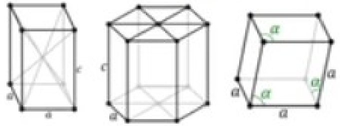


Ben Shepherd, STFC/DL/ASTEC
Permanent Magnets for Accelerators

30 min talk + 1h of Wikipedia :-D   Very pedagogical / good overview

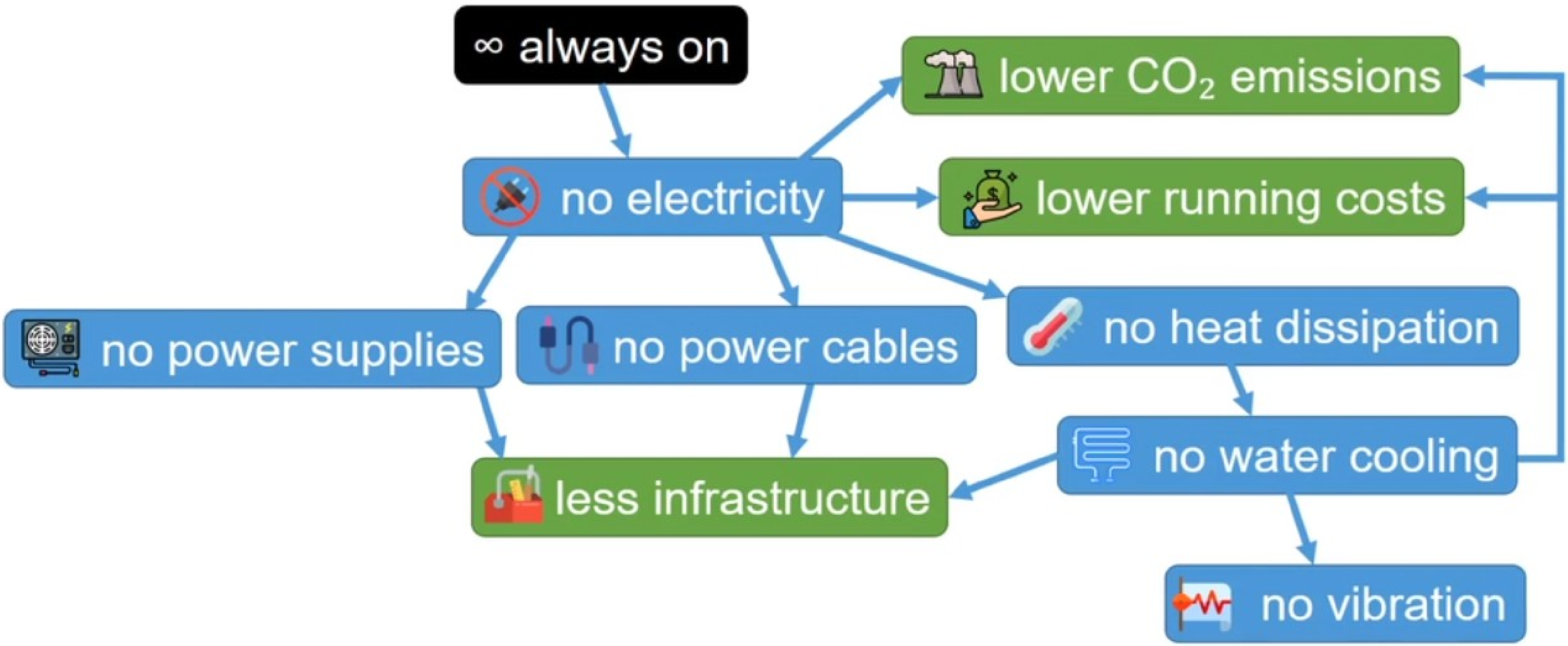
- Pre-20th century:
  - steel needles, bars, horseshoes
- Philips 1951:
  - hexagonal ferrites
  - removed shape constraint
- Need a material with **uniaxial crystal structure** for magnetic easy axis
- 1966: rare-earth PMs
  - $\mathbf{SmCo_5}$ and later $\mathbf{Sm_2Co_{17}}$
  - much higher energy but cost and supply issues
- 1982: $\mathbf{Nd_2Fe_{14}B}$
  - almost ideal: mostly iron, abundant RE element, only 2% B





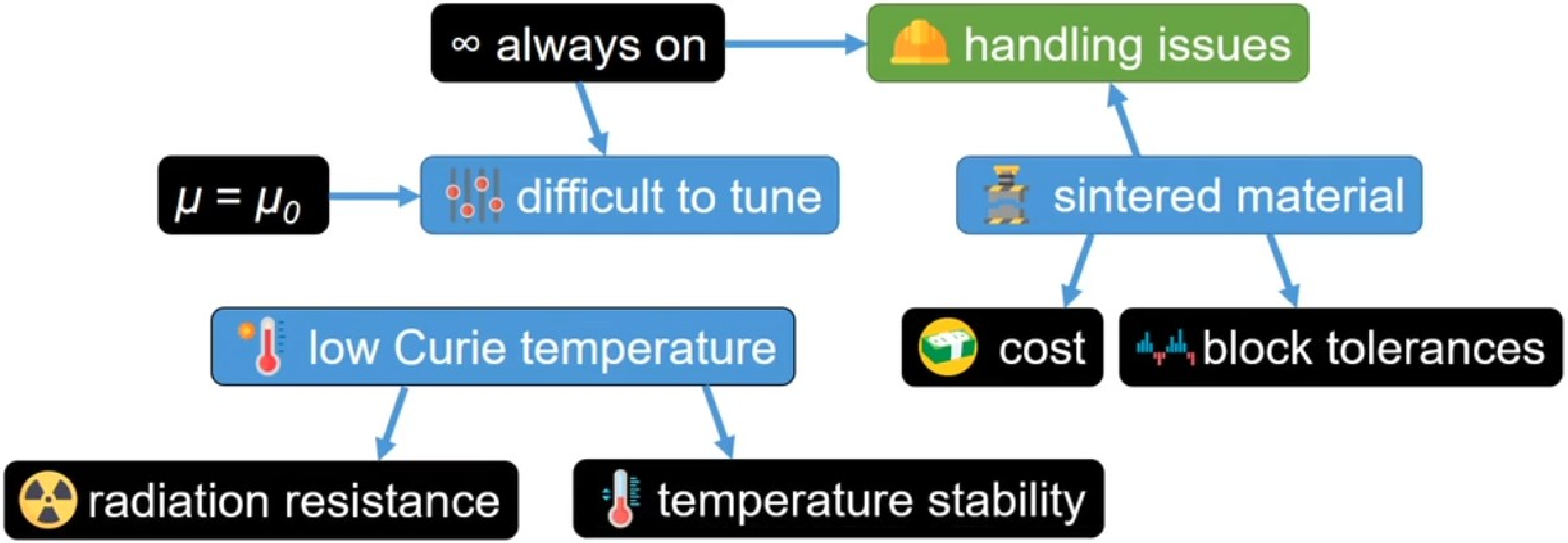
Ben Shepherd, STFC/DL/ASTEC
Permanent Magnets for Accelerators

Advantages of Permanent Magnets



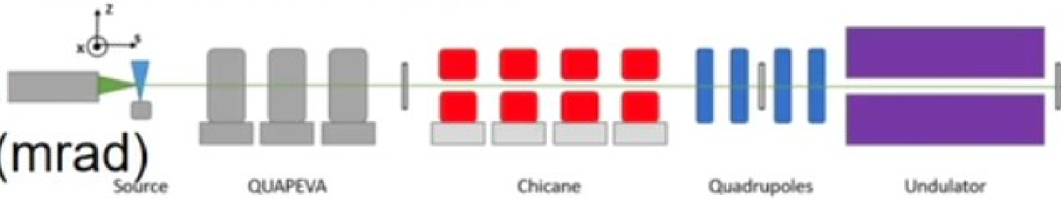
Ben Shepherd, STFC/DL/ASTEC
Permanent Magnets for Accelerators

Disadvantages of Permanent Magnets

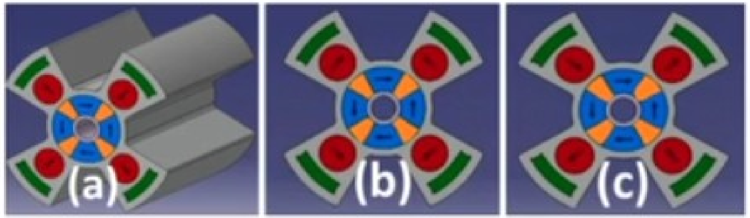


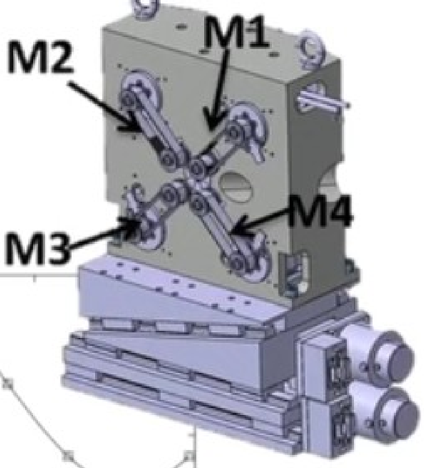
Oumbarek Espinos *et al*, Appl. Sci. 2019, 9, 2447
Ghaith *et al*, arXiv:1712.03857v1
Marteau *et al*, APL (2017)

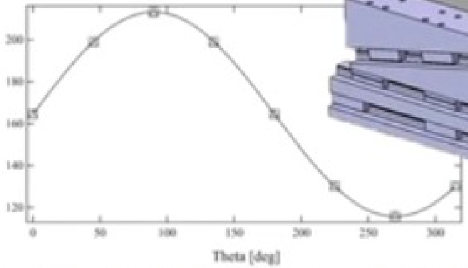
SOLEIL Tunable Quadrupole: QUAPEVA

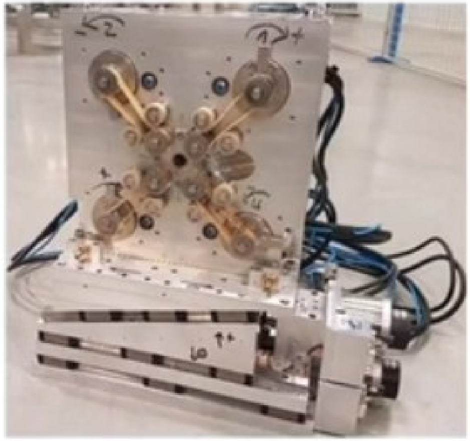


- COXINEL laser-plasma experiment
  - Need to focus highly-divergent beam (mrad)
  - Strong quads immediately after plasma
- Central Halbach array
- **Rotating NdFeB cylinders** for adjustment
- Seven magnets produced
  - One prototype and two triplets
  - **26-100 mm** length
  - **12 mm** gap
  - **100-200 T/m** gradient (factor of **2** adjustment range)
  - Centre movement: **±10 μm**

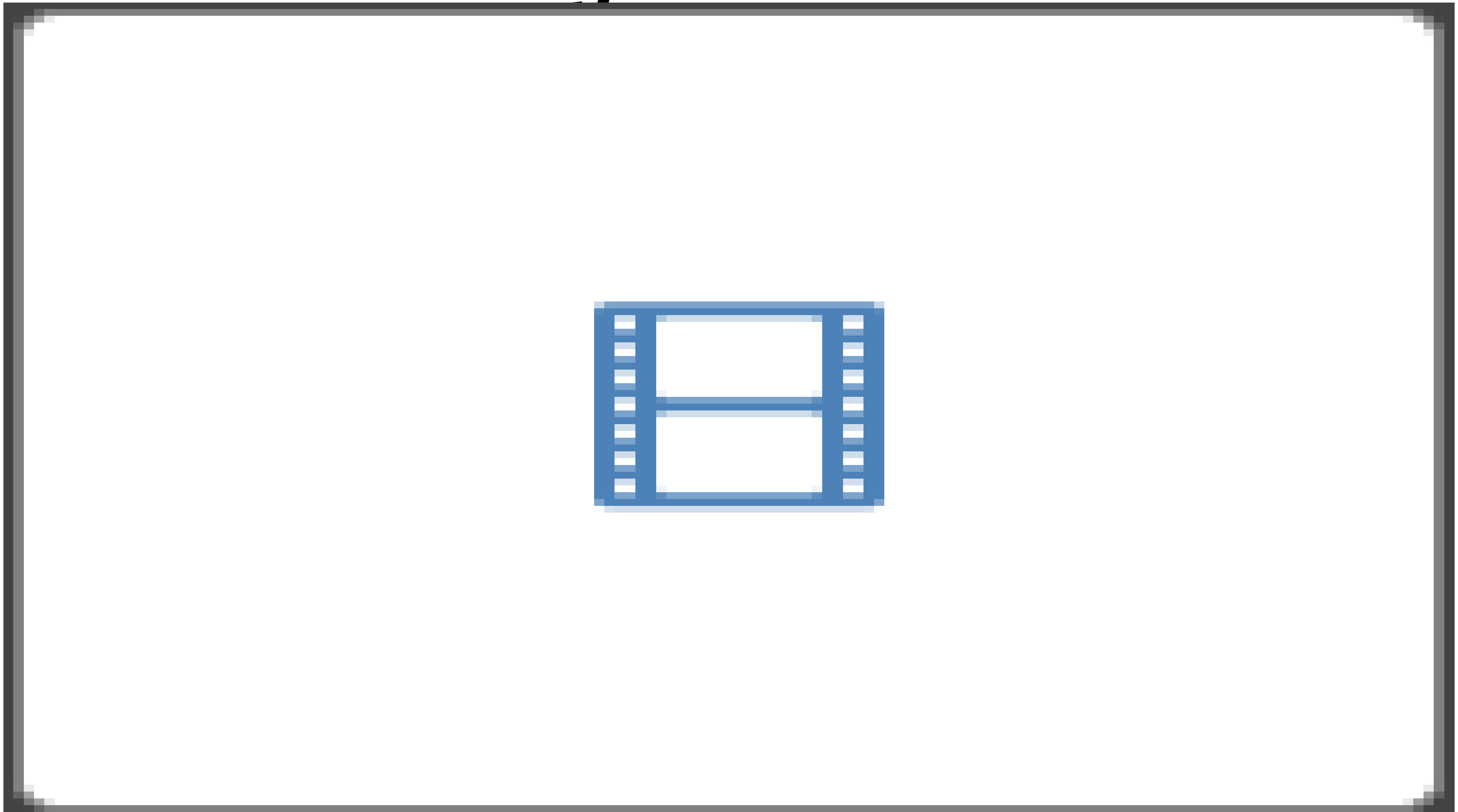








Ben Shepherd, STFC/DL/ASTEC
Permanent Magnets for Accelerators



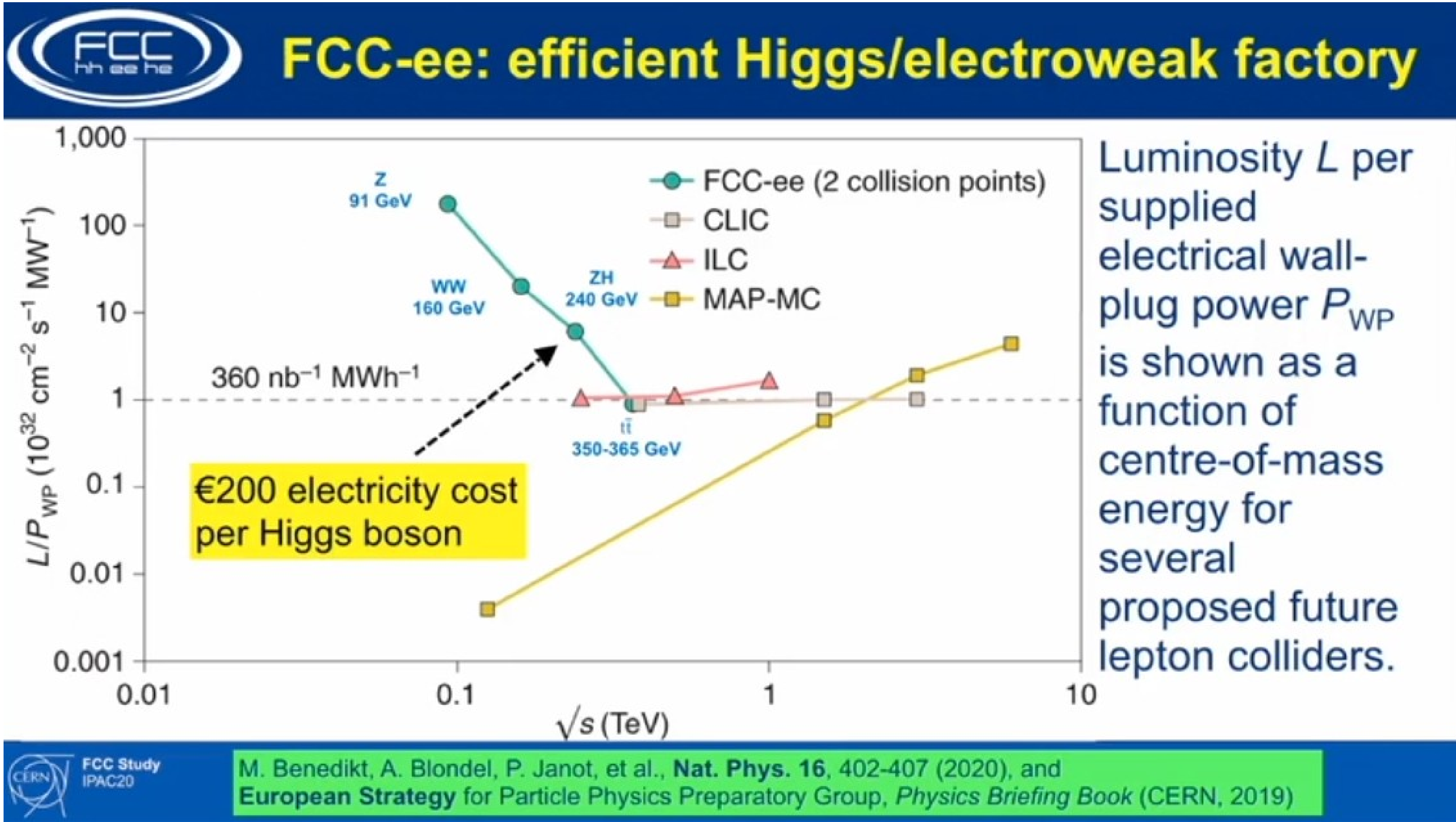
Anke-Susanne Müller, KIT
The Future Circular Collider Study

23 min talk

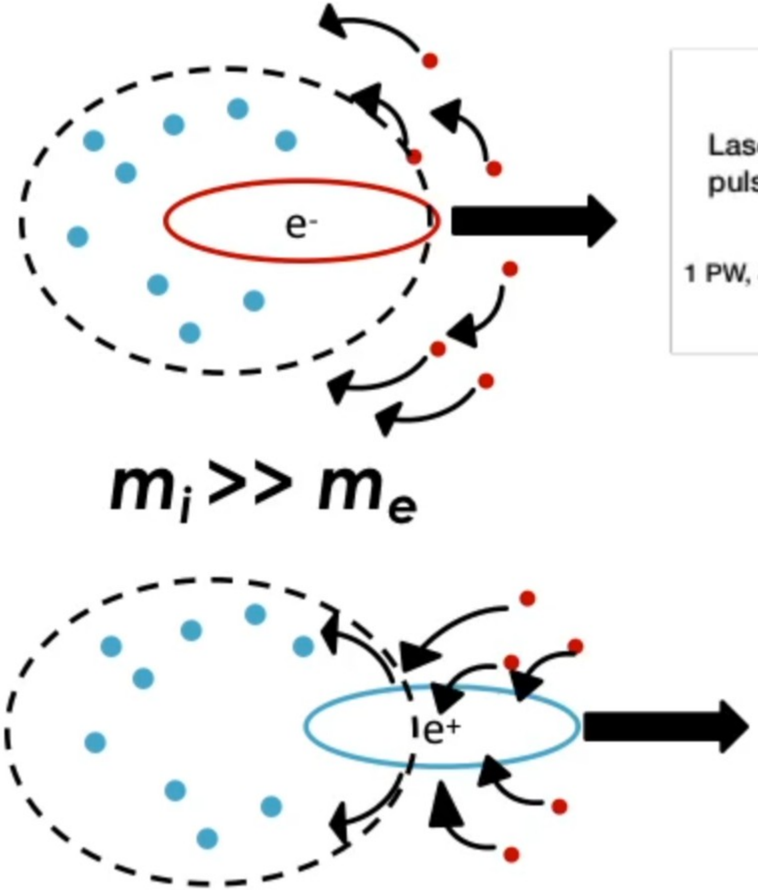
Dense but clear

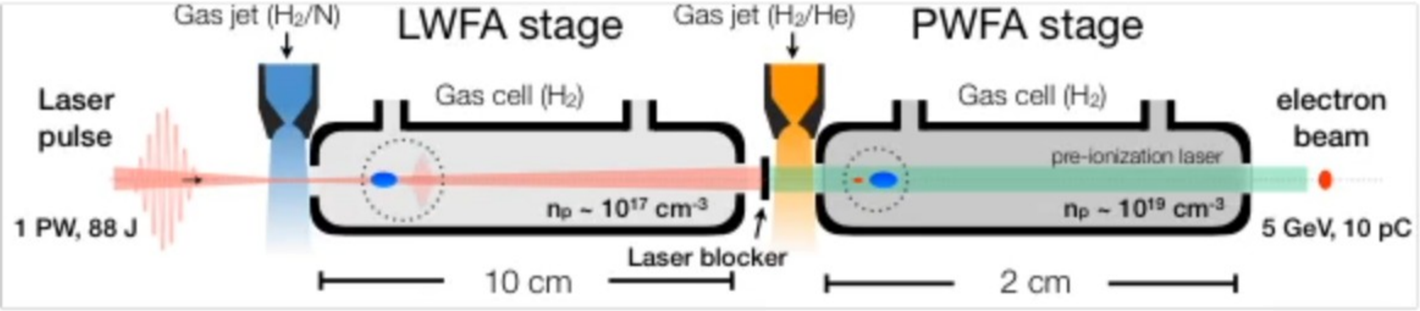
Excellent follow up for Fabiola Gianotti's talk

200€ >= 1 MWh



Sébastien Corde, LOA
Progress in Plasma-Based Accelerators Driven by Particle Beams

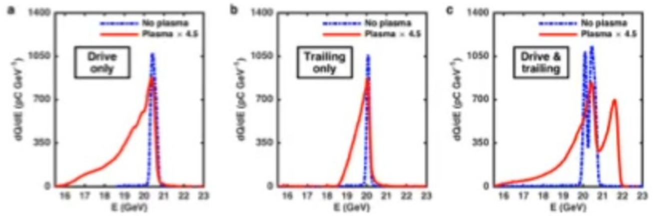


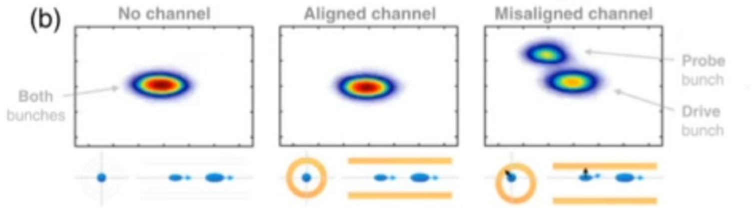


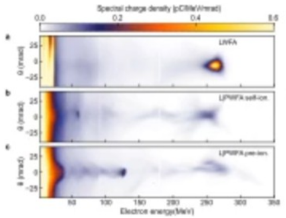
	Driver	Witness
Charge	190 pC	10 pC
Average energy	2 GeV	5 GeV
Energy spread	10%	3%
Sliced energy spread	10%	0.1%
Normalized emittance	15 μm	0.1 μm
Duration (fwhm)	18 fs	0.8 fs
Current	10 kA	15 kA
Brightness	0.044 kA/μm^2	1500 kA/μm^2

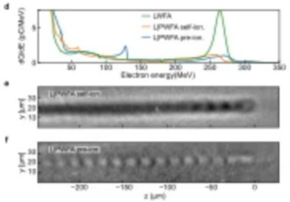
Sébastien Corde, LOA
Progress in Plasma-Based Accelerators Driven by Particle Beams

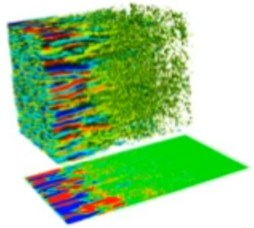
- Demonstrated **acceleration of a distinct positron bunch** in uniform and hollow plasmas with high efficiency, in linear and nonlinear regimes
- Measurement of **transverse wakefields in hollow plasma channels**
- **Staging LWFA and PWFA**: acceleration of an electron beam in a PWFA powered by LWFA electron beams
- First direct **observation of PWFA plasma waves**, PWFA physics with few-cycle shadowgraphy
- **PWFA-induced ion dynamics** at ps time scales
- **Ultrafast probing of current filamentation instability** in solid target separating LWFA and PWFA stages

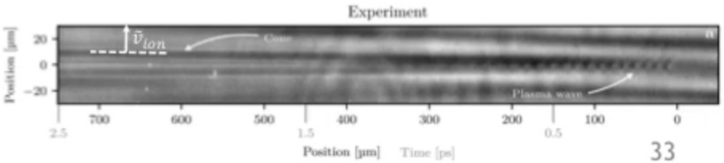












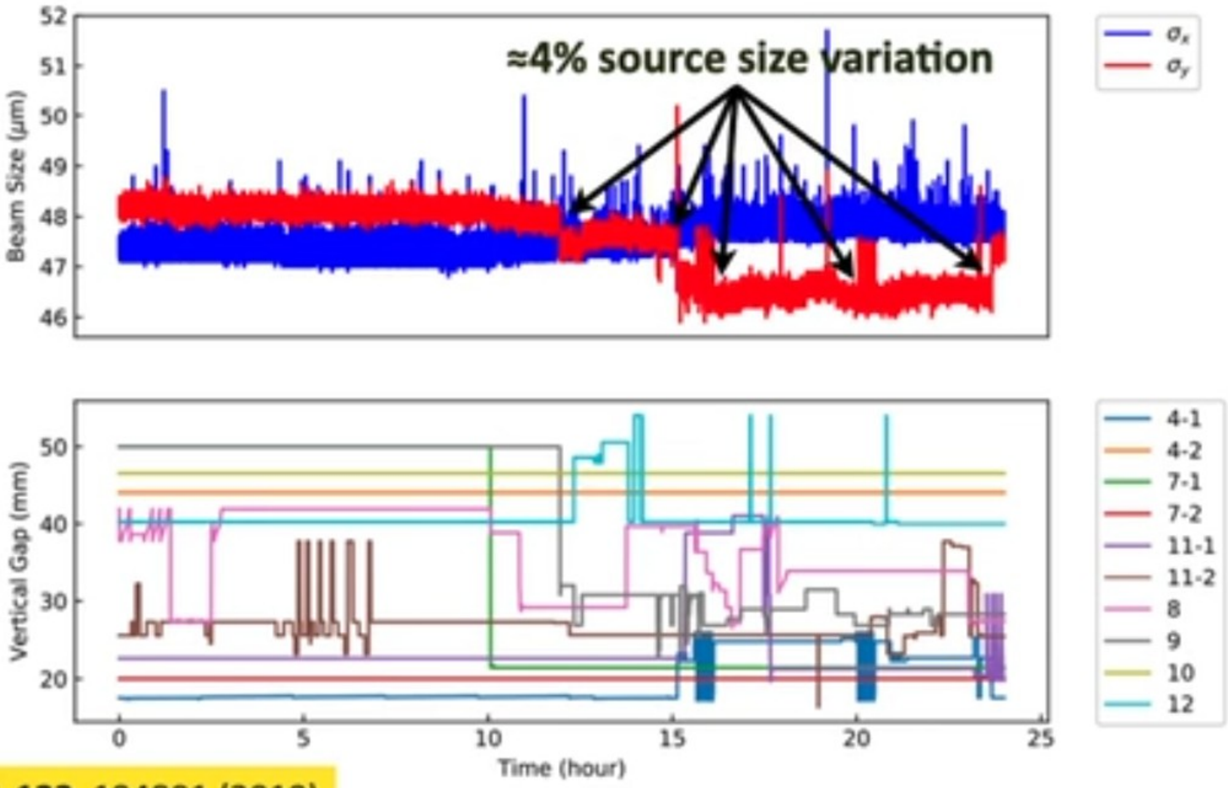
Adrian Fabich, SCK-CEN
Accelerators for Applications in Energy and Nuclear Waste Transmutation

- Collaboration with Jan's section
- Non critical material in a reactor
  ==> no chain reaction
- An accelerator is used to feed the chain reaction ==> possibility to switch off much faster / safer
- Reuse fuel + transmutation of minor actinides
  ==> waste volume / 100, waste lifetime / 1000 (goal of ~300y)

- Proton accelerator, 500 MeV,
  ~ MW, Linac very high reliability/availability:
  - beam trips >~ seconds
    => several stress on reactor
  - beam trips > seconds
    => stop during weeks for checks
- Demonstrate the ADS concept at pre-indusctial scale + transmutation + flexible irradiation facility

Simon Leemann, LBNL
Applying Machine Learning to Stabilize the Source Size in the ALS Storage Ring

- 3rd gen. sources considered <10 % acceptable but ...
- 4th gen. Source < 1%:
  - Small spot size
  - Fast scan: 1ms/pixel
    6min/scan

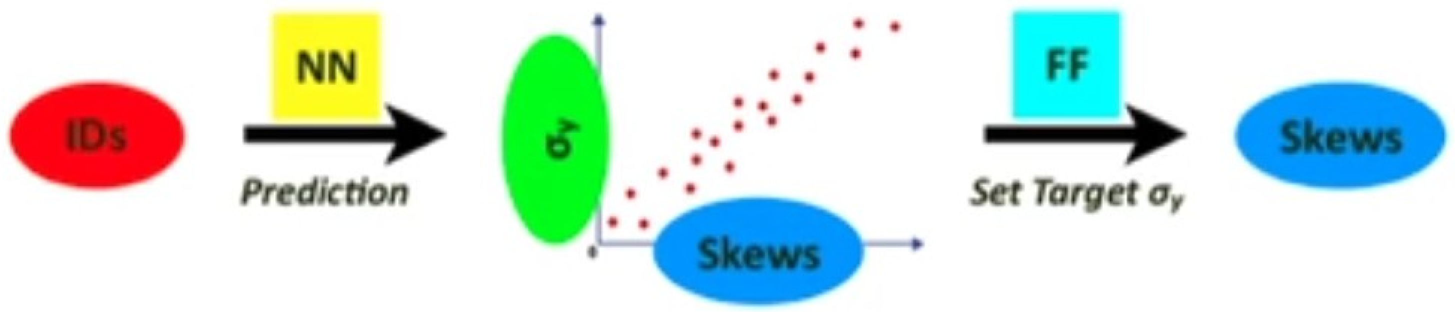


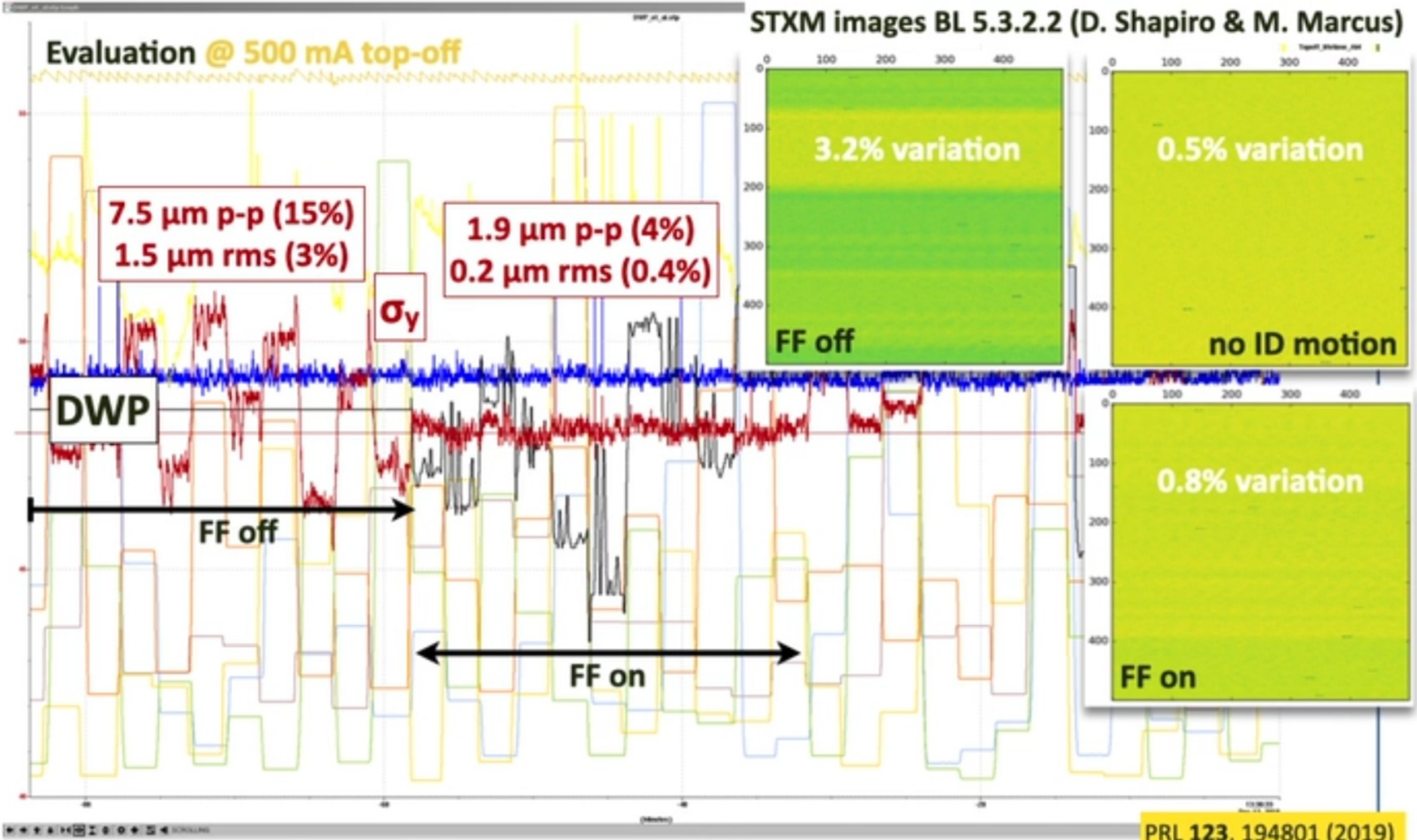
PRL **123**, 194801 (2019)

Simon Leemann, LBNL
Applying Machine Learning to Stabilize the Source Size in the ALS Storage Ring

1) prediction of beam parameters using machine parameters

2) correction of beam parameters acting on machine parameters

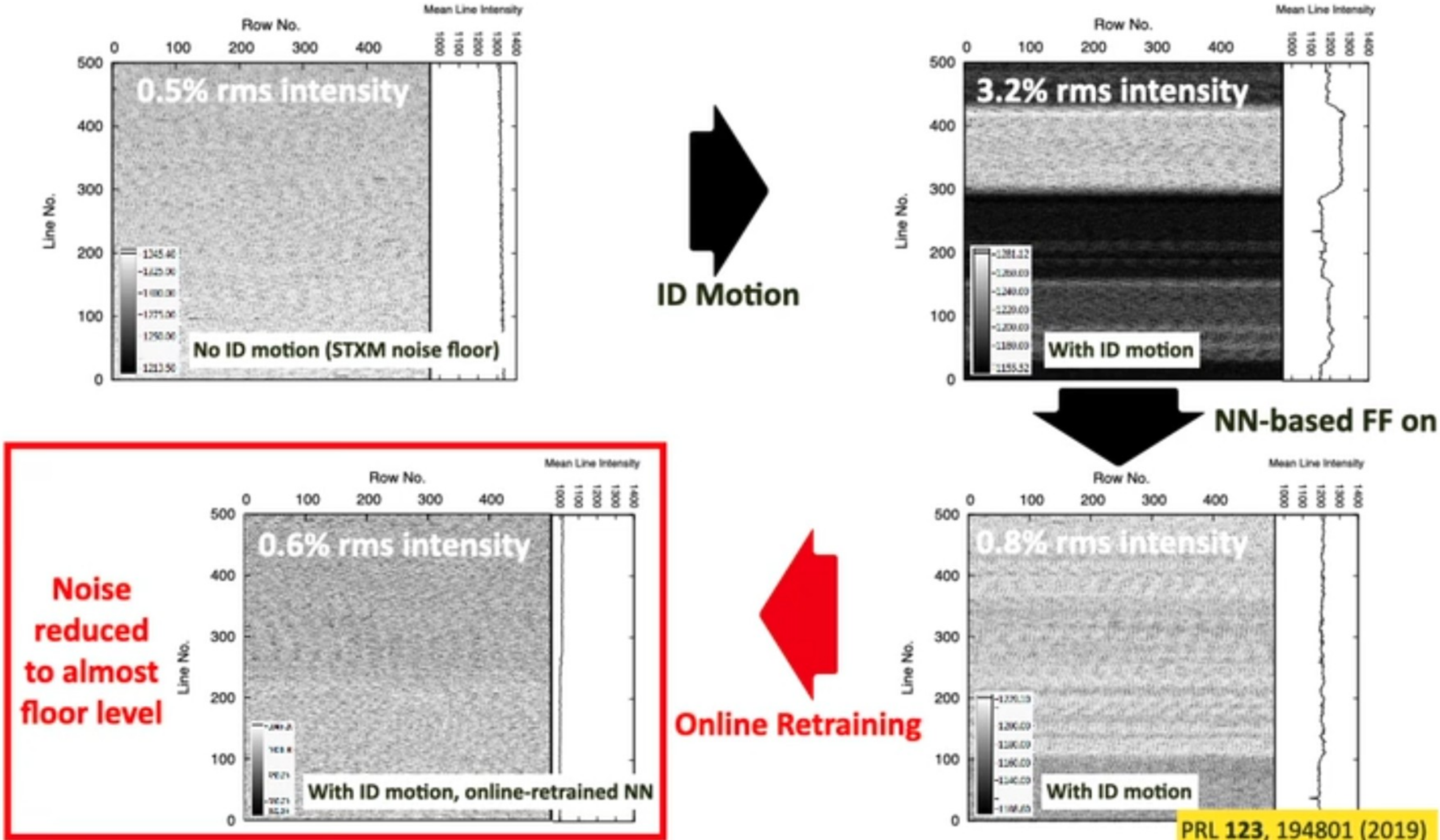




PRL **123**, 194801 (2019)

Stabilization Confirmed at Experiment

ALS Beamline 5.3.2.2



PRL **123**, 194801 (2019)

Alexander Scheinker, LANL
Adaptive Feedback Control and Machine Learning for Particle Accelerators

Non-Invasive Adaptive Diagnostics

- Adaptively tuned models for XTCAV longitudinal phase space predictions at **FACET**
- Adaptively tuned models for XTCAV longitudinal phase space control & predictions at **FACET-II**
- Neural network-based surrogate models for longitudinal phase space at **FACET-II**
- Machine Learning methods for beam diagnostics at **CERN**

Accelerator Tuning and Control

- Model-independent Adaptive Feedback for pulse energy maximization at **LCLS** & **EuXFEL**
- Gaussian Processes for online tuning at **SPEAR3**
- Multi-objective Optimization at **AWAKE**

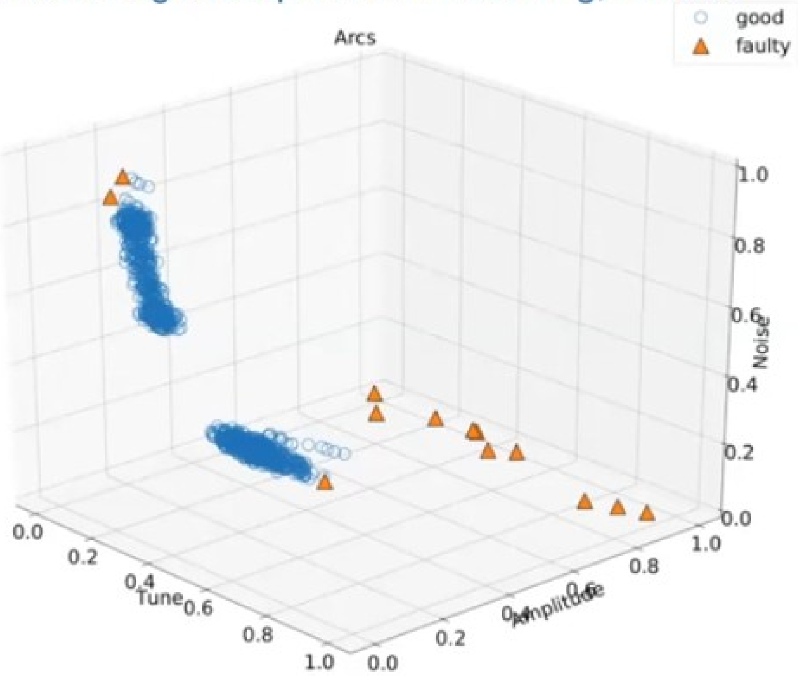
Adaptive Machine Learning for Time Varying Systems

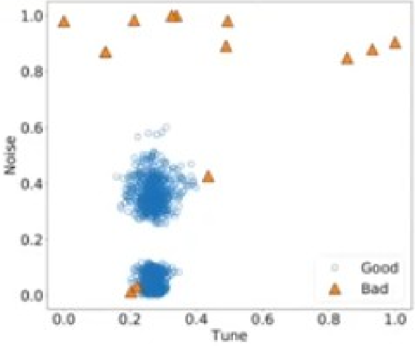
- Adaptive ML for automatic longitudinal phase space control at the **LCLS**
- Neural Network re-training

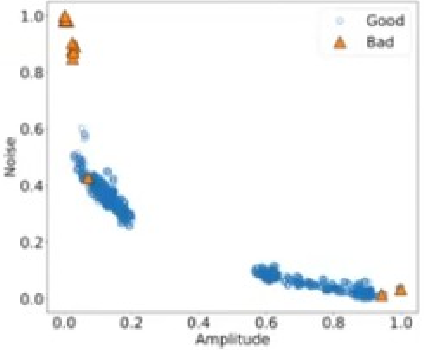
Machine Learning methods for beam diagnostics and control at CERN

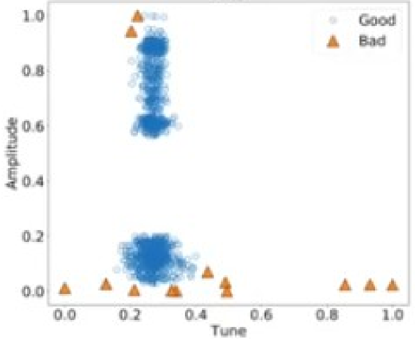
Detection of faulty BPMs: Isolation Forest (technique for identifying anomalies) algorithm applied on FFT analysis of turn-by-turn data

Applied during ions optics commissioning, Beam 2









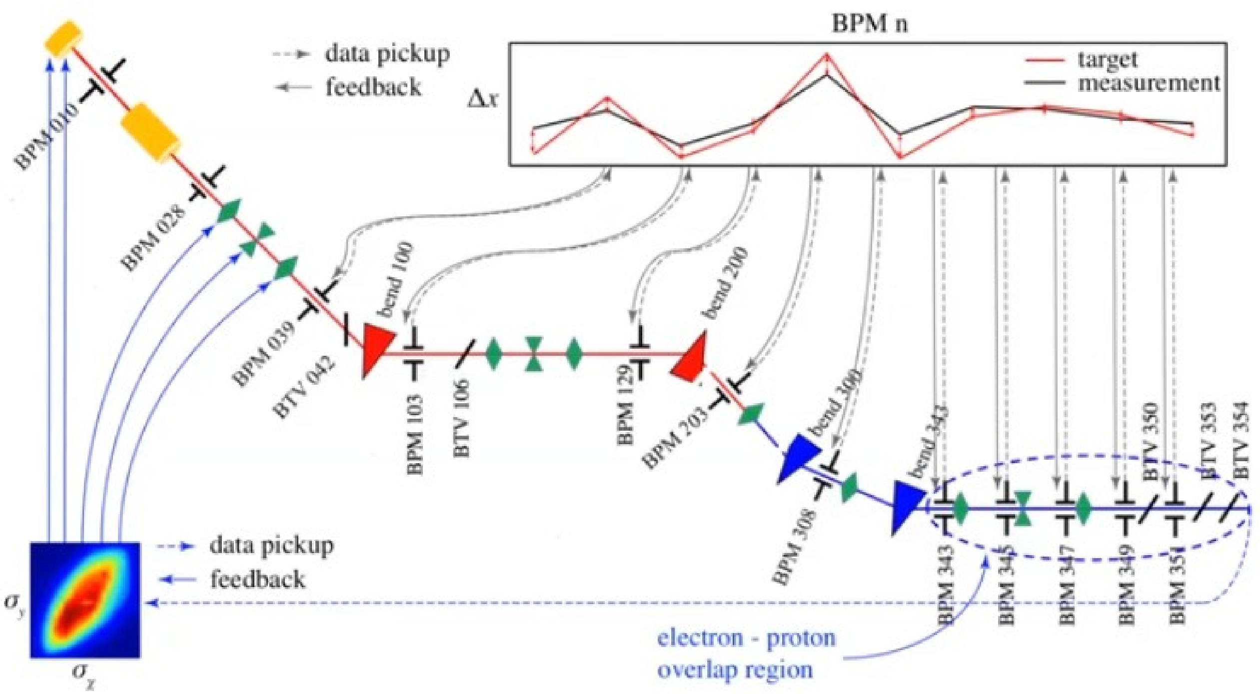
Slide from E. Fol

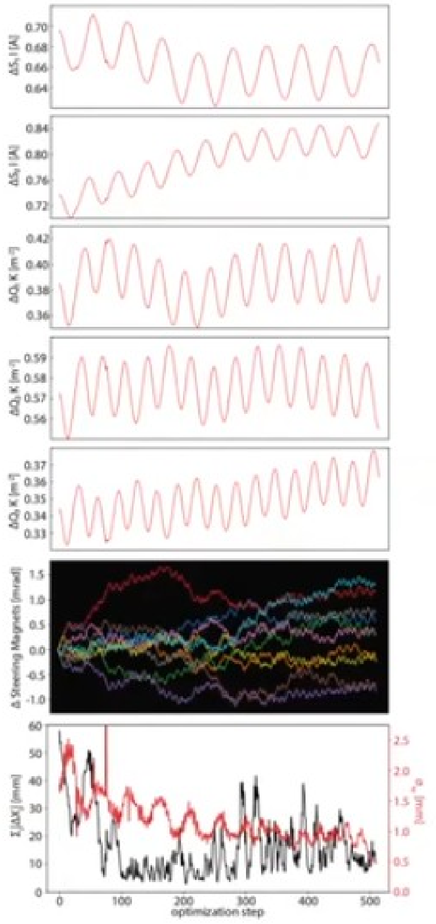
*Features values are normalized to the range [0,1] for visualization onl

E. Fol, J. M. Coello de Portugal, and R. Tomas. "Unsupervised Machine Learning for Detection of Faulty BPMs," in Proceedings of the 2019 International Particle Accelerator Conference, Melbourne, Australia, 2019. https://accelconf.web.cern.ch/ipac2019/papers/wepgw081.pdf

E. Fol, J. M. Coello de Portugal, and R. Tomas. "Optics Corrections Using Machine Learning in the LHC," in Proceedings of the 2019 International Particle Accelerator Conference, Melbourne, Australia, 2019. https://accelconf.web.cern.ch/ipac2019/papers/thprb077.pdf

Multi-objective Optimization at **AWAKE**

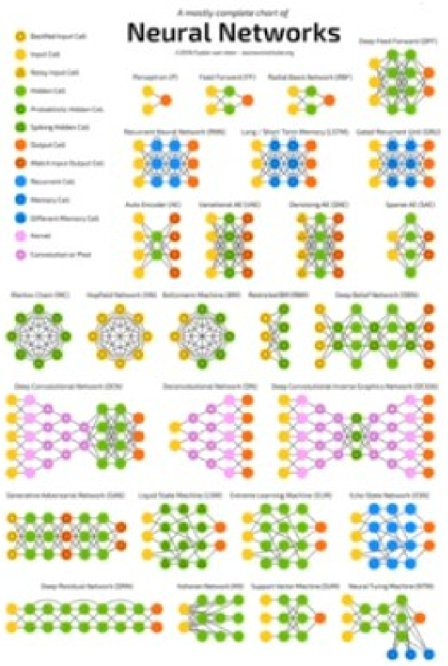


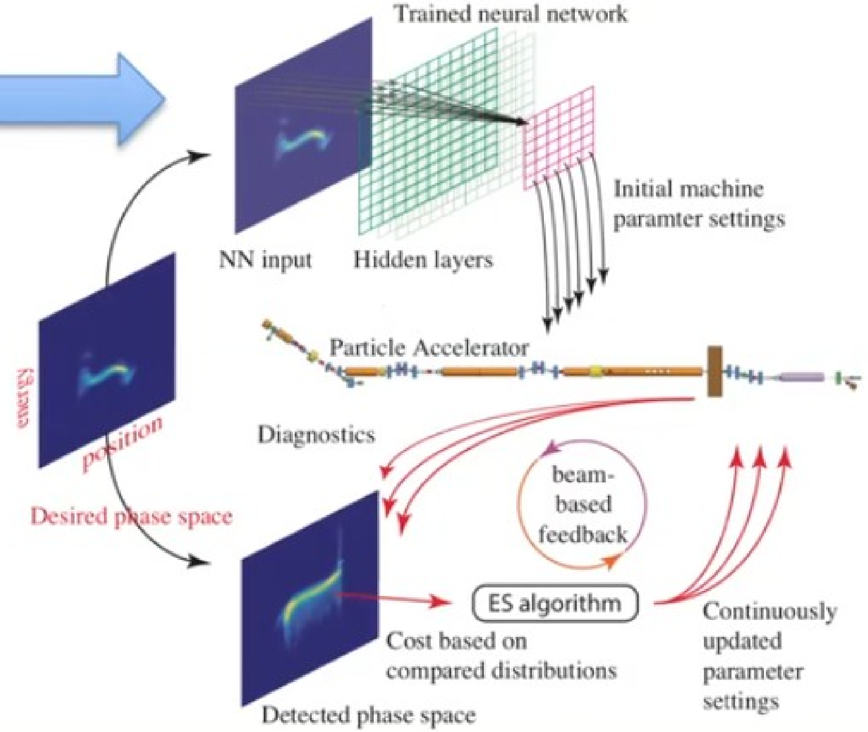


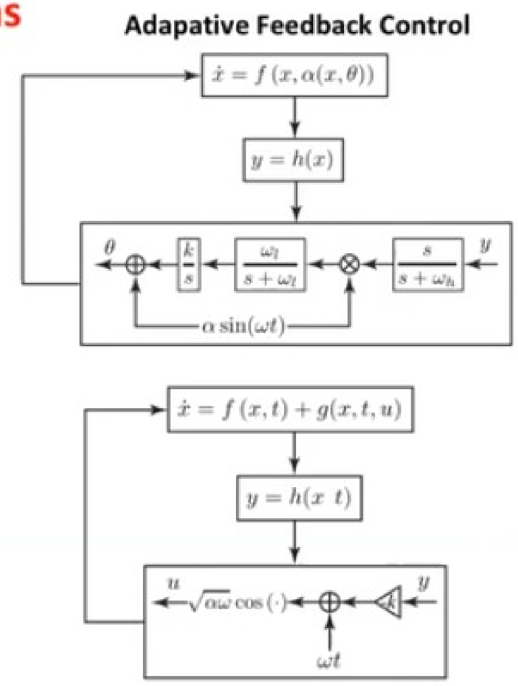
Tuning 15 components simultaneously: 2 solenoids, 3 quads, 10 steering magnets to simultaneously maintain the desired orbit and minimize emittance growth,

A. Scheinker, et al. "Online Mulit-Objective Particle Accelerator Optimization of the AWAKE Electron Beam Line for Simultaneous Emittance and Orbit Control." arXiv preprint arXiv:2003.11155, 2020 https://arxiv.org/pdf/2003.11155.pdf

Adaptive Machine Learning for Time Varying Systems



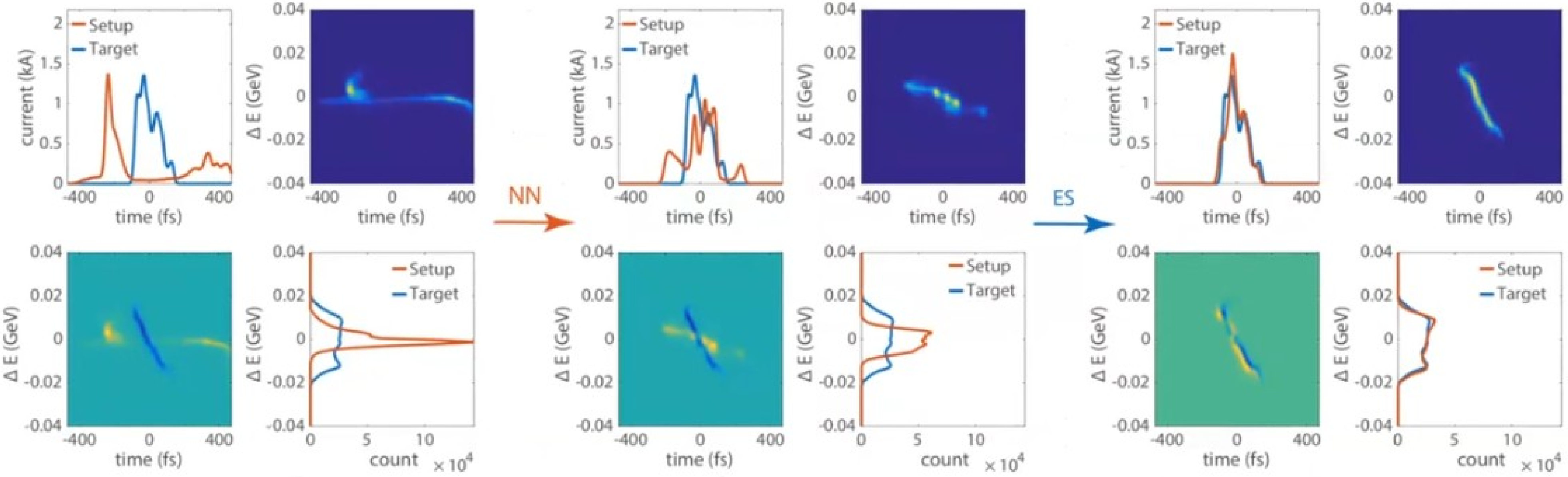




A. Scheinker, et al. "Demonstration of model-independent control of the longitudinal phase space of electron beams in the Linac-coherent light source with Femtosecond resolution." Physical Review Letters, 121.4, 044801, 2018. https://doi.org/10.1103/PhysRevLett.121.044801

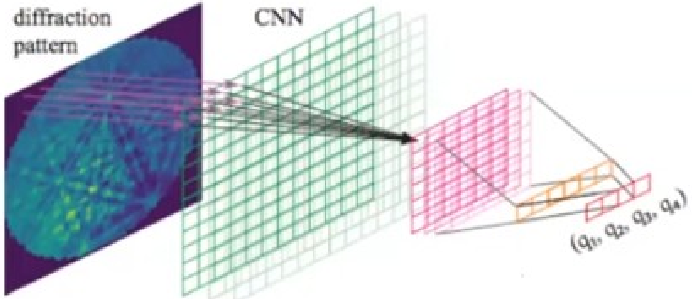
Adaptive ML for automatic longitudinal phase space control at the **LCLS**

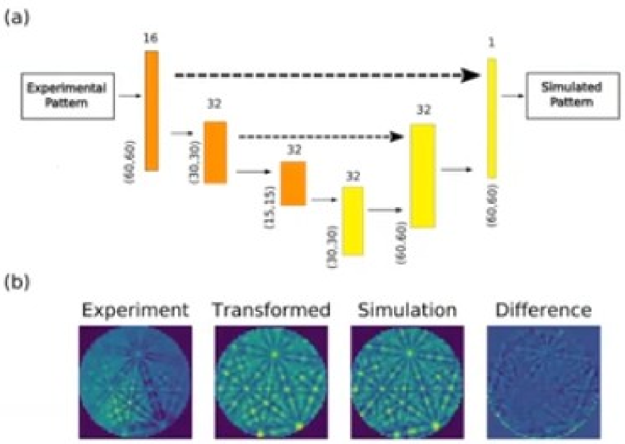
$$C = \int_{-\Delta L}^{\Delta L}\int_{-\Delta E}^{\Delta E} |\hat{\rho}(z,E) - \rho(z,E)|\, dE dz$$

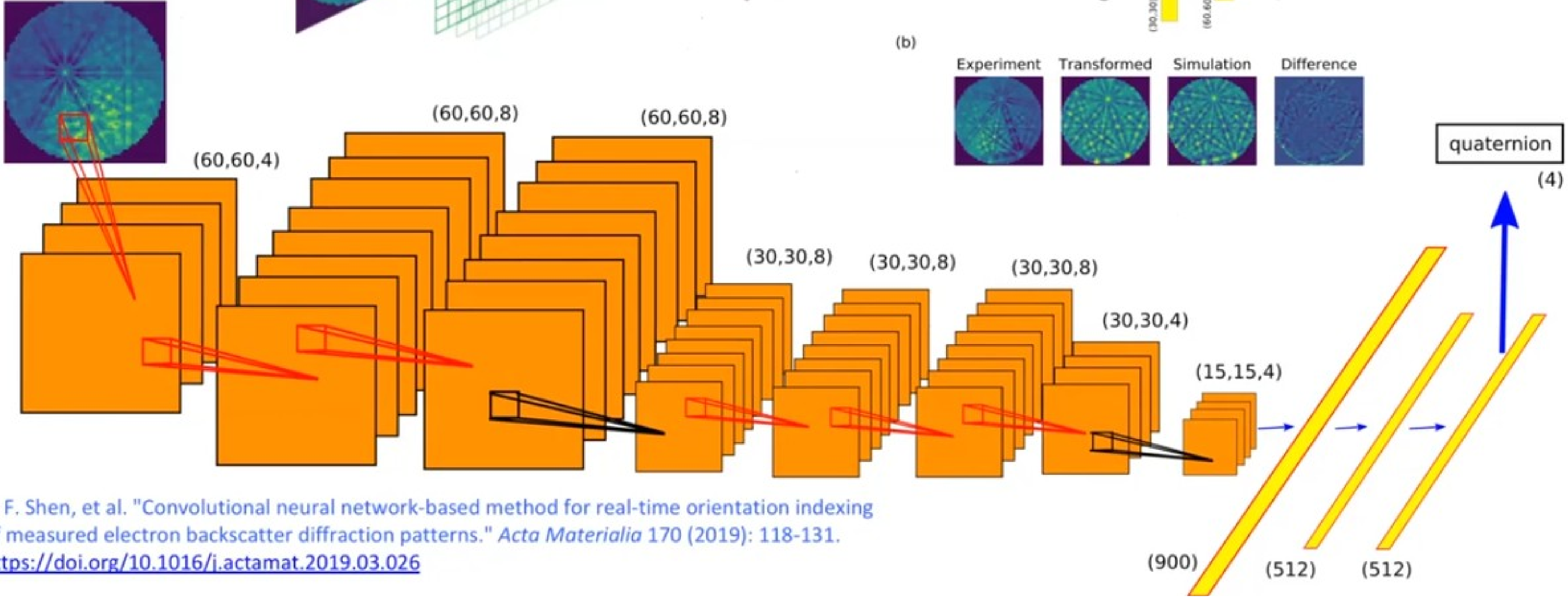


A. Scheinker, et al. "Demonstration of model-independent control of the longitudinal phase space of electron beams in the Linac-coherent light source with Femtosecond resolution." Physical Review Letters, 121.4, 044801, 2018. https://doi.org/10.1103/PhysRevLett.121.044801

Re-Training and Domain Transfer for Convolutional Neural Networks







Y. F. Shen, et al. "Convolutional neural network-based method for real-time orientation indexing of measured electron backscatter diffraction patterns." *Acta Materialia* 170 (2019): 118-131.
https://doi.org/10.1016/j.actamat.2019.03.026

Thank you :-)