

Applied Accelerator Development at SLRI

Electron Linac for Agricultural Irradiation and Proton Source for Isotope Production

Prach Boonpornprasert,
on behalf of the ARD Team

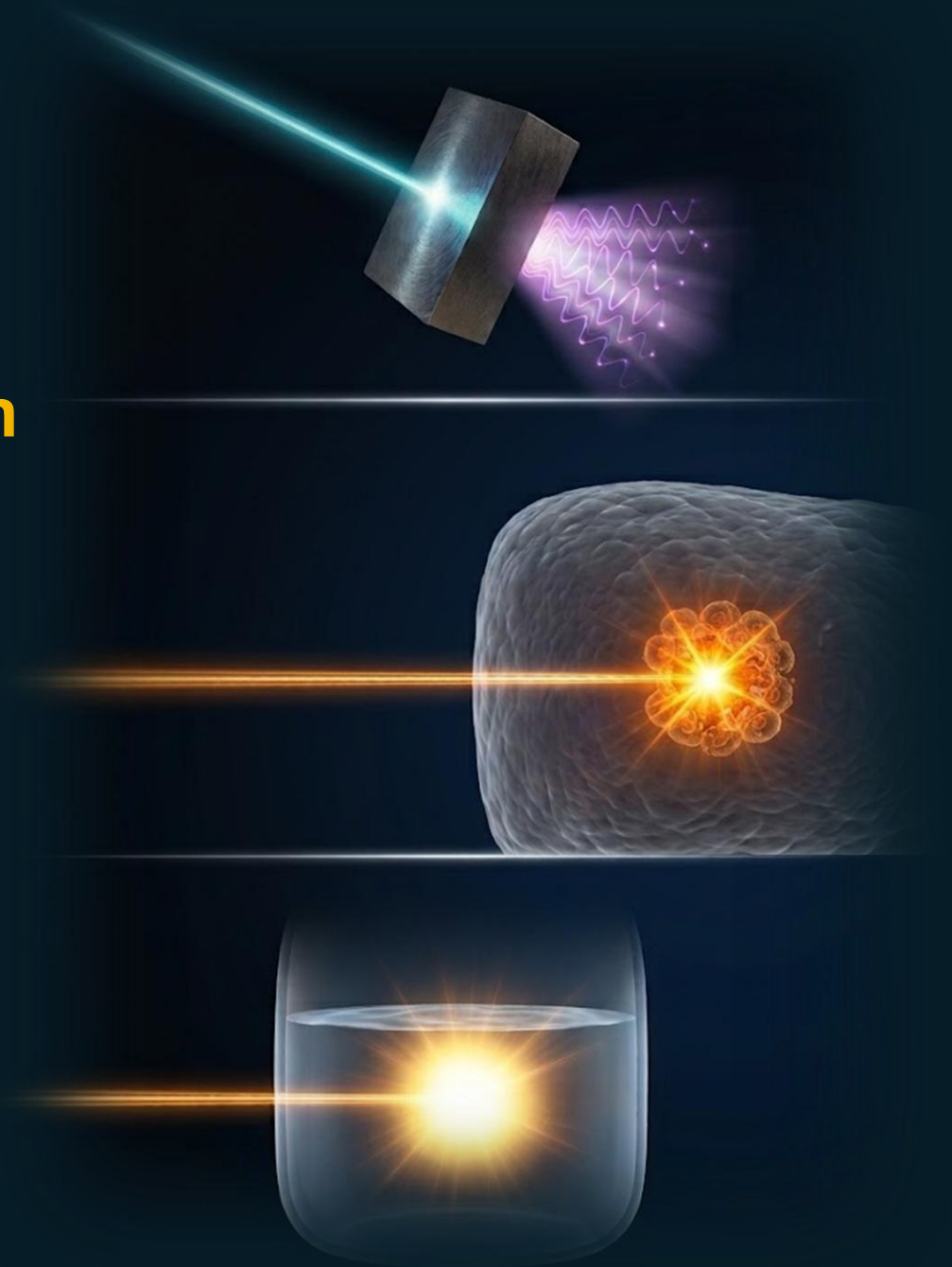
Accelerator Research and Development Division
Synchrotron Light Research Institute (SLRI), Thailand

AFAD 2026, Shanghai, China

15 October 2026



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Accelerator Research and Development Division (ARD)

1

Light-source support

- SPS-I (1.2 GeV): stable operation and injector improvement
- SPS-II (3 GeV): design of the 270 MeV injector linac
- Beam dynamics and diagnostics for both machines

2

Applied accelerators

- Electron linac for agricultural irradiation
- Proton source and linac for isotope production and medical applications

This talk

3

Accelerator ecosystem

- In-house RF, high-power, timing and control systems (EPICS, FPGA)
- Infrastructure for future accelerators
- Support for industry and start-ups



Back row (left to right)

- Kritsada Kittimanapun
- Prach Boonpornprasert
- Jakri Nadeedanklang
- Nattawat Yachum
- Nawin Juntong
- Danai Khampiranon

Front row (left to right)

- Surapong Kokkrathoke
- Phenphicha Niamsakul
- Somjai Chunjarean (team leader)
- Thakonwat Chanwattana
- Yotsapon Anantapak (student)
- Nilaped Russamee

**ALL FOR BEAM,
and BEAM FOR ALL.**

Physicists, engineers, Technical staff, and students working side by side

- Beam dynamics
- Beam diagnostics
- RF and high-power systems
- Control and timing
- Detectors systems
- Mechanics and electronics

**From design to construction,
commissioning and operation**

Electron Linac

Electron Linac: Why Irradiation?

SLRI lab-scale tests

Post-harvest loss of fresh produce,
before and after irradiation

50 % → <10 %

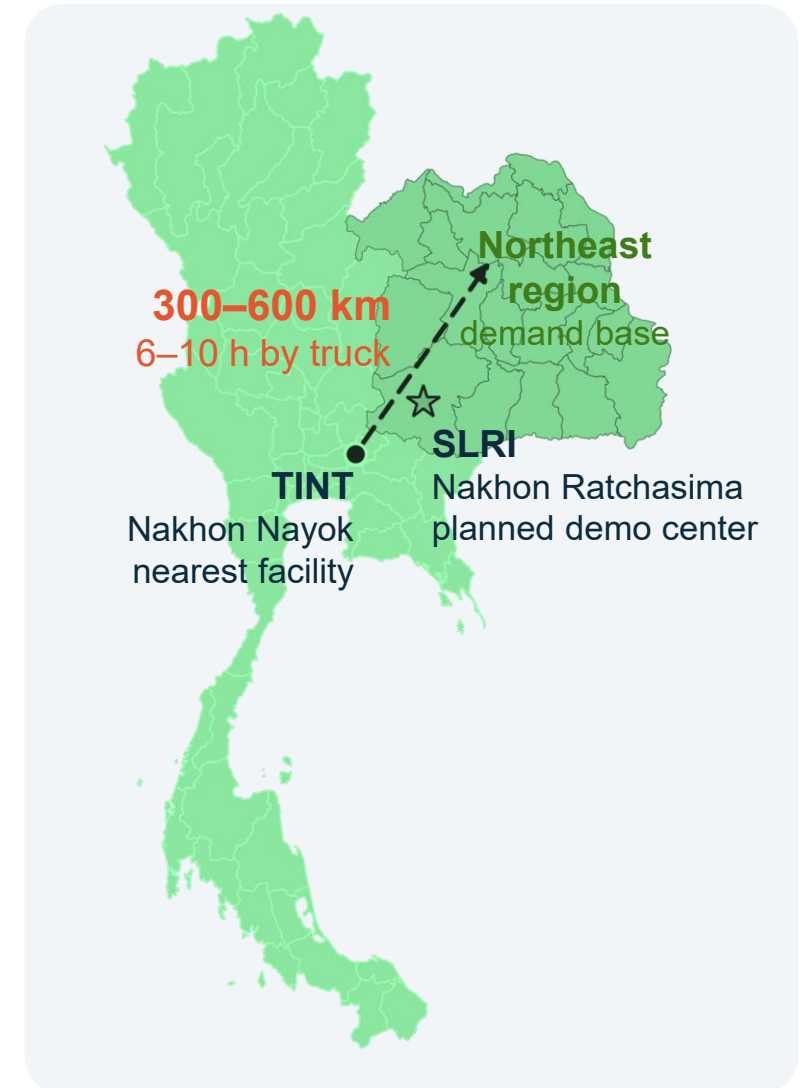
TINT survey

Estimated demand for irradiation in
northeast Thailand (244 operators
in 20+ provinces)

**> 50,000
tons/year**

Target dose by product and purpose

Product	Purpose	Dose
Fresh fruit (mango, strawberry, longan)	Phytosanitary (agricultural health), shelf-life extension	150–400 Gy
Dried herbs and spices	Decontamination (mold, <i>Salmonella</i>)	7–10 kGy
Packaged herbal rice	Shelf-life extension	1–3 kGy



Electron Linac: A Decade of Development

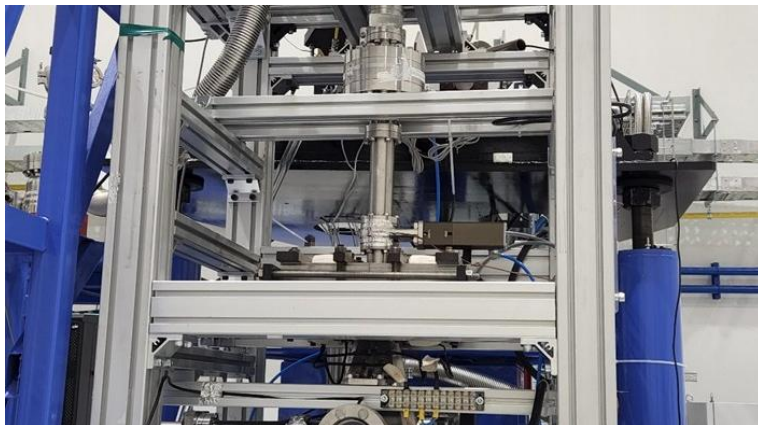


Build 2014 – 2019

2014 R&D on an in-house medical X-ray linac

2016 First X-rays; new linac designed

2018–19 New linac and irradiation system built; first X-rays



Apply 2022 – 2024

2022 Focus on fruit; new building, OAP certification

2023 First fruit irradiation; dual-mode (e-beam / X-ray) R&D

2023–24 Tunable 3–6 MeV system and product tests



Scale up 2026 →

2026 Proposal: LINAC-based irradiation demonstration center

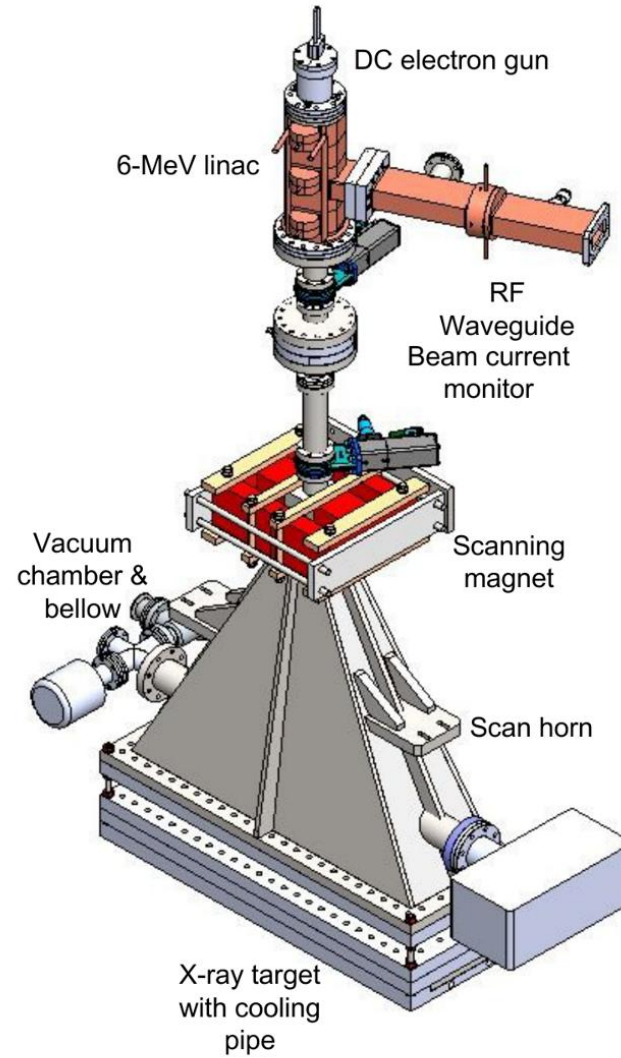
Goal Pilot service for farmers and SMEs



Electron Linac: 6 MeV-class S-band System

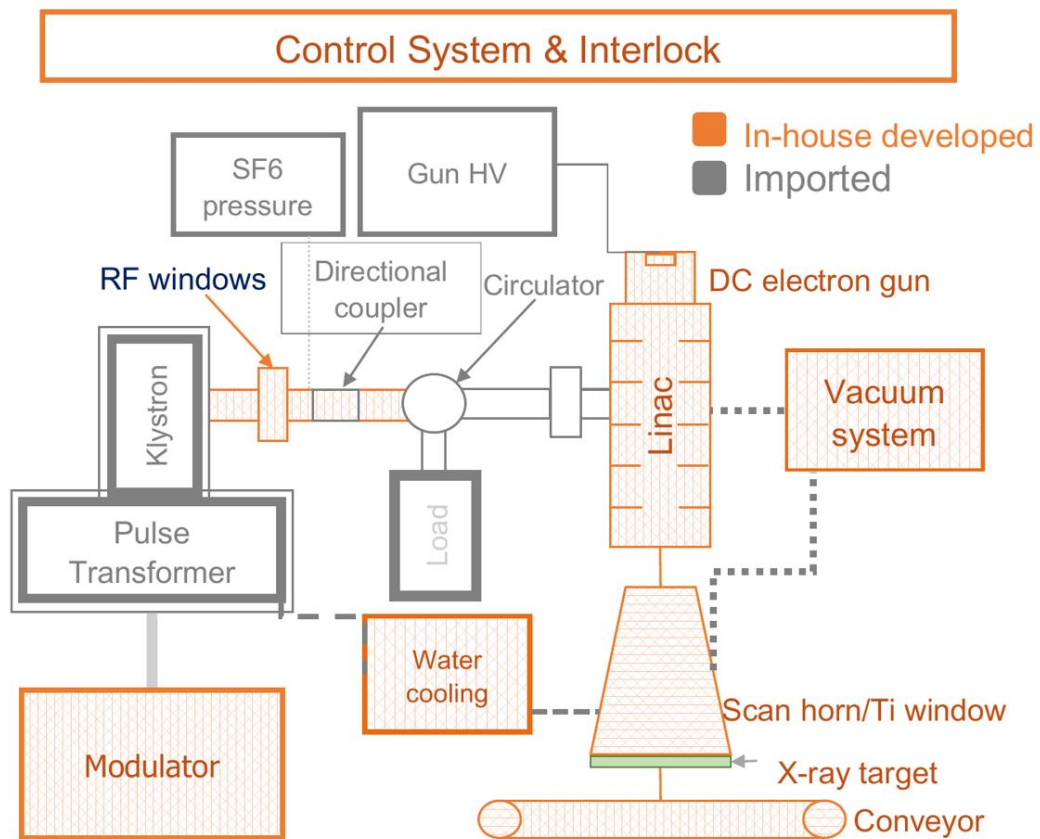


Linac with scan horn and irradiation chamber at SLRI



Parameter	Value
Electron gun	DC thermionic, 30–32 kV
Structure, frequency	Side-coupled, S-band 2997 MHz
RF source	Magnetron, 3.2 MW, auto frequency control
Repetition rate	50–200 Hz, 5 μ s pulses
Electron energy	3.2–5.4 MeV (tunable); 6 MeV design
Peak current	~170 mA at linac exit
Output modes	X-ray (W target) and e-beam
Control, timing	EPICS, FPGA-based

Electron Linac: In-house vs Imported



E-beam/X-rays Linear Accelerator (Linac)
for Research Platform

- Accelerator tube and gun manufactured externally to SLRI design
- RF, control, integration and installation in-house

In-house Advantages

Dual-mode
operation

Open EPICS
control

Domestic
maintenance

Capital cost of the in-house linac compared with an imported commercial system

42.5 % lower

SLRI estimate

Total project investment: 112 MTHB

Share developed in-house

Linac system



Control system



Beamline, magnet, vacuum



Installation, commissioning

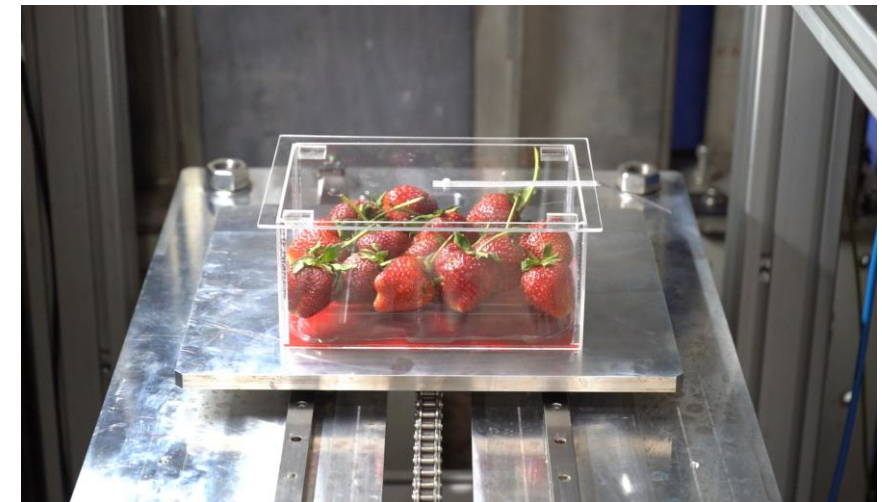
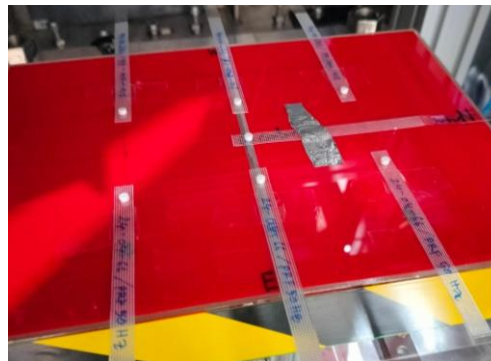


Electron Linac: Irradiation Tests

Product	Dose	Product outcome tests performed by SLRI Food and Agriculture Research Section
Strawberry	400 Gy	• <i>E. coli</i> and <i>Salmonella</i> not detected, also after 7 days. • Texture loss 22 % at 350 Gy, >40 % at 450 Gy
Mango	225–350 Gy	• Quality equal to control • 15 days at 15 °C
Mango	500–620 Gy	• No peel discoloration; anthracnose and stem-end rot delayed (18 days at 15 °C) • Quarantine-pest control

Dosimetry

Alanine dosimeters; surface dose 254–300 Gy over 20 × 25 cm at 30 cm from the target, with beam scanning



Electron Linac: Extending the Building



	Today (R&D prototype)	Phase I: demonstration	Phase II: scale-up
RF source	Magnetron	Magnetron	Klystron
Average beam power	~1.1 kW (design)	2 kW	10.8–15 kW
Duty cycle	≤ 0.1 % (5 μs, 50–200 Hz)	0.1 % (5 μs, 300 Hz)	1.5 % (15 μs, 0.5–1 kHz)
Scan width	≤ 25 cm	40–80 cm	40–80 cm
Throughput at 10 kGy	Batch tests	120 kg/h	≥ 800 kg/h

Electron Linac: Two-Year Roadmap



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Year 1: Integrate

TRL 6 → 7 · prove the full system

- Linac, RF, conveyor, shielding
- Dosimetry and QA/QC, SOPs

Targets

- Beam stability ≥ 95 %
- Dose uniformity ± 10 %
- Uptime ≥ 85 %

Year 2: Validate

TRL 7 → 8 · operate as a service

- Pilot service, ≥ 3 product groups
- Dose-mapping database

Targets

- 30–50 users
- Utilization ≥ 50 %
- 1,000–3,000 t/yr
- Post-harvest loss ~ 30 %

Beyond: Scale up

Klystron RF upgrade

- Trigger: utilization ≥ 75 %
- Upgrade investment > 30 MTHB
- Economy of scale

Targets

- Throughput ≥ 800 kg/h
- $\sim 3,800$ t/yr capacity at full use
- Industrial target $> 20,000$ t/yr
- Lower cost per kg

Background: TRL = Technology Readiness Level (1 = basic principle, 9 = proven in operation)

1

2

3

4

5

6

7

8

9

Research

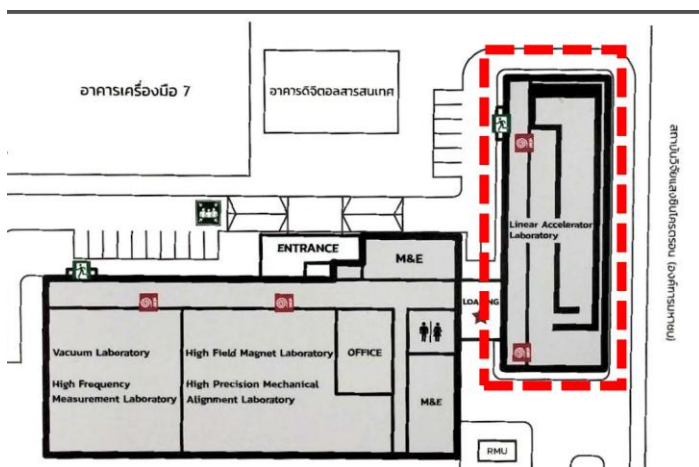
Prototype and demonstration

Deployment

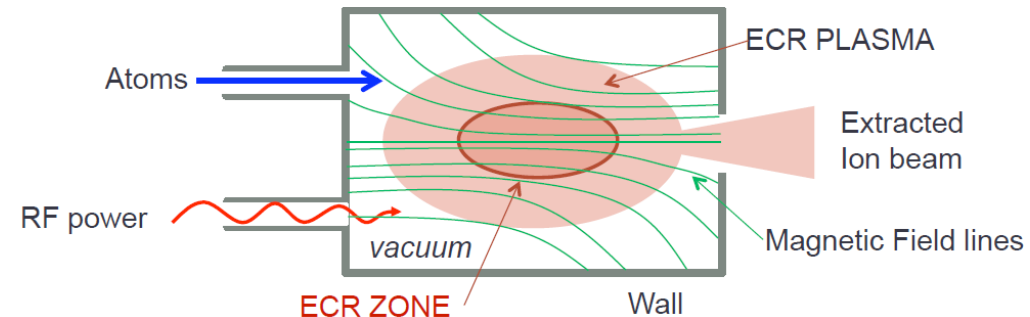
Proton Linac

Proton Linac: Stage 1, the ECRIS

Advanced Technology Facility (Pilot Plant Building)



Linac Laboratory



Principle of an ECR ion source. Schematic: T. Thuillier, "Electron Cyclotron Resonance Ion Sources – I", CERN Accelerator School (CAS 2012)

ECRIS in procurement: Pantech HiQ

Peak H^+ current (target 50 mA)
 ≥ 40 mA

Normalized emittance
 $\leq 0.2 \pi$ mm·mrad

Maximum extraction voltage
60 kV

RF heating, permanent magnets
2.45 GHz magnetron

Dec 2025
Order

2026–2027
Build and
test

**May–Jul
2027**
FAT

**Sep–Dec
2027**
Installation

Stage 1: approved and funded, FY2026

Funded as national S&T infrastructure. Starting point for the isotope linac and for future medical proton applications.

Proton Linac: Why Produce ^{18}F Locally?



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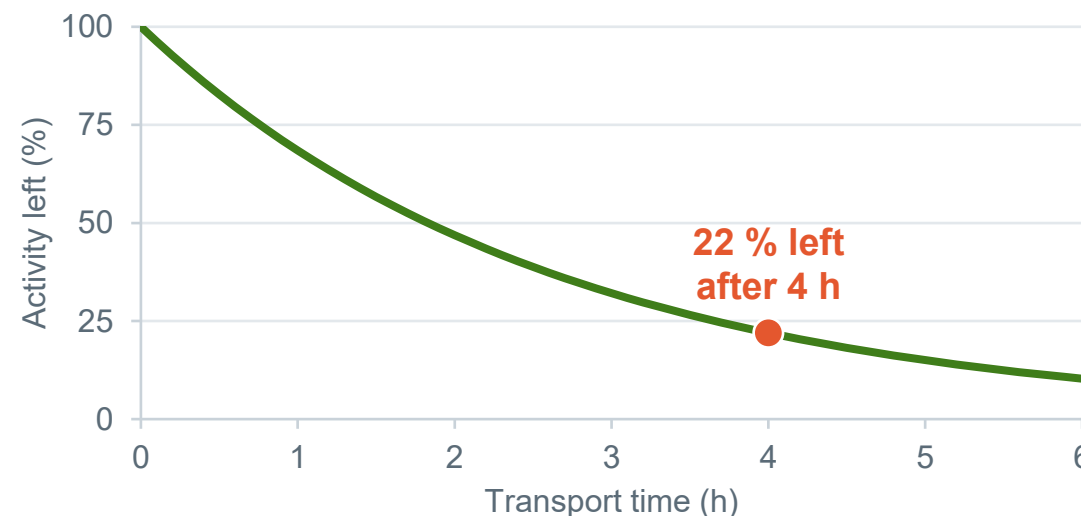
^{18}F : the standard PET isotope

- ^{18}F -FDG is the most common oncology PET tracer
- ^{11}C and ^{15}O (< 20 min) cannot be shipped at all
- ^{18}F (109.8 min) can travel, but only over short distances

409 PET vs **4,641 SPECT**

Nuclear-medicine exams in Thailand, 2024:
PET is used 11× less than SPECT.
SPECT tracers ship easily; PET tracers must be made nearby.

Activity lost in transport from Bangkok to Nakhon Ratchasima



Only ~22 % is left after an assumed 4 h transit

Our goal
produce ^{18}F locally

ECRIS
Stage 1, in procurement

**7 MeV proton
linac**
proposed

**$^{18}\text{O}(\text{p},\text{n})^{18}\text{F}$
target**
proton irradiation

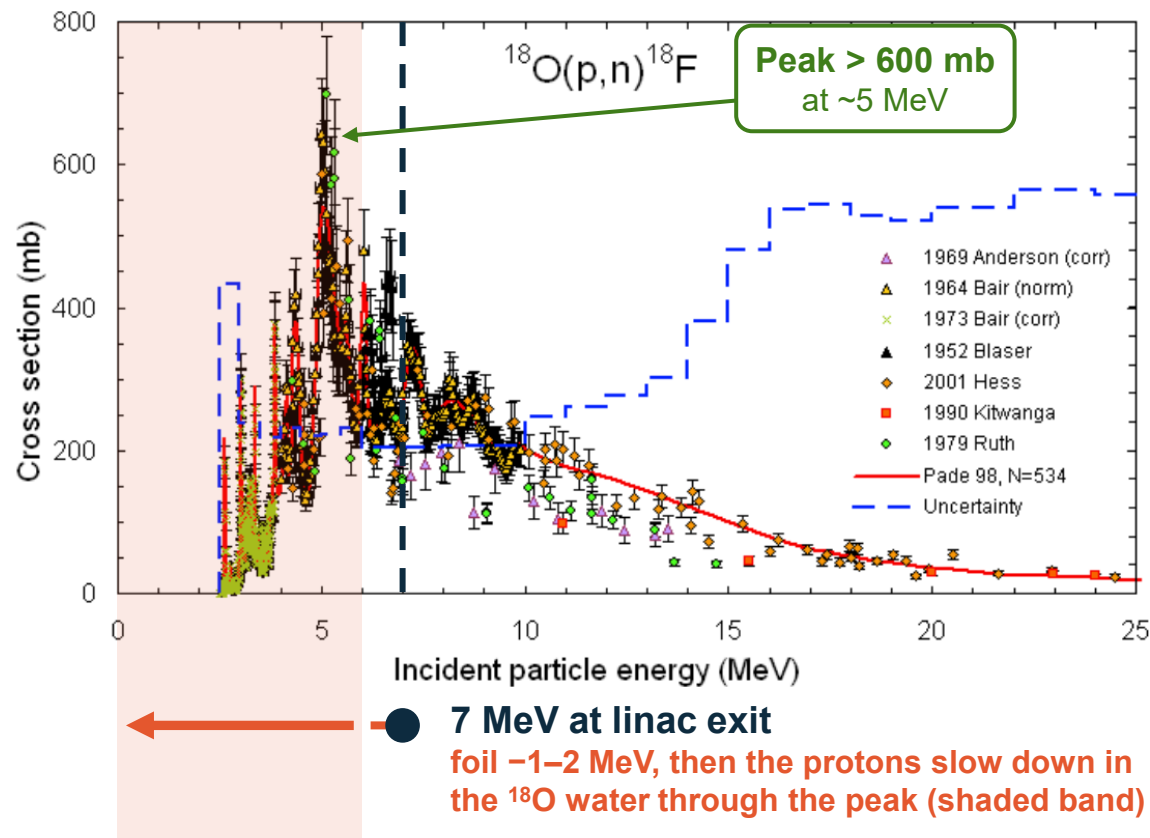
^{18}F -FDG
serve regional
PET centers

Proton Linac: Why Start at 7 MeV?

7 MeV reaches the ^{18}F reaction peak, reuses a reference design, and leaves room to grow.

1 Where ^{18}F is made: cross section

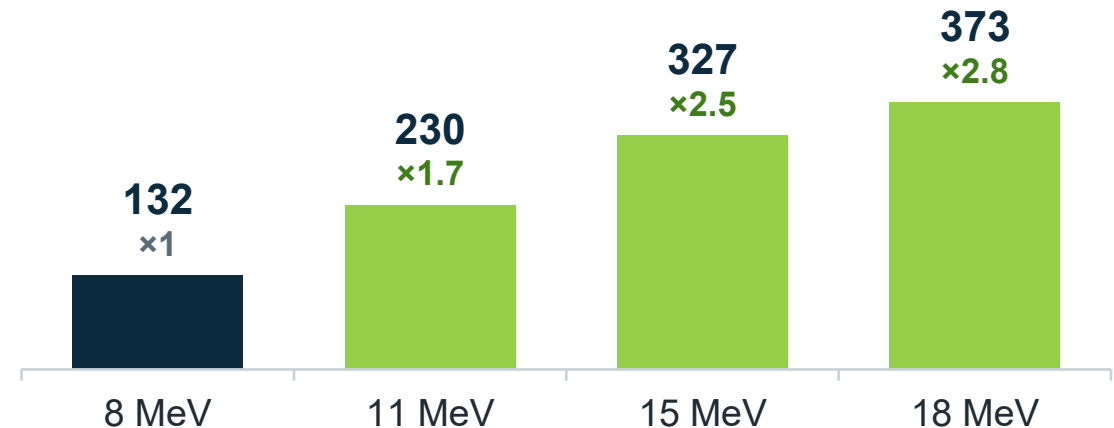
mb = how likely one proton makes ^{18}F at that energy



2 How much ^{18}F : thick-target yield

mCi/ μA = ^{18}F activity per μA of beam (saturation)

■ nearest data to 7 MeV ■ upgrade range



- ✓ On the reaction peak: 5–6 MeV on target
- ✓ Reference design: adapted from the APTF injector design, not designed from scratch
- ✓ Room to grow: second IH tank $\rightarrow$ 11–18 MeV

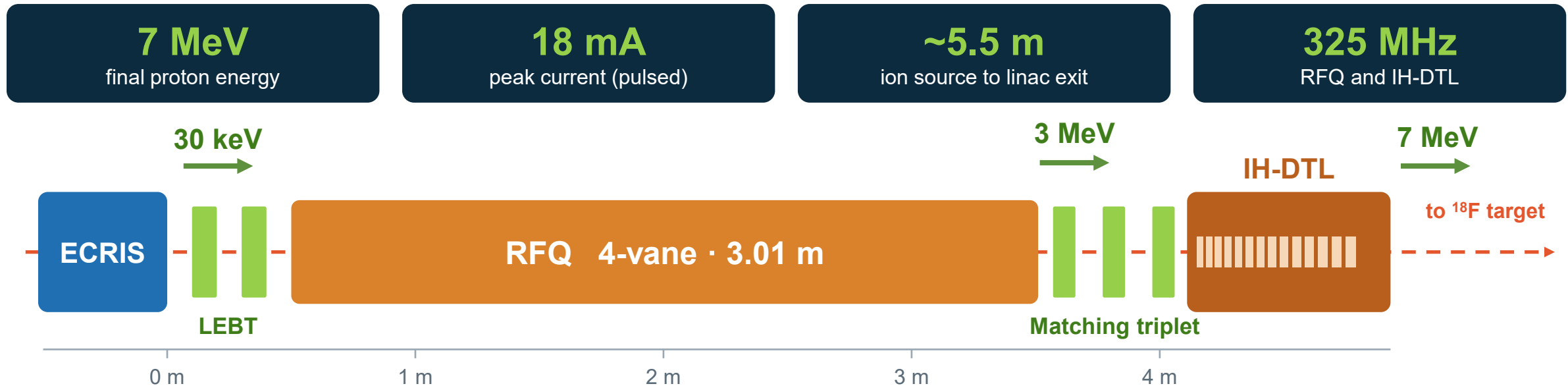
Proton Linac: "Preliminary" Conceptual Layout



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Based on the APTF injector design

Qiao et al., "Physical design of a compact injector for synchrotron-based proton therapy", *Front. Phys.* 11:1201158 (2023). <https://doi.org/10.3389/fphy.2023.1201158>



Proton Source

- ECRIS: 2.45 GHz, permanent magnets
- Up to 50 mA; $\leq 0.2 \pi \text{ mm} \cdot \text{mrad}$ (rms)
- LEBT: 2 electrostatic quadrupoles

RFQ (reference design)

- 325 MHz four-vane, 3.01 m
- 30 keV $\rightarrow$ 3 MeV, 74.6 kV inter-vane
- Kilpatrick factor of 1.7
- 98 % transmission

IH-DTL (reference design)

- 325 MHz, 0.82 m, 15 gaps
- KONUS beam dynamics, 4.9 MV/m
- 3 $\rightarrow$ 7 MeV, no internal focusing magnets

Proton Linac: Pathway and Next Step



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Stage 1 · ECRIS

Funded; in procurement, delivery 2027

Stage 2 · Isotope linac

Proposed: 1-year design study
(below)

Stage 3 · Future

Proton-accelerator skills for medical
applications

1 Months 1–6: Design basis

- Demand analysis for northeast Thailand
- Start-to-end beam dynamics: ECRIS → LEBT → RFQ → IH-DTL
- Design requirements document

2 Months 7–12: Engineering design

- RF structure design and cold model (bead-pull)
- Engineering drawings, shielding, target
- Feasibility report

1 year · ~5 MTHB

duration and proposed budget

> 90 %

beam transmission target,
start-to-end simulation

TRL 2 → 4

design validated by a cold
model in the laboratory

SSRF/SARI/CAS

HZB

collaborations with SLRI

Electron Linac: Agricultural Irradiation



Achieved

- 3–6 MeV S-band linac designed and integrated in-house
- Fruit tests: pathogen reduction, quality retained
- 42.5 % lower capital cost than imported

Next

- Extend the building: demonstration center, TRL 6 → 8
- Klystron upgrade for higher throughput

Proton Source and Isotope Linac



Achieved

- ECRIS funded; in procurement, delivery 2027
- Pilot plant building opened (Aug 2025)

Next

- Isotope linac: 1-year feasibility and design
- Upgrade path to 11–18 MeV
- Future medical applications

Thank you

ARD Team, Synchrotron Light Research Institute (SLRI), Thailand