# “Commercial Use of Phytosanitary Irradiation” (PI)

## Electron Beam and X-Ray Equipment

## Mevex Corporation’s
## Multiple Solutions for PI

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## Toluca, Mexico
## 14 October 2015

# Overview of the presentation

- Framing the PI world seen from the equipment supplier point of view
- Comparison between a private project and government projects
- Inform you about the latest green field PI project in the world
- Wide range of Mevex linacs proposed for PI using X-ray or EB
- an accelerator called “eXTRA”  What; Why; for Whom?
- X-rays obtained  from  5 to 7,5 MeV EB
- Pallet treatment with double row
- Pallet Intensity modulation, with 4 sided treatment for increased efficiency

# Framing the situation…

- There are not many suppliers of EB and X-ray equipment for PI
- Radioisotope-based irradiators are the “standard” for PI
- Machine-source manufacturers are adapting to the requirements of phytosanitary applications.
- Many countries are establishing bio-security frameworks for international  trade of fresh products
- The US government (NNSA) is encouraging non-isotopic technologies
- The demand for machine-source irradiators is growing quickly for both EB and X-ray.
- Selection of the right process, equipment, and vendor seems difficult for newcomers and somewhat subjective.

# What is special to PI

- We target to treat the flies not the food itself
- Maximum allowed dose of 1000Gy for PI is 25 to 50 times lower than doses used in medical device sterilization and hundred times lower than doses used in crosslinking of materials
- Power requirements are thus moderate
- Handling and conveying speeds are often limiting factors, not the machine power
- Treat very low value commodities,  compared to manufactured products
- Low unit cost of treatment is a must for the competitivity of exporters
- Products to treat are delicate , it is important to minimize DUR
- Seasonal activity, what to do in periods when little  PI is needed
- Regulated activity
- Yet a very strategic investment for Governments to empower the exportation of fresh products

# 2 types of user profile

## Government/Agency

- Introduce technology to local growers and distributors
- Research activities
- Pilot scale
- Viable
- Low unit cost is not the priority
- Strong support from government
- Framework agreements with trading partners
- Pest scientists/biologists
- National standards development

## Private/Commercial

- Low unit cost with high quality is the priority
- Integration into the supply chain
- Quick turn times
- High availability
- Competitiveness against non Irradiation technologies
- Profitability based on a seasonal business
- Concern about regulations
- Concerns about long-term viability of the business

# How to reduce risk for machine-source systems

**Reduce business risks:**

- **Can/should the PI facility be designed for multi-purpose irradiation?**
- **Can the facility be “re-purposed” if the PI market disappears?**
- **Can the machine be re-located if the facility geographical environment changes ?**
- **At what cost and effort?**

**Reduce operation risks:**

- **Multiple machines/beams?**
- **Multiple conveyors?**
- **Multiple bunkers?**
- **Network of facilities to cover large geographical area?**
- **Select a well mastered technology that meets ALL your requirements, from a reliable vendor**
- **Make a thorough due diligence on how deeply you will be supported by the equipment supplier during decades of use. Meet and discuss with users of the machine you are tempted to select to anticipate your future upgrade needs**

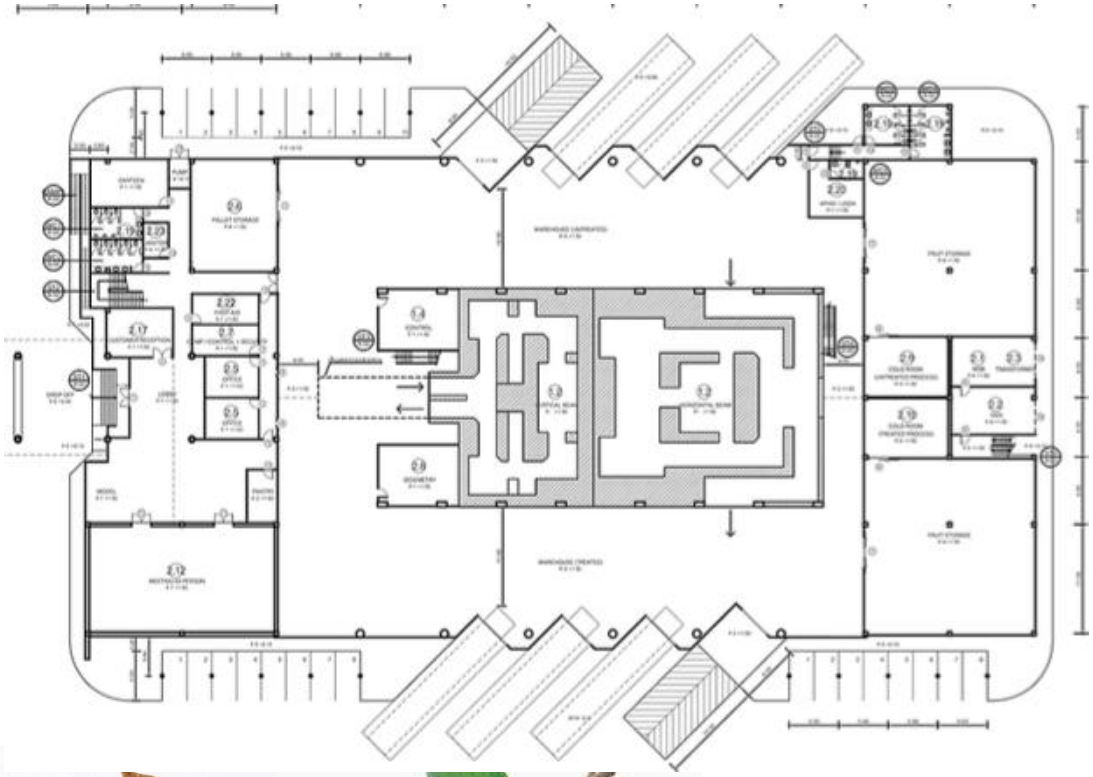
# P I has the most potential in food irradiation

- Quarantine is a requirement, if you want to export your fresh products to certain countries you must have a solution for your country
- If you have no solution, countries that planned a solution have a competitive advantage
- P I enables global trade in fresh food products:
  - Quarantine and pest control
  - Higher crop value for farmers in developing countries thanks to the export markets
- Generic treatments are defined for PI, a lot of research work is available
- Mexico, Vietnam and Thailand have the most experience and expertise in PI

# Latest planned PI Facility

**Thai Irradiation Center (TIC) just finalized a Government Tender for a Turnkey EB and X-ray Facility, mainly for PI**

# Back to Back separate treatment rooms EB and X-ray



MEVEX
THE ACCELERATOR TECHNOLOGY COMPANY

# Mevex Range of machines for P I

- High Energy linacs (5 to 10 MeV)
  - 10 MeV EB (Global)
  - 10 MeV EB and 7.5 MeV X-ray (US only)
- 5 MeV ultra compact machine for X-ray treatment
- eXTRA a production facility for PI combined with a research tool;  affordable investment for government organisations
- Mevex linacs features
  - extremely compact
  - Can vary energy from the same scan horn ( small vault & facility)
- More than 40 Mevex linacs have been installed in industry. Many systems are delivered turnkey to users. 3 X-ray accelerators of 7,5 MeV produced.
- We don’t sell Cobalt, but we do all  kind of beams ☺

# eXTRA – A tool for growing food irradiation

- **What :**
- **Commercial: 10 MeV EB and 5 - 7.5 MeV X-ray**
- **Research: 3 to 10MeV electrons with x-ray at all energies.**

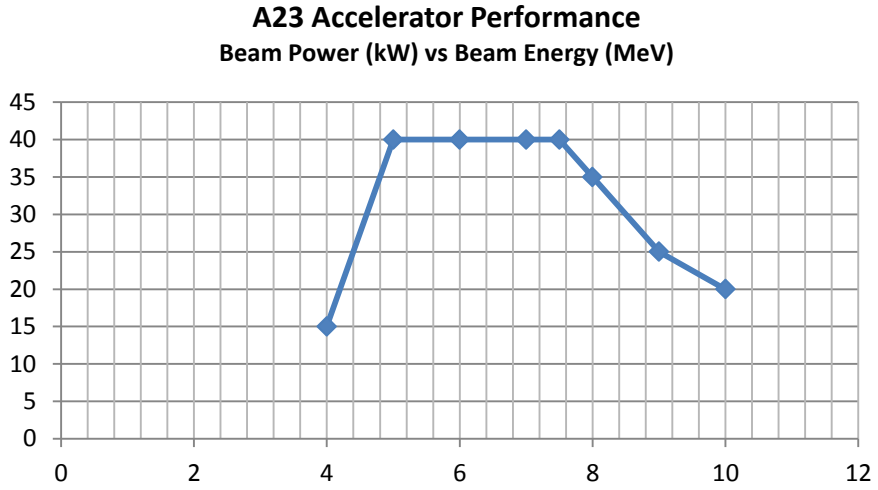
- **Why :**
- **Because a majority of countries do not yet have an access to a food treatment electron /x-ray facility with a capacity for real size testing**
- **Because most countries do not yet have a RESEARCH Tool combining EB and some X-ray**

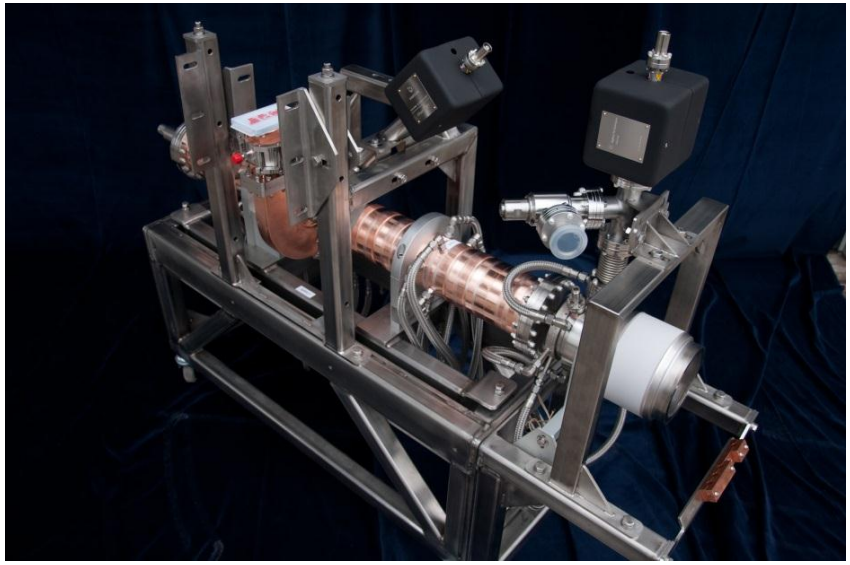
- **Whom:**
- **Typical profile of user is a pilot plant operated by a governmental organization in collaboration with food industry and exporters (or vice versa).**

- **Such a pilot plant is a prerequisite in every country to demonstrate locally the technical and economical feasibility, to educate producers, packers and exporters, to plan, coordinate and execute the numerous regulatory requirements necessary before products can be actually exported.**

# eXTRA the linac with selectable energy exiting from same scan horn

- **Adjustable energy**
  - **5 - 7.5 MeV with 40kW**
  - **10 MeV with 20kW power**
- **X-Ray converters**
  - Tantalum x-ray converters
  - Optimized for up to 5MeV
  - Optimized for up to 7.5MeV
- **Automated change from EB to x-ray mode**
  - X-ray converter on motorized slides
  - Converter out of beam = e-beam mode



A-23 5 to 10 MeV High Power Accelerator Cavity

# Select the best EB energy to minimize the DUR

- DUR requirements are challenging when using a fix 10 MeV EB in PI
- Take the example of minimum required dose of 400Gy.
- Maximum allowed dose of 1000Gy
- Maximum allowed DUR is 2.5
  - By the time the process uncertainties are added to the max and min doses the allowable DUR can be reduced to 2

- By simply selecting the ideal energy from the depth vs dose curve for the specific product to be treated, it is easy to improve the DUR
- A number of products welcome the use of a different energy than 10 MeV to obtain the best DUR
- Productivity also increases when using the optimal treatment energy

# Selection of optimal EB energy to reduce DUR

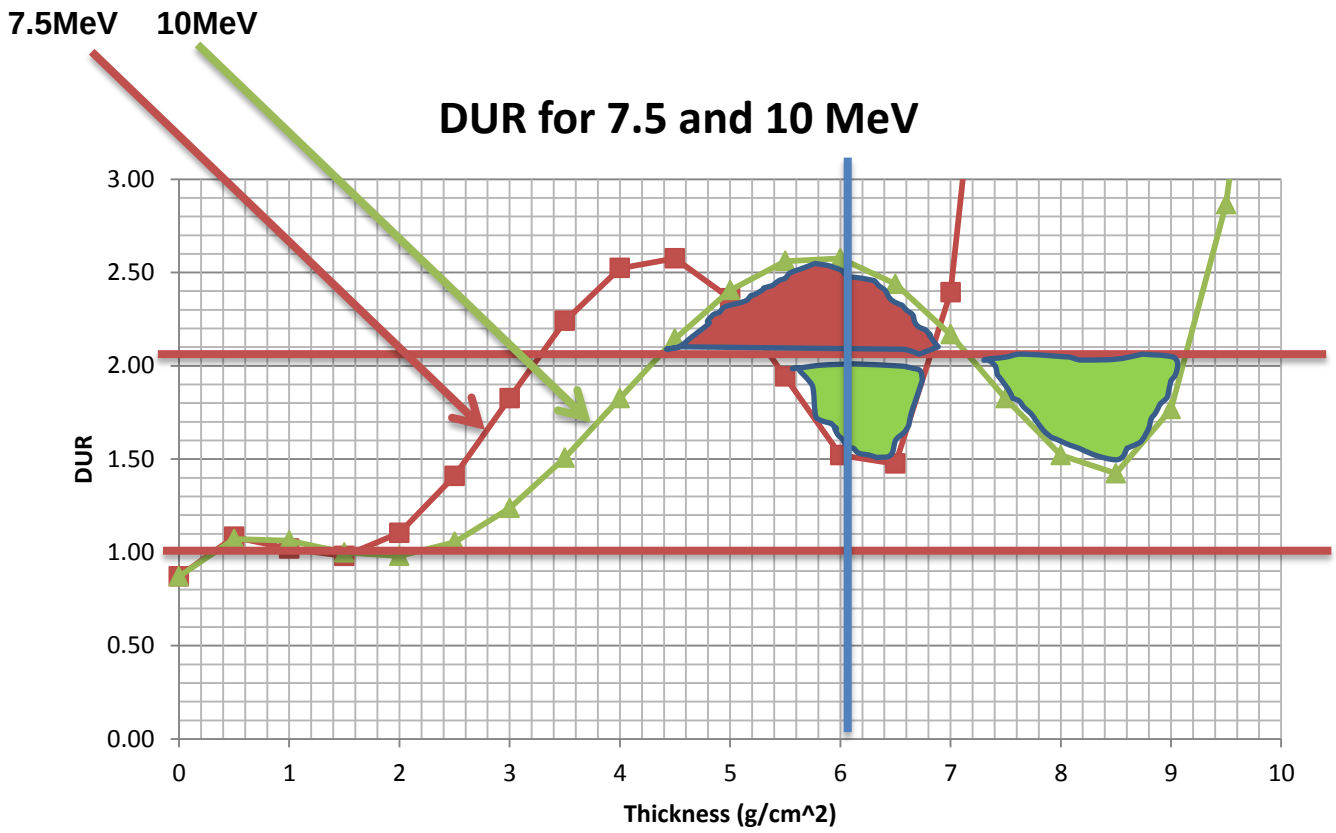
If the product thickness is 6g/cm^2 then the DUR at 10MeV would be 2.5:1 without foam packing.

If the energy can be lowered to 7.5MeV then the DUR is 1.5:1 without foam.

The RED area at 10MeV becomes a GREEN area at 7.5MeV.

The reduction of labor reduces costs.

The reduction of complexity for the loading pattern reduces the possibility of errors.



# Penetration capabilities of a 10 MeV EB

- 88cm thick product for 0.1g/cc
- 44cm thick product for 0.2g/cc
- 22cm thick product  for 0.4g/cc
- 8.8cm thick product  for 1.0g/cc

with DUR less than 2.0 Assuming treatment from 2 sides, for products with uniform density



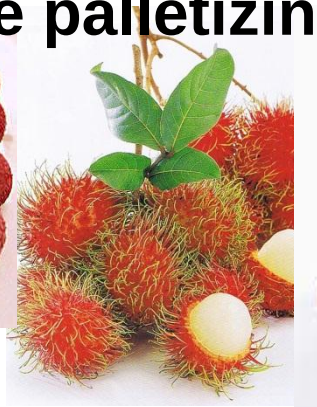



# Benefit of EB: it is extremely efficient

- **EB uses electricity very efficiently and treats the fruit VERY quickly**

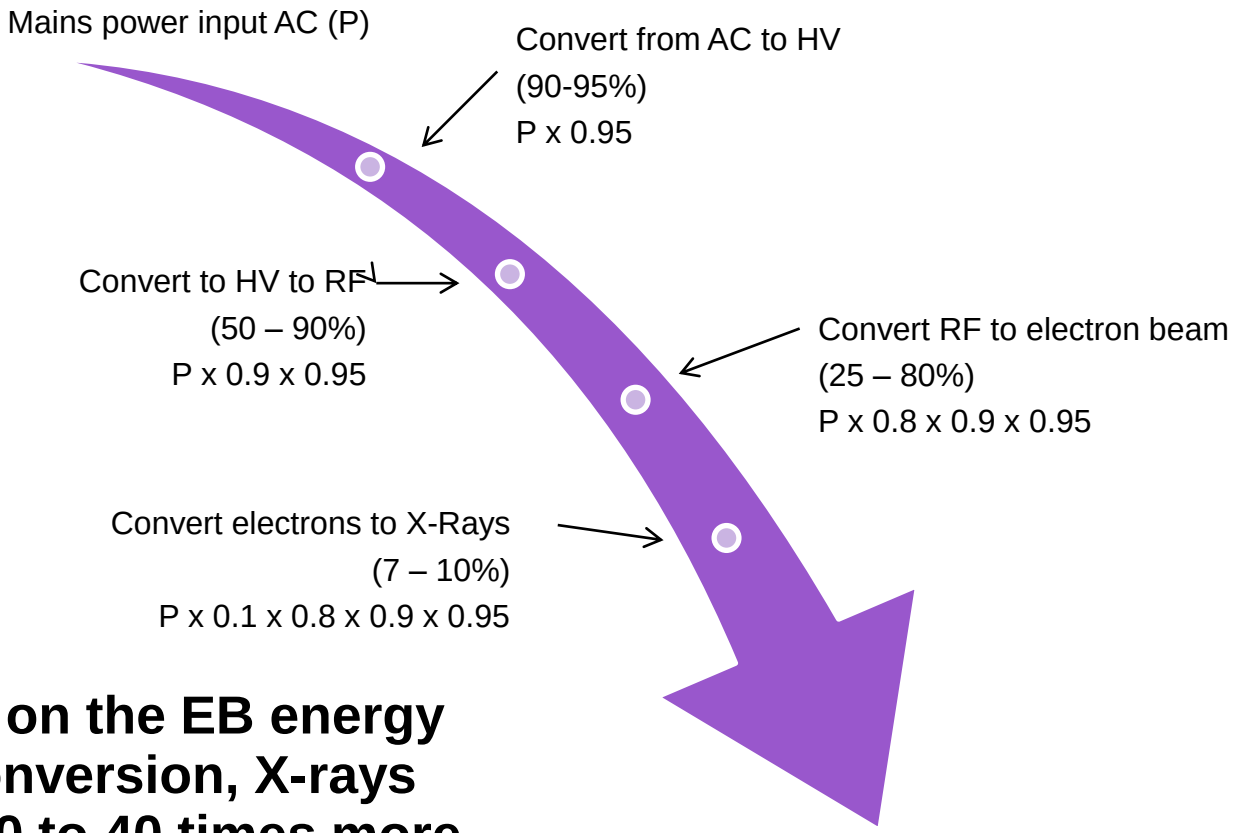
- **After analysis, several type of fruit boxes can be perfectly treated by EB (not all)**

- **It is interesting that in several countries fruits and vegetables do not come palletized but accumulated box by box in trucks. An EB treatment box by box can make sense before palletizing**

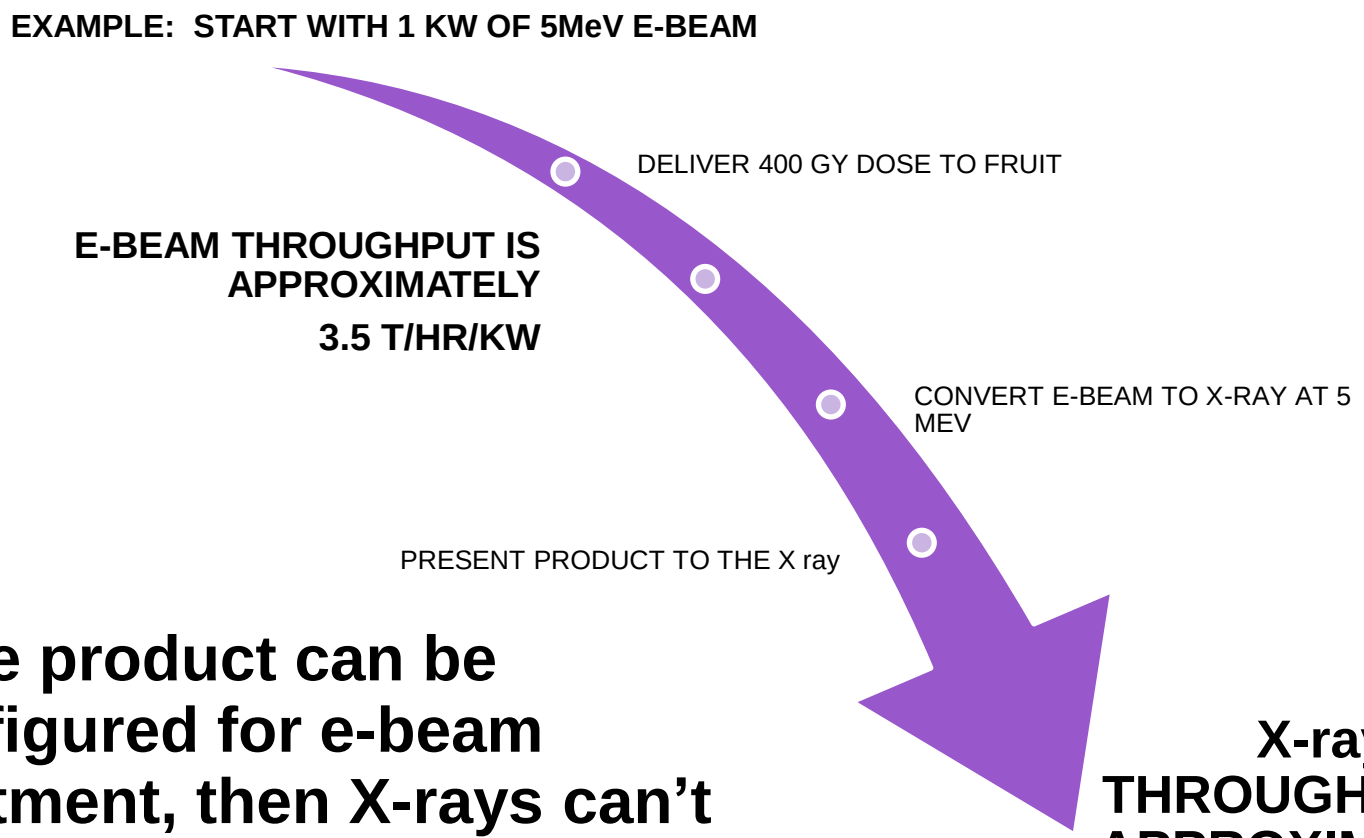


# X-Ray – lots of conversions




**Depending on the EB energy used for conversion, X-rays consume 10 to 40 times more electricity than EB to deliver the same dose to the product**

# What does it mean for X-ray throughput?




**If the product can be configured for e-beam treatment, then X-rays can't compete based on energy consumption and efficiency.**

# Homogeneous product: 50 kW of beam

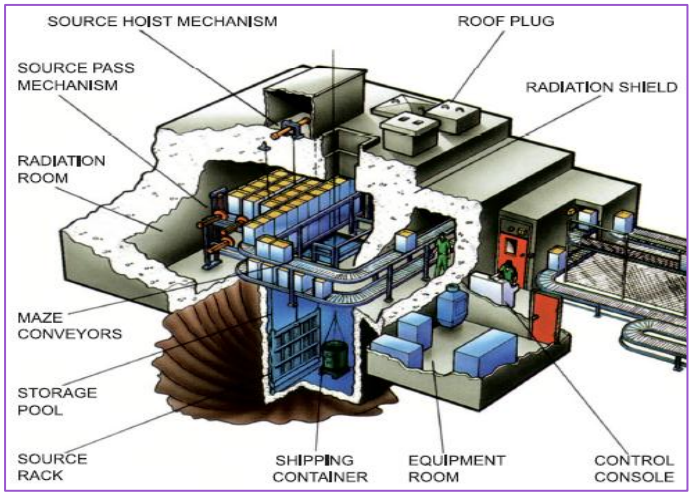
| | Boxes | Pallets | |
|---|---|---|---|
| Dose | E-beam | 5 MeV X-Ray | 7.5MeV X-Ray |
| 150 Gy | 465 t/hr | 16 t/hr | 20 t/hr |
| 250 Gy | 280 t/hr | 9.6 t/hr | 12.5 t/hr |
| 400 Gy | 175 t/hr | 6 t/hr | 7.8 t/hr |
| 1 kGy | 70 t/hr | 2.4 t/hr | 3.12 t/hr |
| 2 kGy | 35 t/hr | 1.2 t/hr | 1.56 t/hr |

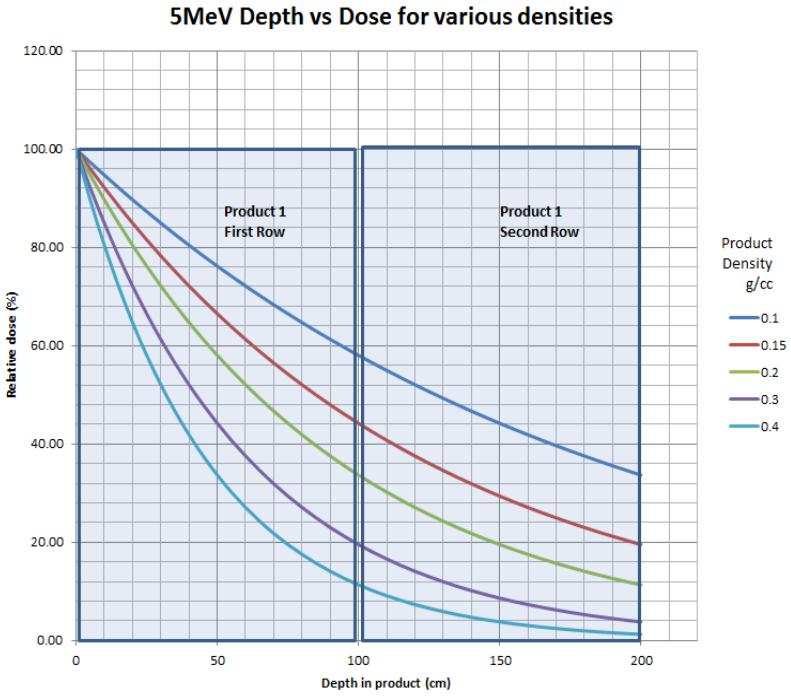
Note:

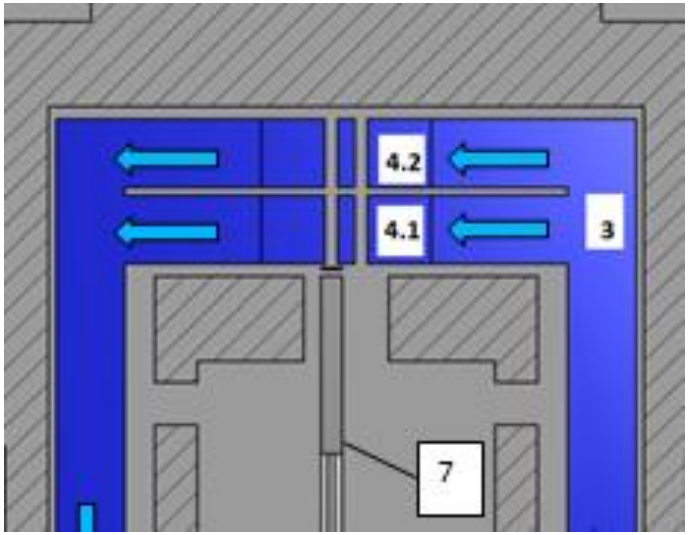
- Simple single-row, 2-sided treatment of pallets
- These values are to show order-of-magnitude effects.
- Higher density tends to improve x-ray efficiency.
- Densities are high enough to give best throughput.

# Double-row irradiation for X-Ray

- Nordion parallel-row irradiator has been around for 40 years. (improved throughput)
- X-rays penetrate further than gamma.
- <u>Wasted dose through the back of the pallet is very high for low density products</u>.

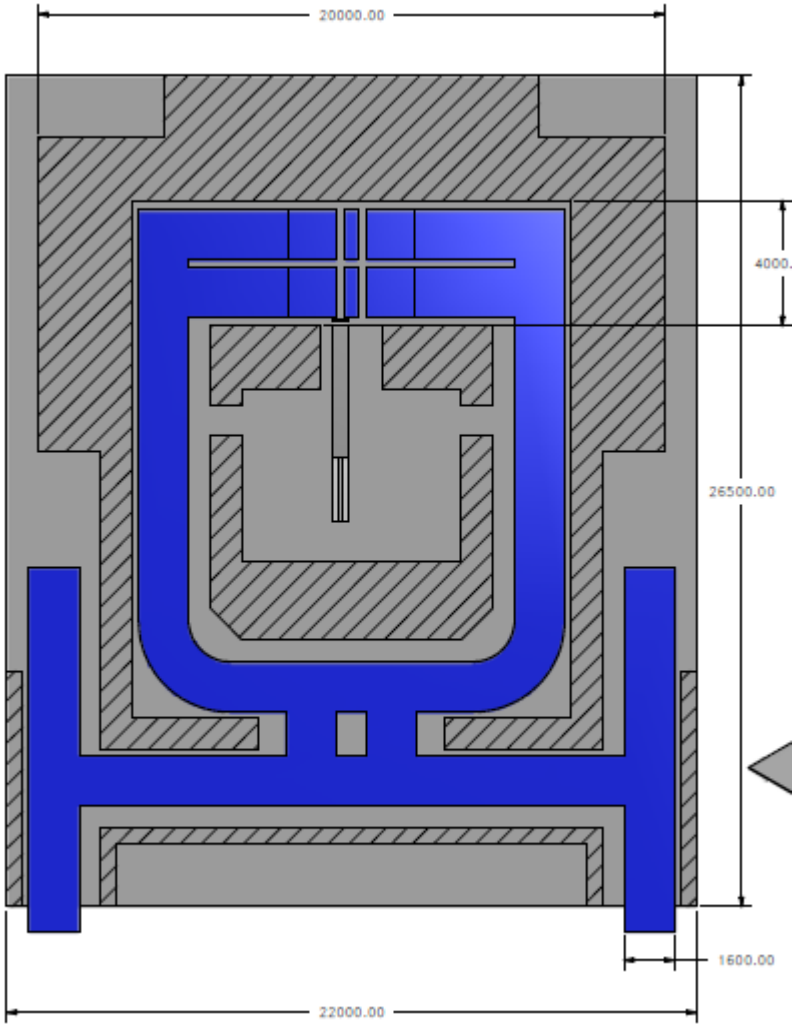


# Double-row irradiation for X-ray

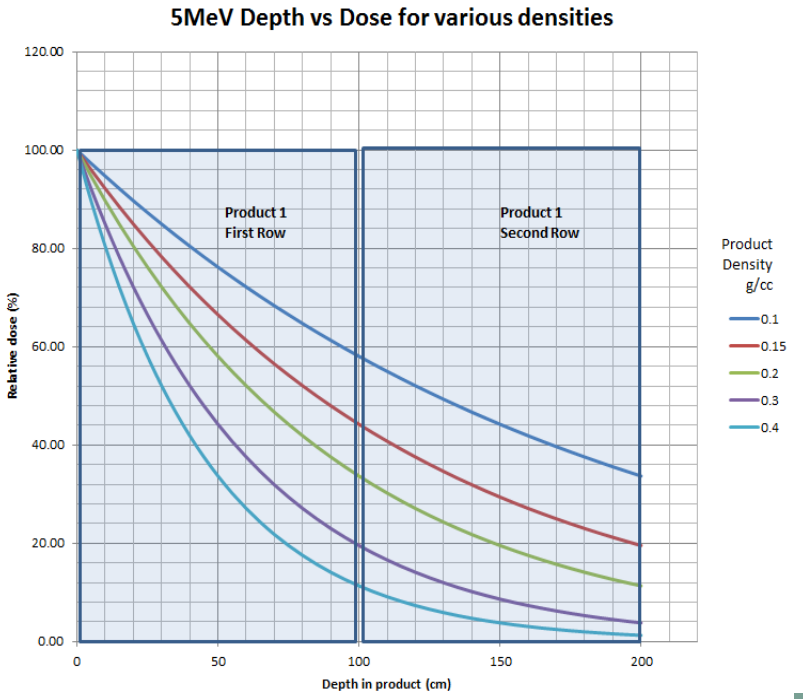
- **Double-row is VERY important for maximizing x-ray efficiency, (especially at low densities)**
- **Footprint is 20m x 27m with double loading and unloading stations.**
- **Footprint can be reduced with single loading and unloading stations.**
- **4 sided irradiation to improve DUR and efficiency is still possible with double-row irradiator.**
- **A space is included in the bunker design for a second accelerator.**



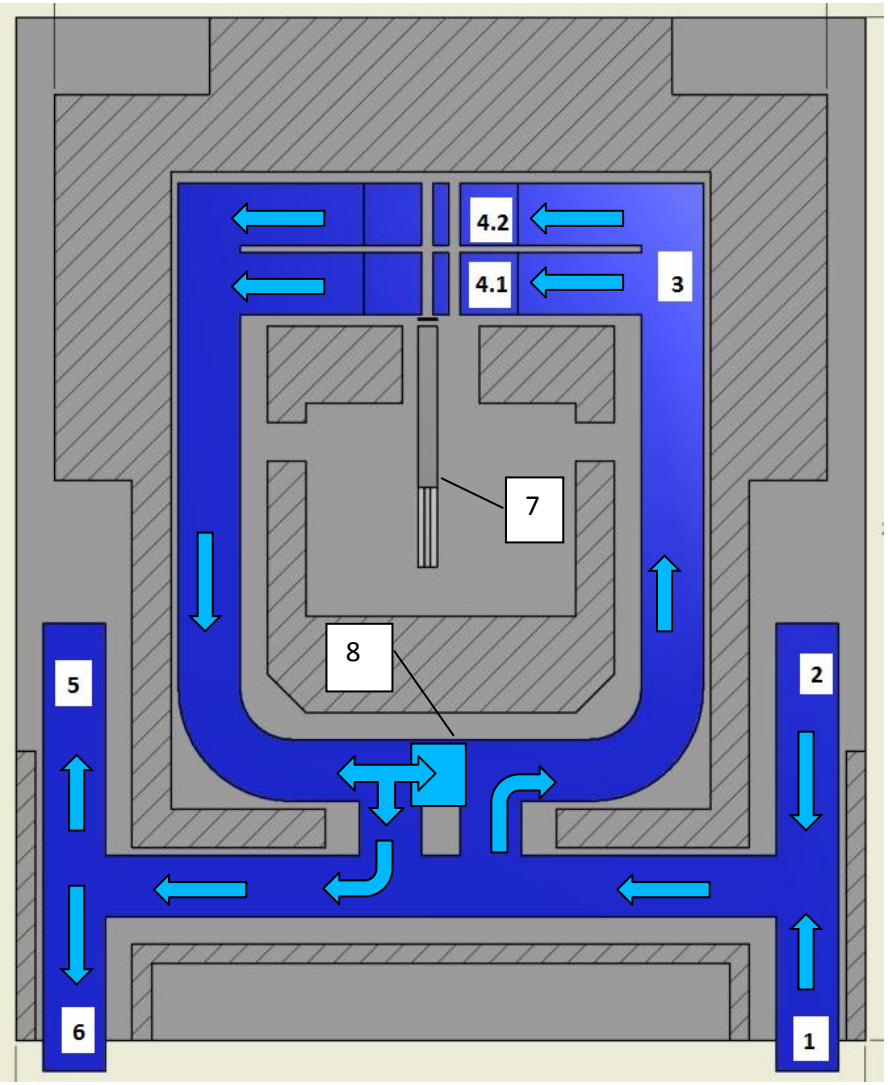
# Double-row irradiation for X-Ray

- The throughput improvement is more significant for low density products.
- For 0.1g/cc the throughput can be improved by around 40%
- For 0.4g/cc the throughput is only improved by around 10%
- Double-row irradiation has limitations:
  - Need large batches of the same product for it to work properly
  - Planning is more difficult than for single-row operation
  - Only use double-row when facility capacity needs to be optimized
  - Not much improvement in efficiency for densities above 0.3g/cc

| Product density (g/cc) | 5MeV Exit dose (% of surface dose) |
|---|---|
| 0.1 | 58.0 |
| 0.15 | 44.2 |
| 0.2 | 33.7 |
| 0.3 | 19.5 |
| 0.4 | 11.3 |



# Process overview




1. Loading station (from cold storage area)

2, Loading station

3.Transfer to UBC 1 or 2

4.1 UBC 1 individual speed control.

4.2 Follow UBC 1 speed.

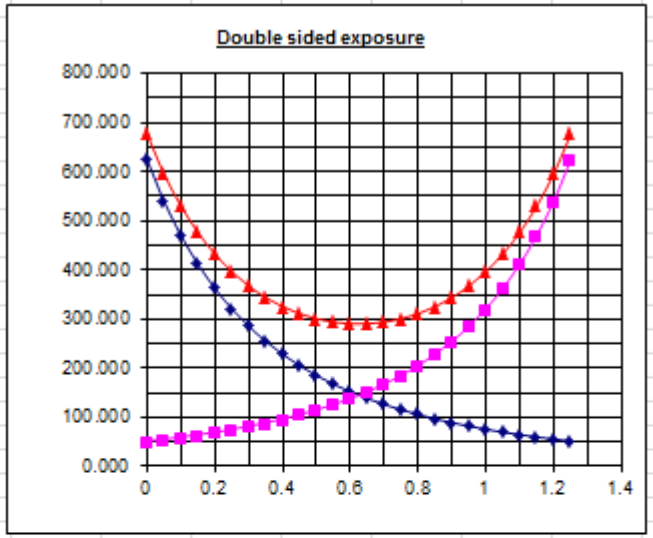
5. Unloading station

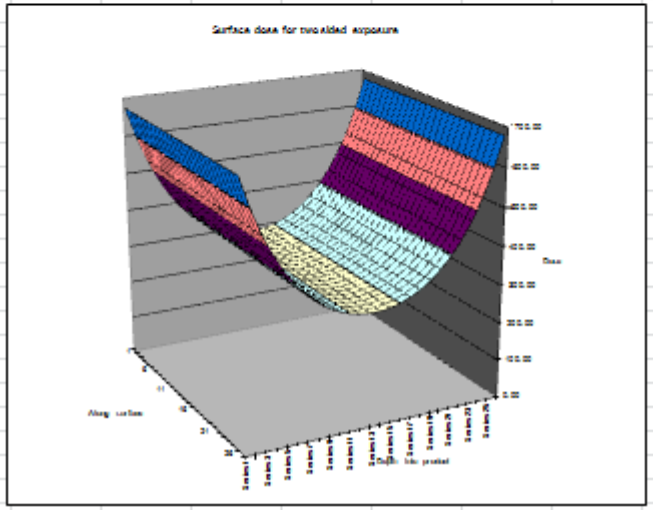
6. Unloading station (to cold storage area)

7. Accelerator

8. Pallet turning station.

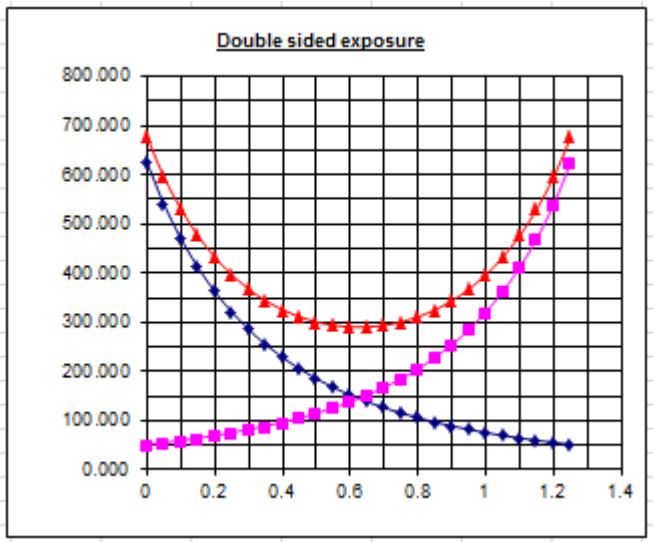
# Pallet Intensity Modulation to improve DUR

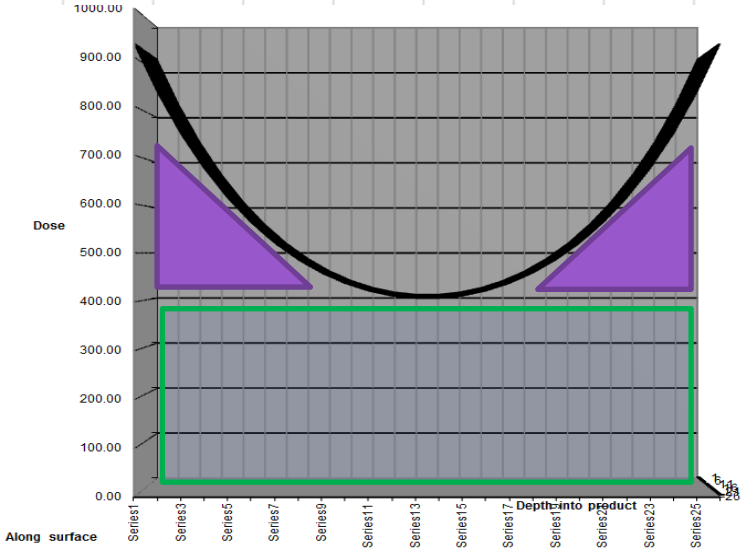



- Intensity modulation (IM) is not new but "high efficiency pallet intensity modulation" is new.
- Normal 2 sided irradiation gives acceptable dose uniformity for most applications. (For density 0.4g/cc DUR of 2.4 is possible)
- Even though the DUR is acceptable from a regulatory point of view, the "extra" dose that is being delivered is wasted energy…. It is dose that is not necessary.
- This "wasted dose" can represent 25% of the deposited dose (Joules/kg).
- If this "extra" dose can be re-distributed in the product then the x-ray process efficiency (throughput rate) will be higher.

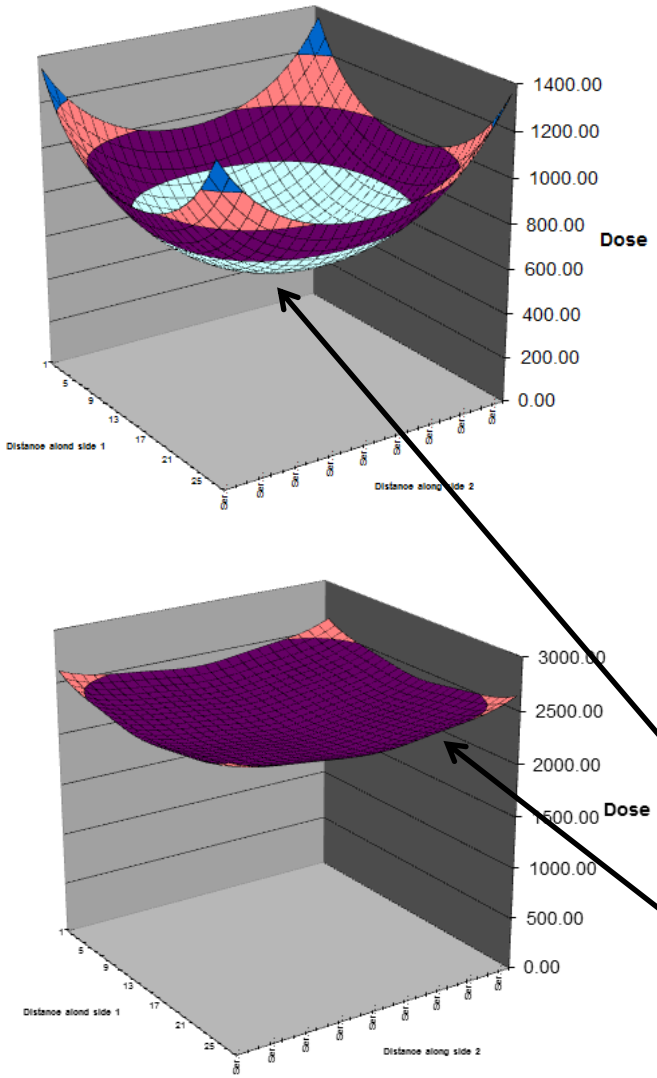
# Innovation: Pallet Intensity Modulation




- Any dose above the minimum required dose reduces the throughput of the system
- Any dose above the green rectangle is “wasted dose”
- The purple triangles are “wasted dose”
- The wasted dose can cause a reduction in throughput of up to 30%
- If there was a way to deliver more dose to the center of the pallet relative to the outside then the throughput efficiency could be improved.
- Treating multiple sides of the pallet and adjusting the radiation intensity can accomplish this

# Innovation: Pallet Intensity Modulation




- 4 sided treatment gives the opportunity to "tune" the dose uniformity for different product densities.
- The dose intensity is modulated (changed) in the scanning direction and in the travel direction.
- With the right intensity modulation function, the 4 sided DUR is much better than 2 sided.
- On the left is a 1m x 1m pallet with homogeneous density 0.3g/cc.
- 2 sided DUR is 2.35 (previous slide)
- 4 sided DUR <u>without</u> intensity modulation is 2.3
- 4 sided DUR with intensity modulation is 1.22
- This represents a 20% increase in overall process efficiency. (reduction of overdose)

# Gracias por su atencion !