

# Agenda

## Plenary session

### Time

8:30-8:50 AM

8:50-9:15 AM

9:15-9:35 AM

9:35-9:55 AM

9:55-10:15 AM

Plenary

### Description

Current and future accelerator applications

Leveraging lab-university-industry partnerships

DOE Accelerator Stewardship Pilot program

Fermilab accelerator facilities & infrastructure

Argonne accelerator facilities & infrastructure

### Speakers

Director Nigel Lockyer, Fermilab

Assistant Director Andria Winters, Illinois DCEO

Stewardship Program Director Eric Colby, DOE

IARC Director Robert Kephart, Fermilab

APS Upgrade Project Director Stuart Henderson, Argonne

## Tours of Fermilab and Argonne accelerator facilities and infrastructure

10:30 AM

Tours

Tour buses, including to Argonne, depart from in front of Wilson Hall

1:00 PM

Tour buses return to Wilson Hall

1:00 PM

**Lunch** (Box lunch provided for registered participants, Wilson Hall, 2nd floor crossover)

1-3:30 PM

"Speed date" (Wilson Hall) Attendees meet with experts from Argonne and Fermilab, learn about available infrastructure and discuss possible partnerships **Coffee at 2 PM**

## Plenary closing session (Wilson Hall, One West conference room)

3:45-4:00 PM

Plenary

Lab partnership mechanisms

Cherri Schmidt, Fermilab Office of Partnerships and Technology Transfer

4:00-4:30 PM

Discussion & industry feedback; next steps

Robert Kephart, Stuart Henderson

4:30 PM

**End of meeting**



U.S. DEPARTMENT OF  
**ENERGY**

Office of  
Science

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# Current and Future Accelerator Applications

Nigel Lockyer  
Fermilab Director  
April 28 2015

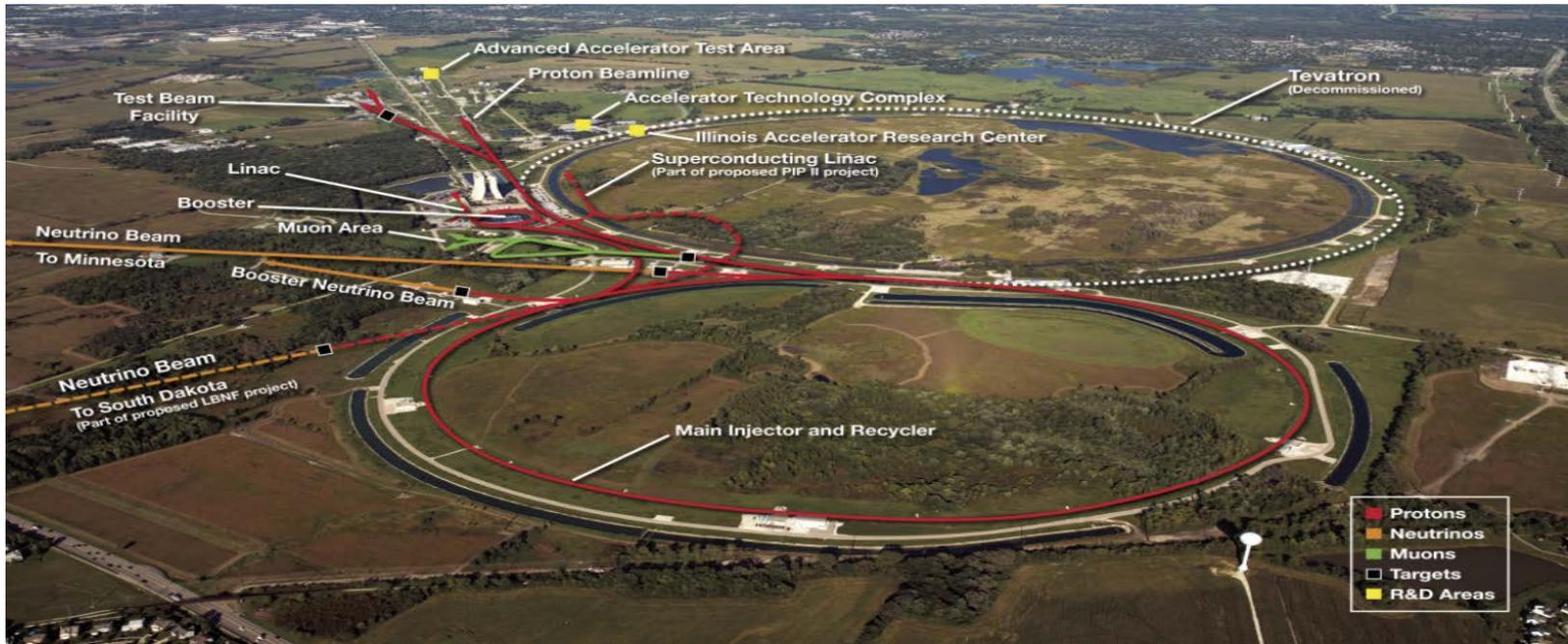
# Welcome to Joint ANL/FNAL Outreach Event:

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## Meeting Goals

- Announce the launch of the DOE Accelerator Stewardship Test Facility Pilot Program to promote Lab-University-Industry partnerships on accelerators and related technology
- Inform you about laboratory technical capabilities
- Understand your biggest technical challenges and whether a lab partnership might be useful to address them
- Discuss possible partnerships (old friends & first dates)
- Part of a larger effort to encourage the National Labs to partner with industry to promote innovation & U.S industrial competitiveness, launch new industries, create jobs, etc.
  - Approach successful elsewhere (e.g. Germany)
  - Recommended by blue ribbon panels and by congress

# Fermi National Accelerator Laboratory



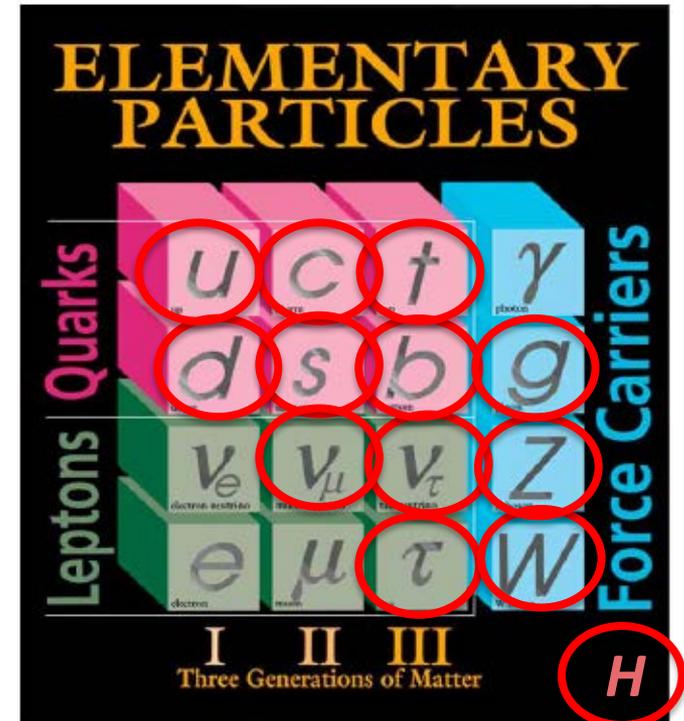
- National Laboratory: Funded by the Department of Energy
- Mission: High Energy Physics Research (Discovery Science)
- To carry out that mission Fermilab designs, builds, & operates: High Energy, High Power (MW), High reliability Accelerators
- 6800 acre site, ~\$380M/yr budget, Staff of 1700, > 2200 users

# At Fermilab we build state-of-the-art accelerators to understand our world via Particle Physics

- Accelerators have enabled the construction of the Standard Model of the visible world (39/141 Nobel Prizes since 1939)

## Rich history of discovery:

- Discovery of antiproton showing matter-antimatter symmetry
- Discovery of J/Psi meson (charm)
- CP symmetry is violated
- Discovery of two types of neutrinos
- Discovery of W, Z bosons responsible for the weak force
- Discovery of 3<sup>rd</sup> generation leptons



FNAL

- Discovery of bottom and top quarks and flavor mixing
- Discover of the Higgs Boson ( origin of Mass)

CMS

Fermilab

# Despite their impact on science, most accelerators that have been built are used for other purposes

- About 30,000 accelerators are in use world wide
  - Sales of accelerators > \$ 2 B /yr and growing
  - Accelerators touch over \$ 500B/yr in products
  - Major Impact on our economy, health, and well being

- Some Products:

Radial Tires



Shrink wrapped food



Aircraft



Digital Electronics

# Accelerators: Essential Tools in Industry

## Ion Implanted into:

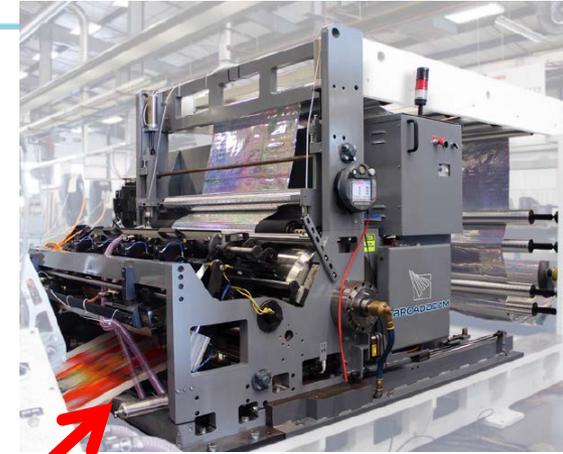
### Metals

- Harden cutting tools
- Reducing friction
- Biomaterials for implants

### Ceramics and Glasses

- Harden surfaces
- Modify optics
- Color in Gem stones!

N2 ions reduce wear and corrosion in this artificial femur



### High Speed solvent free printing

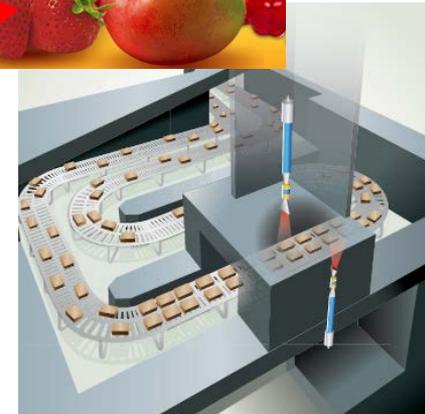
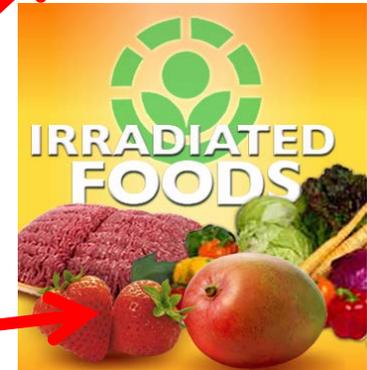
- 12 colors at 600 fps!

### Food Irradiation

- Becoming increasingly accepted

### Medical accelerators

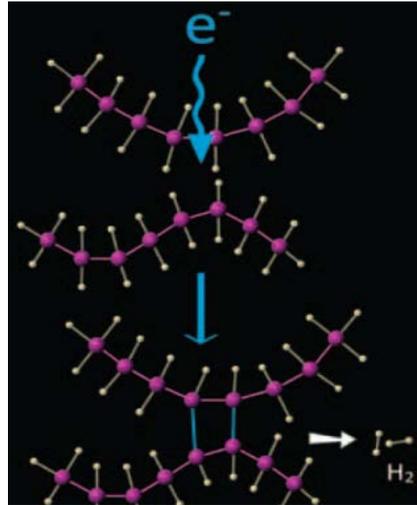
cancer treatment, isotopes



# Accelerators: Essential Tools in Industry

A wide-range of industrial applications makes use of low-energy beams of electrons to drive chemistry

- 0.1-10 MeV up to MW beam power



## Electron Beam Irradiation

Improved heat resistance of coatings, wire and cable, crosslinking polymers, radial tires, etc)  
1500 dedicated facilities worldwide



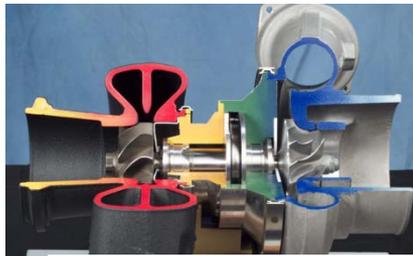
# Accelerators for Industrial Processes

## Electron Beam Welding and Machining

- Deep welds, low weld shrinkage
- Dissimilar or refractory metals, etc
- Widely used in automotive and aerospace industry
- Drill 3000 holes/sec!



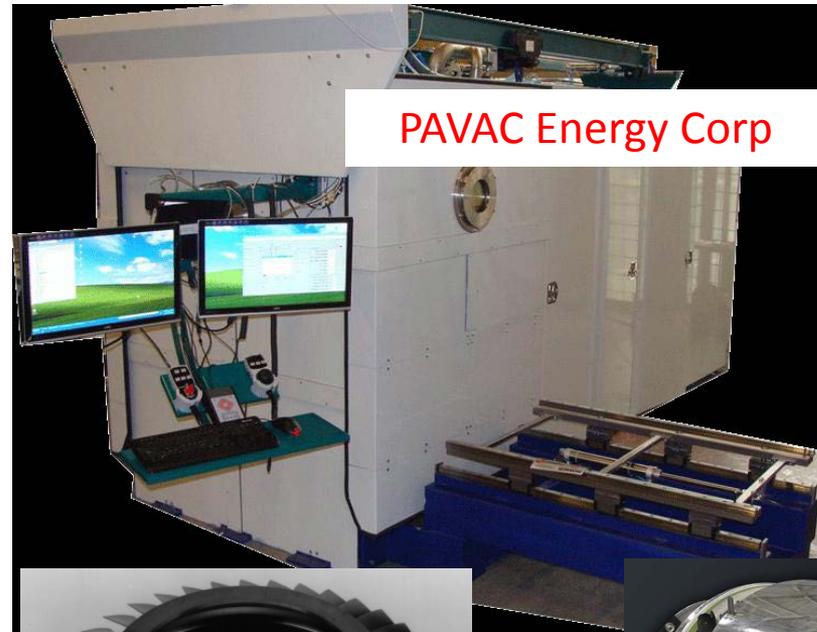
Fuel injectors



Turbo chargers



Weld gear boxes  
Harden gears



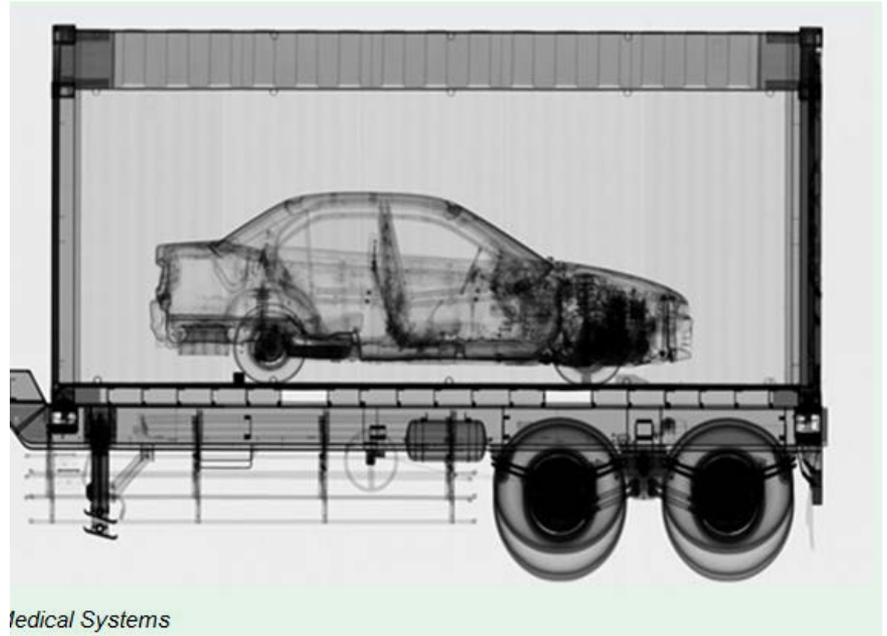
PAVAC Energy Corp



Jet engines &  
Gas turbines



# Accelerators for National Security



- More than two billion tons of cargo pass through U.S. ports and waterways annually.
- Accelerators are used for cargo scanning and “active interrogation” to detect special materials

# Accelerators in Medicine

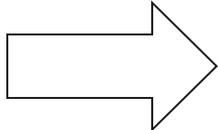
## Proton Cancer Therapy



Loma Linda Proton Therapy and Treatment Center

World's 1<sup>st</sup> proton accelerator built specifically for proton therapy

Designed and built at Fermilab

Technology Demonstration  Industry



New compact SC magnets (another HEP technology!)  smaller size/ costs



# Despite widespread use, many additional **Future Accelerator Applications** are envisioned... some examples:

Sector	Opportunities
<b>Energy and Environment</b>	<ul style="list-style-type: none"><li>• Flue gas treatment</li><li>• Gas to liquids conversion and flare gas recovery</li><li>• Upgrade of heavy oils</li><li>• Down hole evaluation of rock strata,</li><li>• Superconducting wind generators</li><li>• Accelerator driven power plants, Nuclear waste destruction</li><li>• Waste Water and sludge treatment</li></ul>
<b>Industrial</b>	<ul style="list-style-type: none"><li>• Next generation semiconductor fabrication</li><li>• Food preservation and safety</li><li>• Improved welding and fabrication (3D metal printing)</li><li>• Improved Highway construction</li><li>• Materials transformation/processing</li><li>• Industrial isotopes as wear indicators, etc</li></ul>
<b>Medical</b>	<ul style="list-style-type: none"><li>• Accelerator-driven medical isotope production</li><li>• Particle beam cancer therapy</li></ul>
<b>Safeguards and Security</b>	<ul style="list-style-type: none"><li>• Non-invasive and stand-off inspection</li></ul>

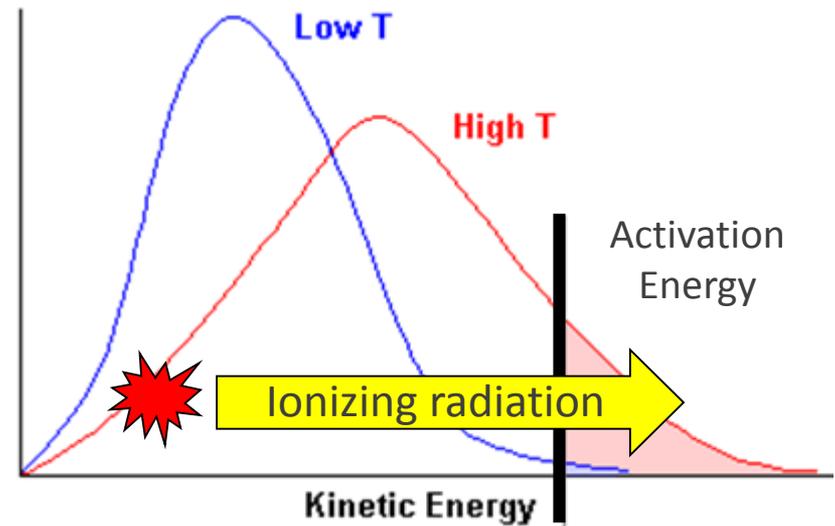
- Also accelerators can catalyze difficult chemical reactions saving energy/time
- Some new applications are expected to create entire new (large!) industries
- Detailed descriptions are part of a much longer talk! A few examples:

# Accelerator Driven Chemistry

Radiation energy is different from Thermal energy !

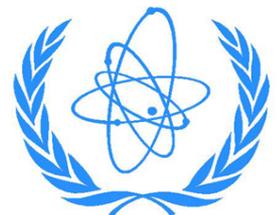
**Thermal energy** is very strongly coupled to **Translational, Rotational and Vibrational modes** of the energy absorber. Ionization, bond rupture and other processes leading to chemical reactions occur only in the high energy region of the Maxwellian tail.

**Ionizing radiation** is almost entirely absorbed by the electronic structure of absorber, which increases the energy level of its orbital electrons.



Energy in the form of large quanta have more pronounced chemical effects than energy in the form of small quanta (ie processes can occur at lower temperatures → more efficient!)

**Effective & efficient generator of reactive species**



# Accelerators for the Environment: Water

- Electron accelerators are effective for
  - Destroying pesticides, organics, pharmaceuticals, etc in water
  - Sterilize industrial/municipal water/sludge
  - Allows water reuse, valuable as fertilizer



SRF is Compact!  
400 KW = 10 MeV, 40 mA  
 $Q_0 = 2 \times 10^{10}$  @4K ?

- Beyond energy... availability of clean water is the next looming world crisis
- Technology demonstrations but not deployed... **Why?**
  - Municipalities = conservative users, not able to finance R&D
  - Reliable, compact, efficient, high power (MW class), cost effective accelerators provided as a turn-key service are needed.
  - Opportunity for the right industrial partners **SRF?**

# Accelerators for the Environment: Flare Gas

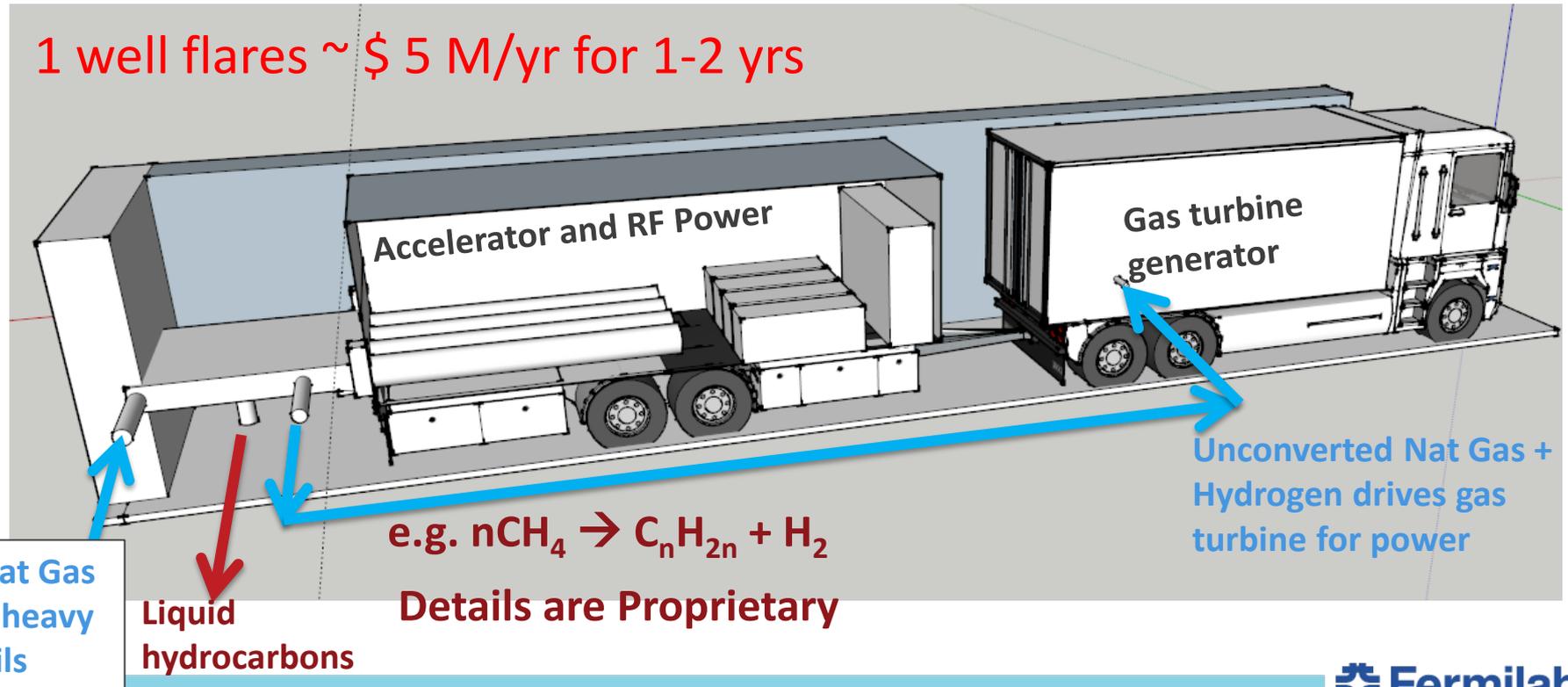
- Many wells produce both oil and natural gas, but not all gas is recoverable
  - Remote, so pipelines are not economical
  - Produce a burst of gas for only a few years
  - Methane is a powerful green house gas... so most companies “Flare” stranded gas at the well
- World wide \$ 30 B/yr of gas is flared
  - Equal to 25% of the natural gas usage of U.S.
  - **Adds CO<sub>2</sub> with no useful work for mankind**
- “Fischer-Tropsch” can convert gas to liquid hydrocarbons but requires large plants for high temperature/pressure reactions
- Mobile accelerators could in principle break C-H bonds to efficiently convert stranded gas to liquid hydrocarbons at the well head, could also lower viscosity of heavy oils



# Accelerators for the Environment: Flare Gas

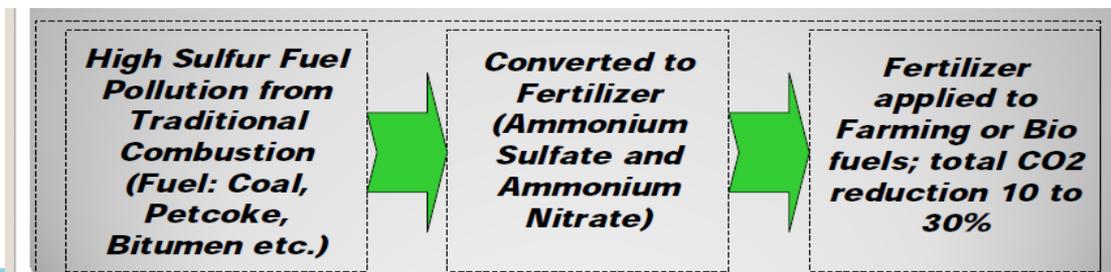
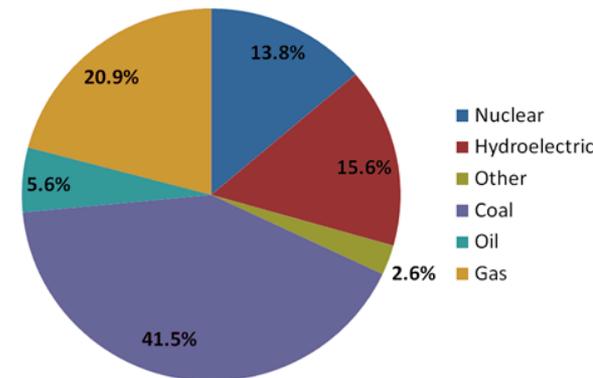
- Trailer mounted high power electron accelerators
- Natural gas turbines provide the local electrical power
- Liquid hydrocarbons created can be mixed and collected with crude oil produced by the well

1 well flares ~\$ 5 M/yr for 1-2 yrs



# Accelerators for the Environment: Coal

- 41% of all electrical power worldwide is generated by burning coal
- China and India are ramping up use
- US EPA regulations will reduce coal but it will remain an important energy source
- NO<sub>x</sub> & SO<sub>x</sub> emissions remain an issue, current technology uses lots of water!
- Accelerators can treat flue gas turning NO<sub>x</sub> and SO<sub>x</sub> into fertilizer (little water)
- 1<sup>st</sup> step towards sequestration of CO<sub>2</sub>

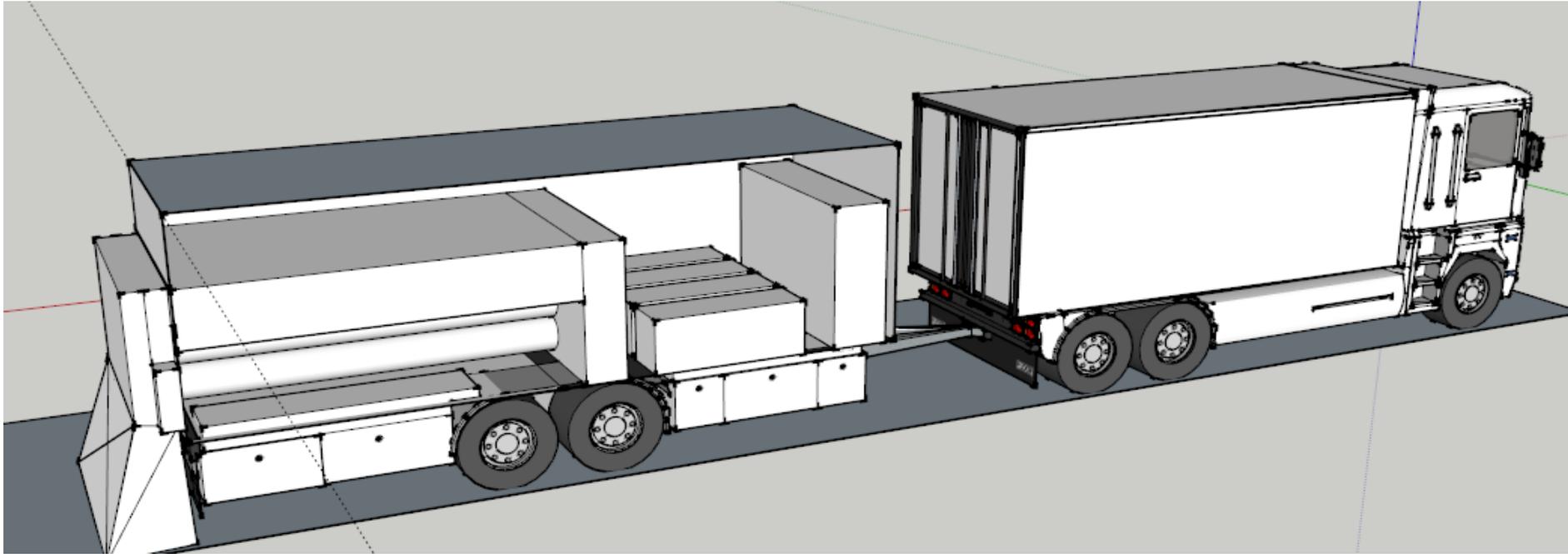


# Accelerators for the Environment: Highway Life Extension

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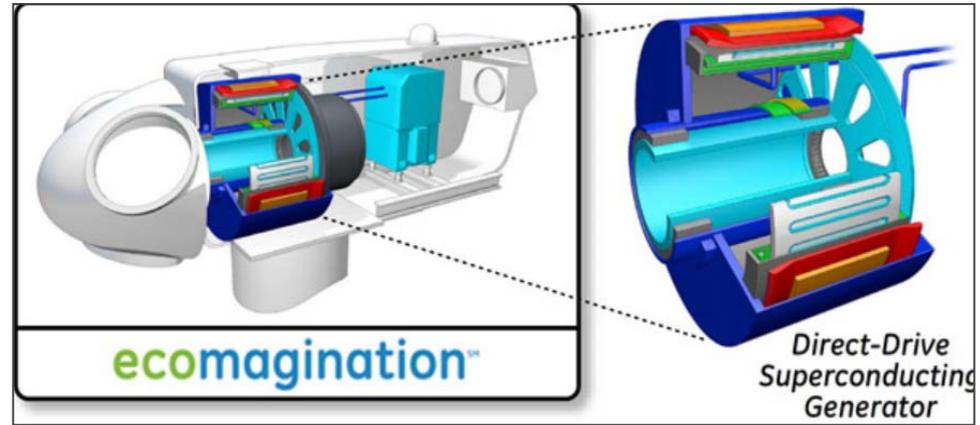
- 2.3 million miles of paved roads in the U.S.
  - 94% are constructed from asphalt, technique little changed in 100 yrs
  - Average road must undergo major repair, crack and pothole repairs every 1-3 yrs and must be completely rebuilt every 5-8 yrs depending on the climate
  - The U.S. places 550 million tons of hot mix asphalt each year at a cost of \$ 25 B/year to taxpayers
  - The heavy machinery used to rebuild asphalt highway creates a huge carbon foot print.
- Even a 1 yr extension of life of a road would save enormous amounts of diesel fuel and taxpayer dollars each year
- Solution: **Crosslink binder (bitumen+?) in situ with mobile accelerator**
  - increase strength and toughness.

# Mobile EB to extend lifetime of highways



- 4 accelerators: 1400 KW → 2 lane-miles per 8 hr shift
- Cost of 1 lane-mile interstate highway = \$ 2.4 - 6.9 M
- **Huge value added** ~ \$ 500 K- \$1.4 M per shift (1 yr extension)
- FNAL filed for IP protection, process development in progress
- Seek industrial partners, can test using roads on FNAL site

# Accelerator Technology Applied to Wind Turbines



- Generators and motors based on high temperature superconductors like  $MgB_2$  have great promise
  - Allow operation at higher temperatures simplifying designs
  - Cryogen free (e.g. closed pulse-tube coolers) Self starting
  - Conductor, coil designs, insulation and curing technology, etc developed for High Energy Physics can be directly applied
- Higher power densities and they require NO gearbox.
- Can allow wind turbines in the 10-25 MW range (vs 3-4 now)

# So what's the obstacle?

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**Risk & the high cost of entry! (esp. experts, infrastructure)**

**Hence IARC (a joint DOE-State of Illinois Center)**

- To enable Fermilab to work more closely with industry and university partners to develop new accelerator technology; demonstrate new applications, & support accel. education
- To develop new accelerator technology based products and high tech industries in the U.S. ( and especially in Illinois)
- IARC intended to be a portal for industry into the larger core capabilities and infrastructure at the lab

Vision is well aligned with the goals of DOE Accelerator Stewardship Test Facility Pilot Program... more from Eric

# Illinois Accelerator Research Center (IARC)

## Mission

Partner with industry to exploit technology developed in the pursuit of science to create the next generation of industrial accelerators, products, and new applications.



Joint DOE- Illinois DCEO Project



## Vision

IARC will be the preeminent national enabler of accelerator based products and services serving as the seed for industry growth.

# Summary

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- Fermilab is actively engaged in accelerator R&D in support of its basic High Energy Physics(HEP) science mission
- Technology we develop has applications beyond HEP
- Opportunities for lab-industry-university partnerships with transformative impacts: manufacturing, energy,& environment
- Opportunities to create new products and new industries
- DOE Accelerator Stewardship Test Facility Pilot Program will provide one source of funds for such partnerships
- Other funding sources also exist (SBIR, NSF, etc) to promote such partnerships
- ANL & FNAL look forward to showing you our capabilities and discussing possible future partnerships