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Title: ATO 1 - Health Physics Day

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ATO 1 – Health Physics Day

Agenda

Morning

- Introductions
- Detectors
  - Ion Chambers
  - α/β
  - GM
  - Neutron ^{3}He
  - Remball
  - Tritium Monitor
  - Solid State
- Units/Math
  - dose/dose rate
  - Stay times
  - efficiency (dpm/cpm)
- Criticality Concerns
- Betatron Operations

Afternoon

- Survey Techniques
- Contamination Control
  - What/how to don
  - Working in CA
  - What/how to Doff
- Decontamination
  - Areas that accumulate
  - Dry vs Wet
  - Disposal
- WP and CCS Setup
- Scenario
- Recap/Questions

Introductions

Detectors

Designs/Physics/Flaws

Operator Detector Theory

- All detectors are designed to do one thing…
  - Answer a question
  - Make sure that your detector can answer the question you are asking it
- Think of detectors in three components
  - Active Volume
    - The part that you want the radiation to interact with
    - Some materials are better than others ~ charge carriers
      - Example: 33 eV NaI(Tl) vs 3 eV HPGe
  - Electronics
    - Shape/Amplify/Bin/Digitize signal from the active volume
  - Output system
    - Apply meaning ~ units, analysis, warnings/alarms
    - Some type of display, noise or data file

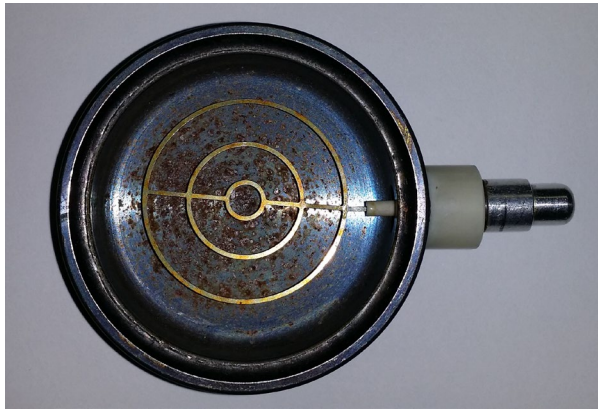
Ion Chambers

- Physical design of this type of detector
  - Volume of gas
  - Unpressurized or pressurized
  - Some have Beta window
  - Measures electrical charge
- Some capable of α/β discrimination
- Designed for area dose rate assessment
- Issues
  - Slow to respond
  - Beta window, should you use it?
  - Ideal Gas Law $PV = nK_bT$
  - Will produce erroneous readings with RF interference or high humidity

α/β Probes

- Physical design of this type of detector
  - Thin mylar
  - Sandwiched scintillators
  - Sweet spot
  - PMT
- Some capable of α/β discrimination
- Designed for contamination surveys
- Issues
  - Thin Mylar
  - Crosstalk between the α and β layers
  - Will produce erroneous readings in high gamma-ray environments
  - Calibrated in concert with a base station

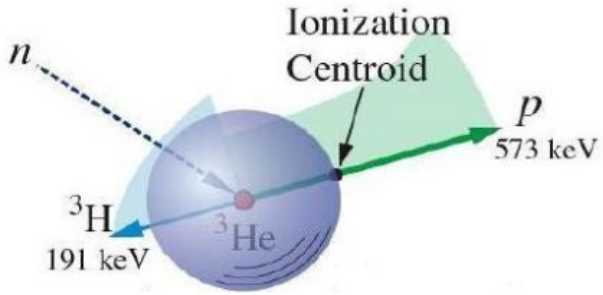
Geiger-Mueller



- Physical design of this type of detector
  - Thin mica window
  - P10 fill-gas
  - Circular anode
  - Metal housing and screen
- Possible to discriminate α/β from γ
- Designed for contamination surveys
- Issues
  - Will produce erroneous readings in high gamma-ray environments

^{3}He Neutron tubes

- Physical design of this type of detector
  - Tube of 3He gas: $^3He + n^0 \rightarrow {}^1H + {}^3H$
  - Tube detects the ^{1}H ion
  - Good for thermal neutrons
  - Provides gross count rate
- Only responds to neutrons
- Easily packaged along side other rad. detectors
- Issues
  - Often poor efficiency due to small tube volume
  - Doesn't tell you anything other than there are thermalized neutrons in the area



Remball

- Physical design of this type of detector
  - Tube of ^{3}He gas: $^{3}He + n^{0} \rightarrow {}^{1}H + {}^{3}H$
  - Tube detects the ^{1}H ion
  - Moderator surrounds tube
- Only responds to neutrons
- Designed to characterize neutron dose rate
- Issues
  - Often poor efficiency due to small tube volume
  - Moderator is a fixed amount and may not be appropriate for the neutron field present (under/over moderation)
  - System is heavy/cumbersome

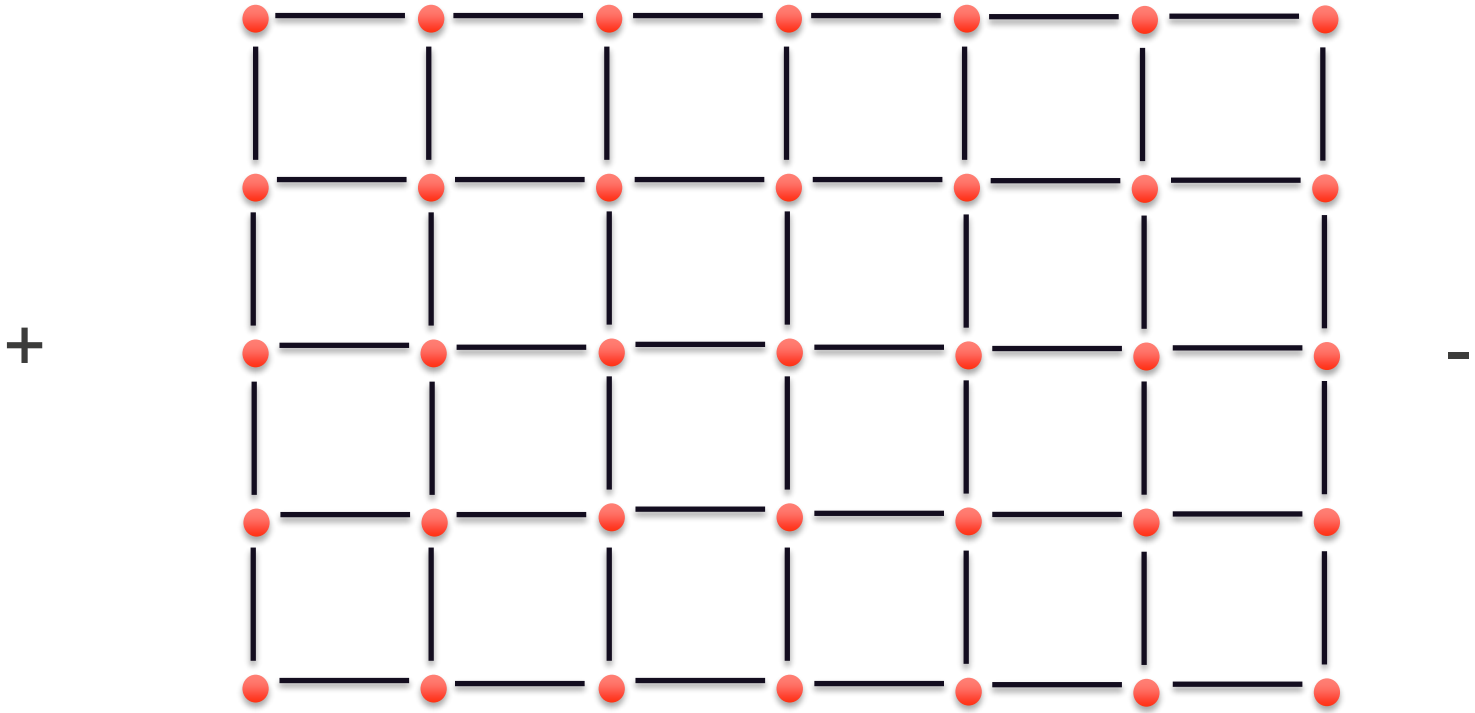
Tritium Detector

- Physical design of this type of detector
  - Vacuum draw atmosphere into an ion chamber
  - Ion chamber reads build-up of charge
- Designed to characterize tritium in μCi/m^3
- Tritium itself is not a significant health risk, but its presence is an indication of the physical/chemical state of the object
- Issues
  - Nearby radiation will cause false readings
  - Slow

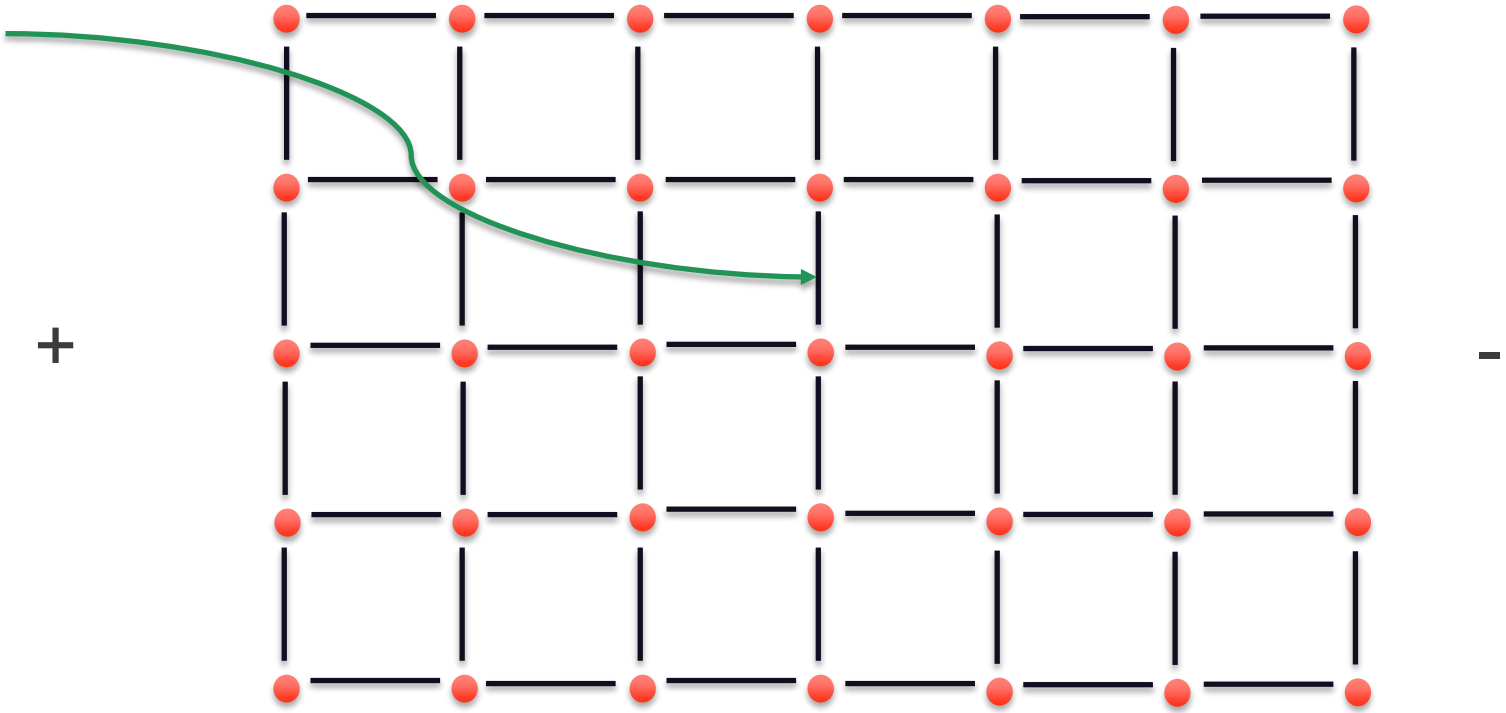
Solid State Detectors

- Physical design of this type of detector
  - Uniform repeating chemical structure (think crystals)
  - Semiconductor best choice
  - Radiation produces electron/hole pairs in structure
  - Bias HV across volume sweeps electrons and holes in opposite directions
  - Electrons and holes measured as current
  - Current is proportional to input radiation energy
- Designed to identify/characterize radioactive material
- Issues
  - Time required to acquire/analyze data
  - Bulky, noisy and thermally unstable
  - May require cooling systems (electric or LN_2)

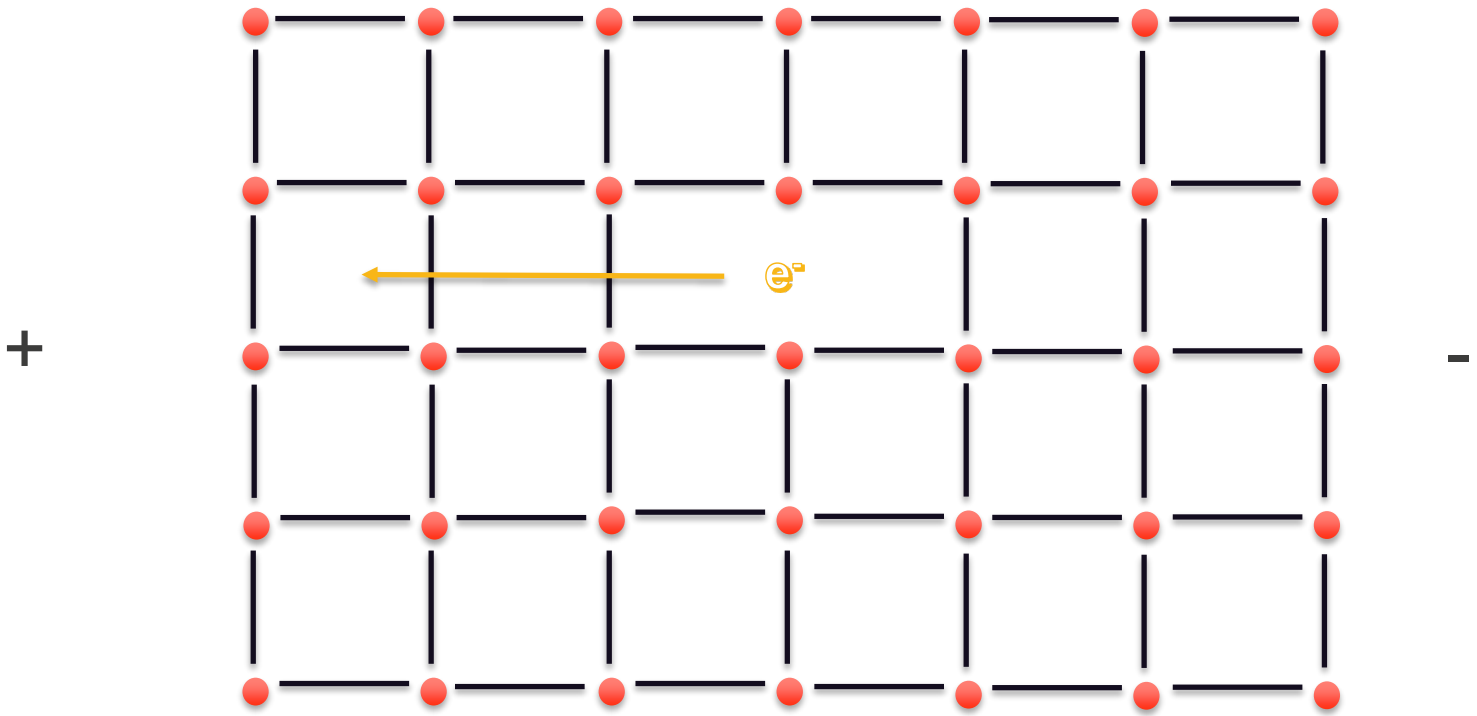
Solid State Detectors



Solid State Detectors



Solid State Detectors



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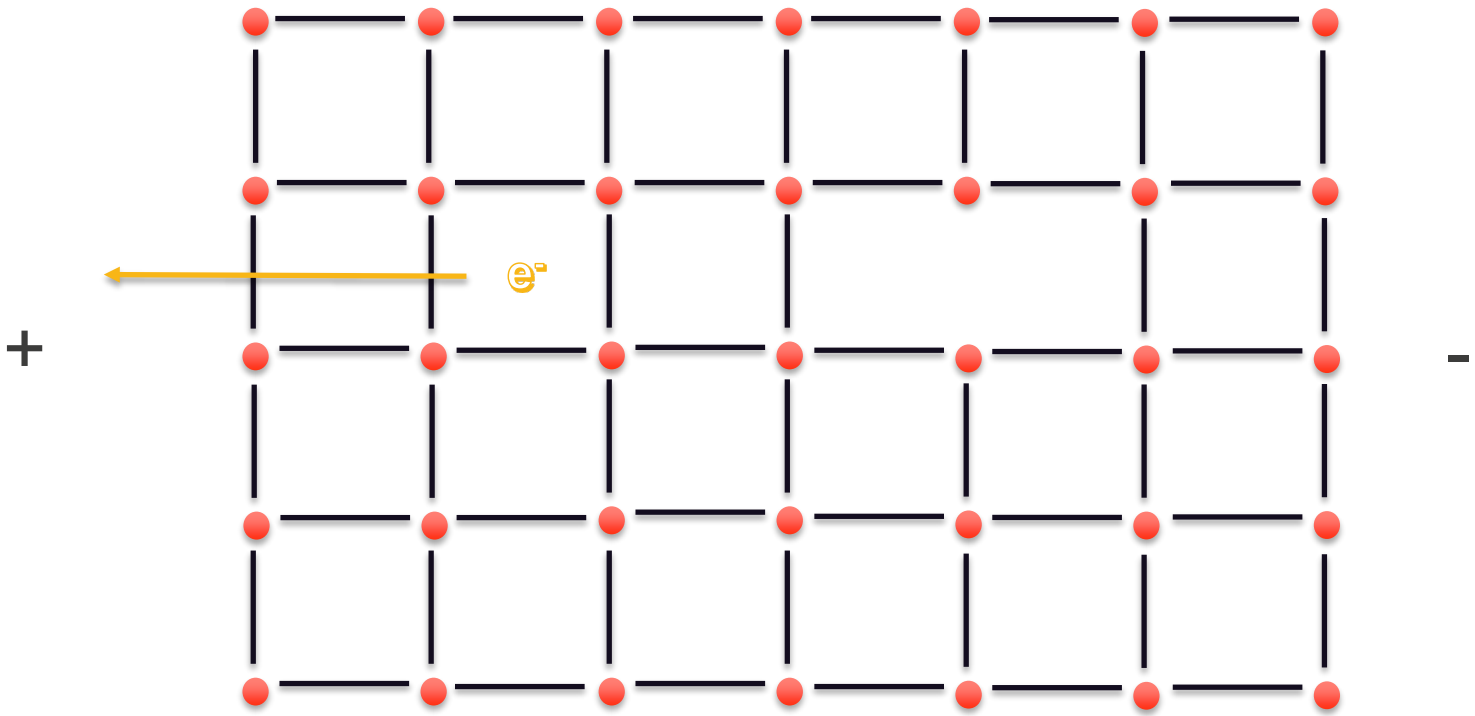
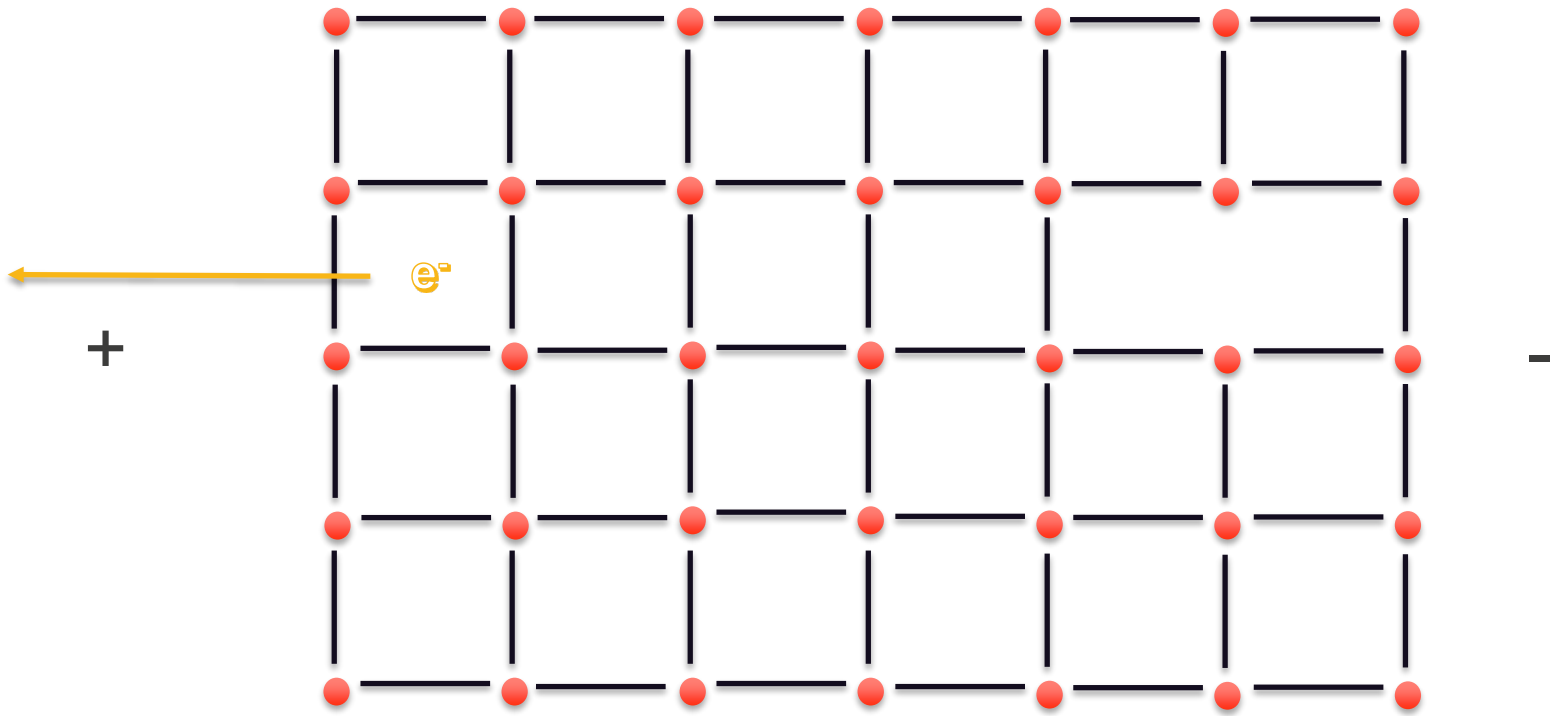
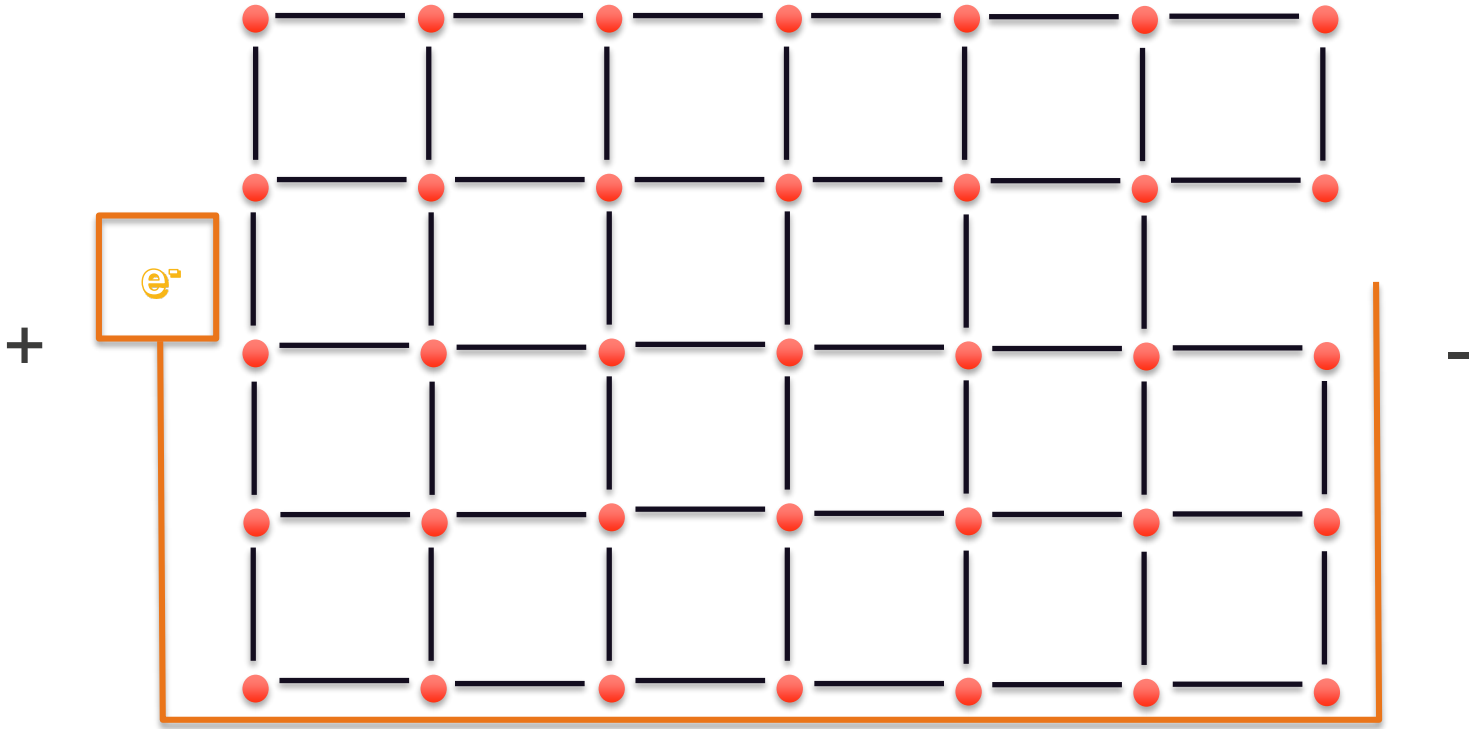


Solid State Detectors

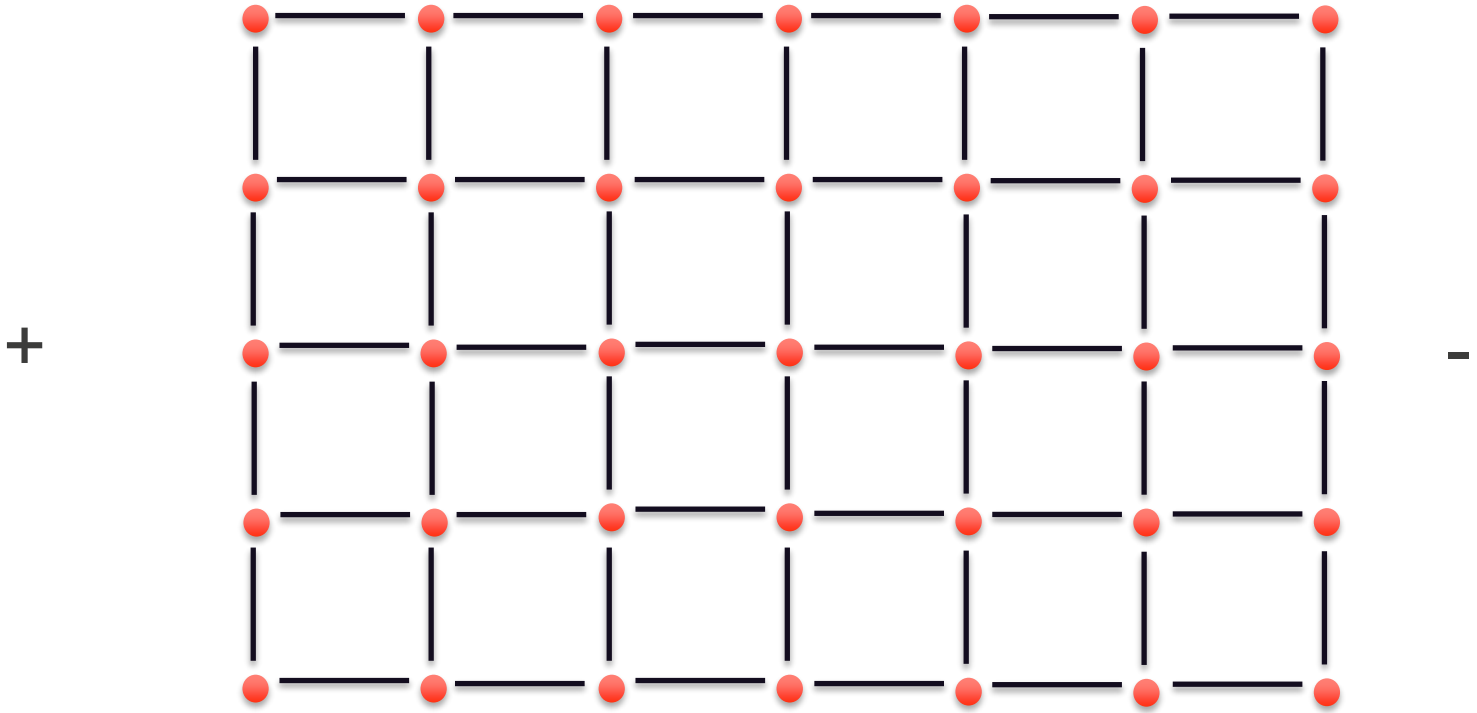


Solid State Detectors



Amp/Shape/Digitize – Analysis/Result

Solid State Detectors



Units

Dose Rate, Dose and Stay Times

- Scientific Notation: keV vs MeV or mR/hr vs μR/min
- What is the difference between R, rad, Gy, rem and Sv
- Lets calculate stay times:
  - JP 3-11 allows for up to 75 rem during non-wartime operations (one time exposure). The working point reads 100 mR/hr gamma and no neutrons or contamination. How many days can you operate in this environment?
    - Gamma only: 1 R ~ 1 rem, 100 mR/hr = 0.1 R/hr = 0.1 rad/hr
    - 24 hours you absorb 2.4 rad, 75/2.4 = 31.25 days
  - Now the working point reads 350 mR/hr gamma and 250 mrem/hr neutron. How many days can you operate in this environment?
    - Gamma component: 1 R ~ 1 rem, 350 mrem/hr = 0.35 rem/hr
    - Sum gamma and neutron: 0.35 + .25 = 0.6 rem/hr
    - 24 hours you absorb 14.4 rem, 75/14.4 = 5.2 days

Detector Efficiency

- Counts Per Minute (CPM) – What the detector was able to record
- Disintegrations Per Minute (DPM) – Quantity of radiation that was emitted
- The difference between CPM and DPM is efficiency, how good the detector was at taking a measurement…
  - Intrinsic efficiency ~ The radiation the detector was able to process vs the radiation that made it to the detector, “inherent to the detector”
  - Geometric efficiency ~ The amount of radiation that made it to the detector vs the amount of radiation emitted in total
  - Absolute efficiency ~ cpm/dpm, this number captures everything
- Now lets calculate how efficient the probes actually are!

Criticality Concerns

Criticality

- It is difficult to determine how close a physics package is to a critical configuration
- There is no warning that your actions on the object are bringing it closer to critical or into a critical configuration
- MC15 data will give the best estimate of neutron behaviors
- Two simple rules to follow to keep everyone safe
  - Place the object at the center of a tarp that is 20’x20’, if you only have 10’ tarps, put some tape at double the distance from the center. No one has died from a criticality event that was at least 3 meters (10ft) away from the criticality configuration
  - Place potentially near critical objects at least as far apart as the longest measurement off the largest object

Betatron Operations

Getting it wrong

- The radiation produced by a betatron are high energy x-rays
- A focused beam may cause serious local injury to tissue
- A scattered beam will provide dose to the whole body
- Severity of injury is dependent upon total dose and how quickly that dose was delivered

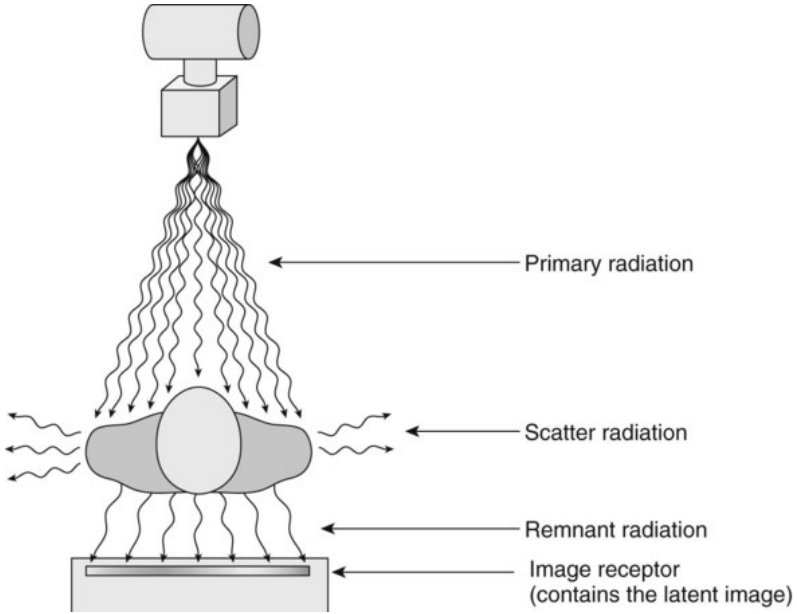
Dose estimates:

- Whole Body: 1.21 Rem
- Left 3rd Digit: 5835 rad

- Left 3rd digit was amputated

Understand the hazards

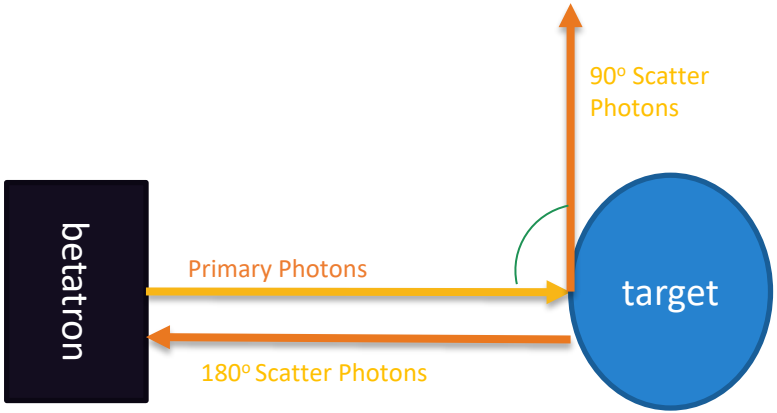
- X-rays are emitted in a 22° solid angle from the betatron head
- Any object within that solid angle will receive radiation dose and will also scatter the x-rays
- Scattered x-rays will produce additional areas of external radiation hazard
- Possible to generate a radiation hazard when not intended (dark currents)



Understand the hazards

$$Energy_s = \frac{Energy_p}{\left(1+\frac{Energy_p}{m_e c^2}(1-\cos\theta)\right)}$$

- $Energy_p$ = Energy of primary photon
- $Energy_s$ = Energy of scattered photon
- θ = Scatter angle
- m_e= mass of electron in AMU
- C^2 = 931.5 MeV/AMU

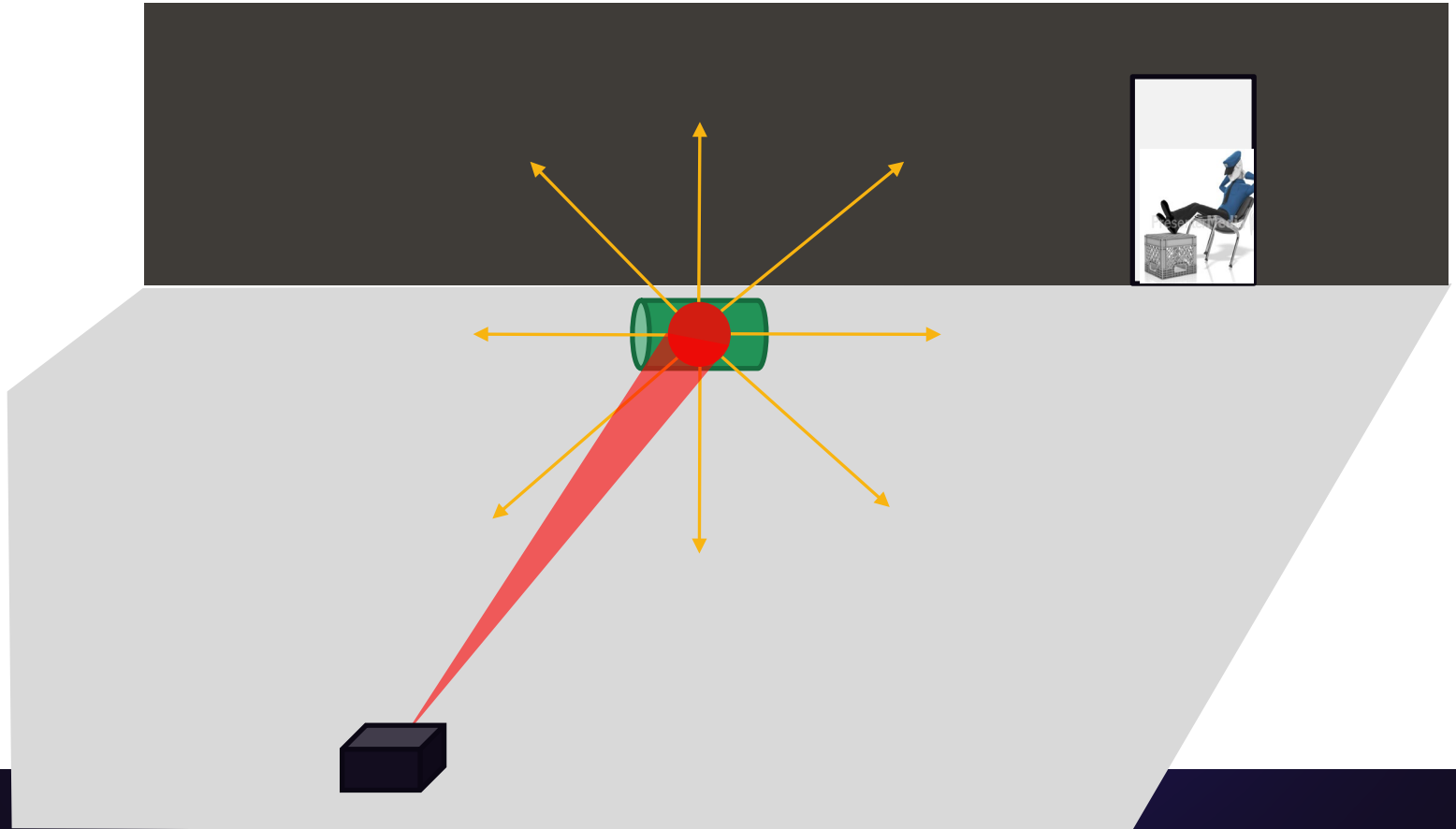


- $Energy_p$ = 7 MeV
- $Energy_s$ = ?
- θ = 90° and 180°
- m_e= 5.4858E-4 AMU
- C^2 = 931.5 MeV/AMU

$$Energy_s = \frac{7\ MeV}{\left(1+\frac{7\ MeV}{(5.4858E{-}4\ AMU)(931.5\,{}^{MeV}/_{AMU})}(1-\cos 90)\right)} = 0.477\ \text{MeV}$$

$$Energy_s = \frac{7\ MeV}{\left(1+\frac{7\ MeV}{(5.4858E{-}4\ AMU)(931.5\,{}^{MeV}/_{AMU})}(1-\cos 180)\right)} = 0.247\ \text{MeV}$$

Understand the hazards



Control the risks

- High energy photons are difficult to protect against
- Time, Distance and Shielding are your best tools
- This is a 3-dimensional problem: you must consider what is above/below/behind the object
- If practical, before each shot, physically clear the area of unnecessary personnel
- While shooting, maintain visual on as much of the area as possible and be prepared to terminate the shot if need be
- If possible, post radiation warning signs around your area

Control the risks

- Your radiation detectors and dosimetry must be certified to read photons of energy up to 7 MeV
- Most commercially available detectors and electronic personal dosimeters are only rated to 1.33 MeV
- The general public is allowed a maximum exposure of: "*2 mR in any one hour*"
- Ion Chambers should be used to measure the dose rates at:
  - Publically accessible areas near your working point
  - The control console
  - Areas that you cannot visually/physically clear prior to each shot

Best practices

- Betatron is serviced and performance checked annually
- Personnel wear TLD and a form of direct read dosimetry (EPD, PIC, etc.) capable of recording high energy photons (at least 7 MeV)
- Dedicated radiography direct read dosimetry and detectors are purchased/maintained
- Only energize the betatron when you are ready to shoot and the area around the object is clear

Best practices

- Designate a safety for betatron operations, this person holds the operations key at all times except when shooting
- The safety is responsible for:
  - Radiation Area postings if applicable
  - Area around the object is clear before each shot
  - All personnel are accounted for and are wearing appropriate dosimetry
  - Maintaining visual of area around object during shots
  - Verifies the betatron is not operating prior to allowing others to go down to object

Lunch Time

Survey Techniques

Survey techniques

Some basic concepts:

- Alpha particles travel ~1” in air
  - When the surface is smooth
  - When the surface is dry
    - Moisture doesn’t stop them all
    - But if you have some, you at least know that
- Betas travel meters in air
  - Depends on energy
- Instruments have a response time
  - 1-2” per second scan speed
  - Stop when instrument begins to respond

Doing the survey

- Use the instrument's audio
  - More sensitive than meter movement
- Probe
  - Wrap gloved fingers around probe
  - Lightly touch surface with fingers
  - Consistent distance
  - Can look elsewhere
  - Check fingers when contamination is being detected
- Find hottest area(s)
- Quantify extent (contaminated area)
- Develop mental "topographic" map
- Document the survey

Problems

- Light leak?
  - 2μm (8E-5 - .00008 in) thick aluminized mylar
- Flip probe over
  - If reading goes down – contamination
  - If reading stays the same – neutrons or high gamma
  - If reading goes up – light leak
  - Bright sunlight can penetrate the mylar
- Mask areas of the probe to isolate the light leak
- Black fingernail polish on leak
  - Be mindful of how much you cover – efficiency can be affected
- Cables/Connectors

Contamination Control

When/how to don PPE

- Follow unit SOP:
  - Inner Tyvek, booties, gloves taped
  - Outer Tyvek, boots and multiple layers of gloves not taped
  - >10k CPM α – consider resuspension controls
  - >100k CPM α – HFR/PAPR
  - >600k CPM α – SCBA recommended
- Check for tears/damage prior to starting work
- Help each other into PPE
- Ultimate responsibility for correctly worn PPE falls on the user
- If you don’t wear it properly, it won’t protect you effectively
- When in doubt use common sense

Working in contamination

Prevent the spread, prevent the spread, prevent the spread

- Try to know what's where
- You can tape or cover contamination to minimize spread
- If you can, place absorbents, etc., in work area and change out or cover with fresh ones
- Segregate tools as used
- Always have another set of gloves on
- You can decon high levels in the area
- Remember what you've touched
- Mark high areas
- Keep your hands together when not busy, unless one is contaminated and one is not

Resuspension

- Resuspension is the re-entrainment of settled airborne contamination in an air mass.
- Shuffling feet, stomping, etc., can cause resuspension
- Rule of thumb is E-6 for a resuspension factor
  - E.g. 1,000,000 DPM/1 m^2 => 1 DPM/m^3
  - Active movement can increase 100x
  - Dryness, surface type (dirt, grass, asphalt) affects amount of resuspension
  - Chemistry of contaminant can affect bonding
  - Water may drive contaminates into cracks and crevasses
- Must take reasonable precautions until air sample results are known

Decontamination

- For people:
  - Dry wipe or low-tack tape
  - Areas that enhance sweat will also accumulate contamination, particularly at the skin/respirator contact zone on the jaw/chin
  - If dry wipes are not effective, try wet wipes (moist toweletts, baby wipes, etc.)
  - If wet wipes are not effective, wash with lukewarm water (cold closes pores over contamination, hot opens pores), gentle scrub and mild soap
  - Do not proceed past skin irritation – can provide transdermal path
- For things:
  - Dry wipe with cloth/paper towels
  - Expose fresh sections of wiper after every wipe
  - If you have time and people, one person wipes, one person checks wipe with frisker
  - Use cleaner (409, simple green, etc. – no hazardous solvents) and wipe
- ***Clean from clean areas to dirty areas***
- ***Control liquid runoff***

When taking down the CP

- Survey and decon chairs as applicable
- Bag and seal trash and contaminated PPE.
  - Do not aggressively collapse bags – you can spread contamination, and first of all, on you. Collapse bag so if punctured they wont leak contamination
  - Twist top of the bag tight
  - Tape near bolus of trash
  - Fold neck over and tape again tape over the end with exposed bag interior
- Survey bag exteriors – overpack as applicable if contaminated, tape as above
- Remove everything to clean side
- Survey hot line
- Cut tarp at hot line, move to clean side of tarp
- Carefully fold hot tarp into progressively smaller squares, contaminated side in.
- Bag the tarp, stay there. Seal the bag.
- Survey selves, doff PPE, may need one more bag for your PPE, survey clean tarp

WP and CCS Setup

Scenario

Recap / Questions

Recap

- Use the DOE HP and DOE kit to support your operations
- Rad work: slow is smooth, smooth is efficient and efficient is fast
- Trust, but verify your detectors (functions check, calibration, etc.)
- Double check units and make sure the detector is answering the question you're asking
- Only let essential personnel on the tarp, the fewer people on the tarp, the fewer die if it goes critical
- Keep suspect critical objects as far apart as reasonable, but at least as far apart as the longest side of the largest object
- Assign a safety that controls the keys to the betatron at all times
- Time, Distance and Shielding
- Think in 3D and visually verify areas are clear

Recap

- Don PPE according to TTP, checking for damage
- Wear multiple gloves and peel as needed
- Clean guy / Dirty guy or Clean hand / Dirty hand
- Periodically check yourself for contamination
- When contamination levels go up, resuspension goes up
- Dry decon is preferred and scale up as needed
- Discuss CCS/WP tear down requirements during down time