Low Dose Rate and Pulsed Dose Rate Afterloaders UT MDACC Perspective

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Conflicts of Interest

- Nucletron sponsored research agreement supports a portion of this research
- Transpire sponsored research agreement supports a portion of this research

Course Objectives

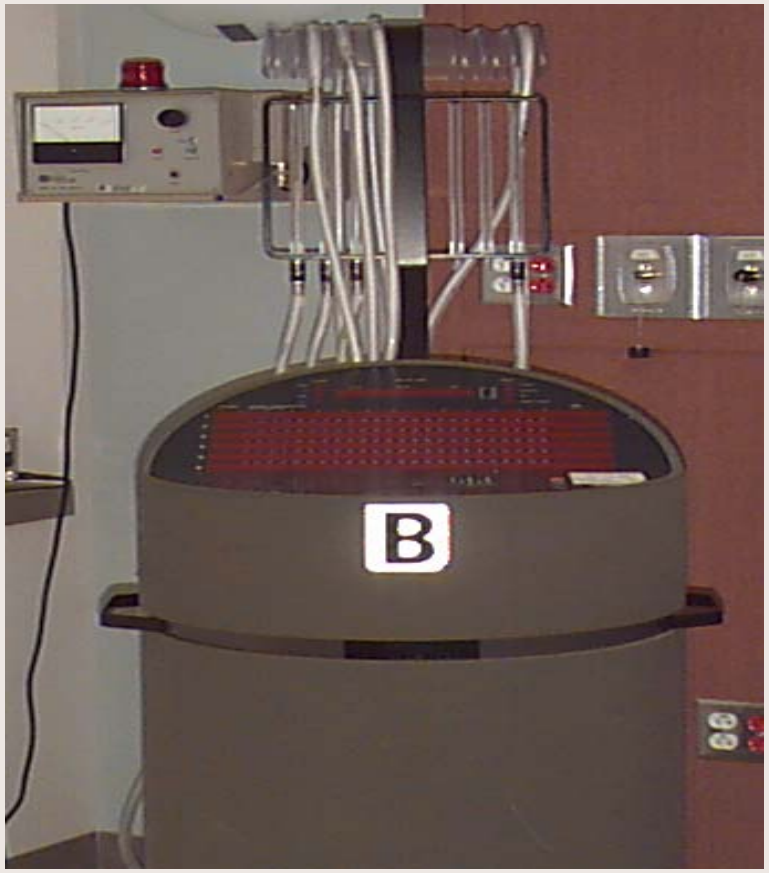
- After this lecture, the participant should be able to discuss
  - LDR and PDR remote afterloading units
  - Issues to address when changing to a new radioisotopes, e.g., ^{137}Cs to ^{192}Ir, to treat a disease
  - Issues to address when changing afterloading techniques, e.g., manual to LDR or LDR to PDR

LDR Afterloaders

- UTMDACC – 4 Selectron LDR ^{137}Cs afterloaders for gynecological cases
- Average 3 cases per week
- Principal replacement for ^{226}Ra
- Manually afterloaded ^{137}Cs sources for small number of cases

Selectron LDR Afterloader

- 4 channels
  - 1 for tandem
  - 1 for each ovoid
  - 1 spare
- 48 pellets, 2.5 mm dia.
- 20 active
  - 5mgRaeq (36.135 U) nominal
  - ^{137}Cs on surface of 1.5mm ceramic (borosilicate) bead, 0.5mm SS encapsulation
- 28 inactive pellets
  - Ferromagnetic, 304 stainless steel



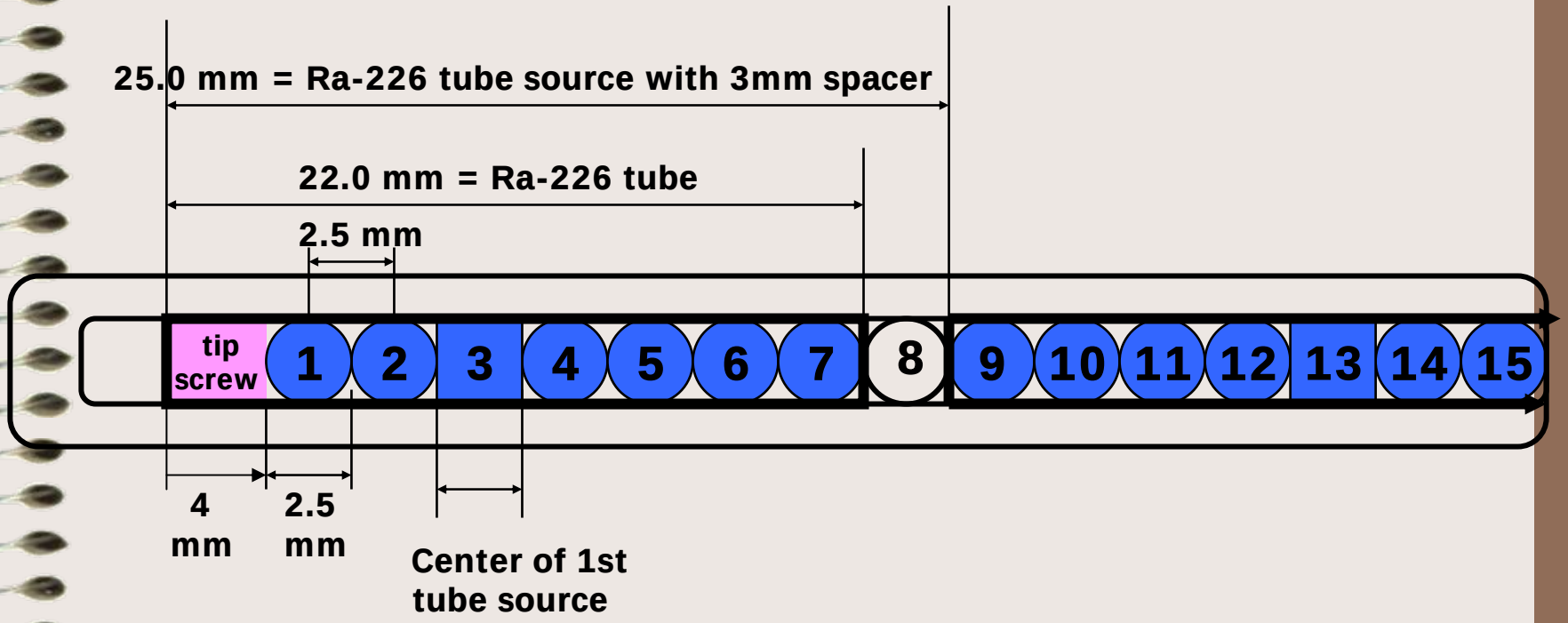
Selectron LDR Afterloaders

- Pellets sorted magnetically
- Active pellets stored in radiation protection safe
- Program active and inactive pellets in each channel
- Programmed pellets, in intermediate safe
- Compressed air transfer of pellets

Radium to Cesium

- ^{226}Ra tube sources, 22 mm PL, 14 mm AL
  - Sources spaced “uniformly” tip to flange
  - 3 mm spacers used, if required
  - Loadings w/o spacers, “sources” loading
  - Loadings w spacers, “inches” loading
- ^{137}Cs tube sources, 20 mm PL, 13.5 mm AL
  - 2 mm spacers, “sources” loading
  - 5 mm spacers, “inches” loading
  - No spacers, “short sources” loading

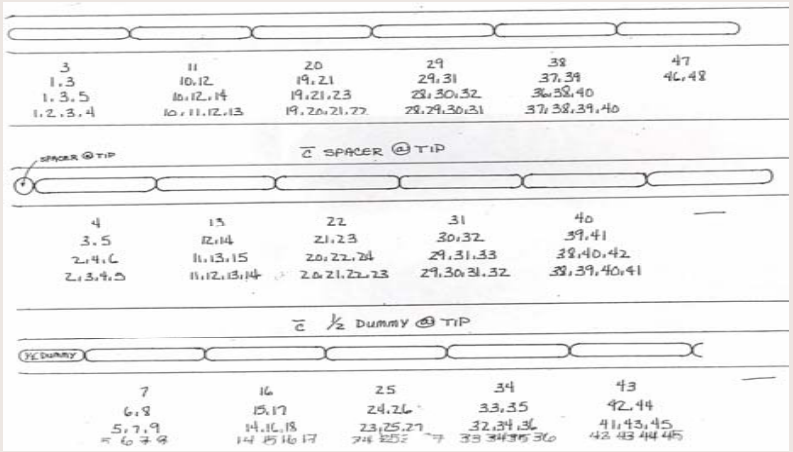
Radium Tube Sources to Cesium Selectron Pellets in the Tandem

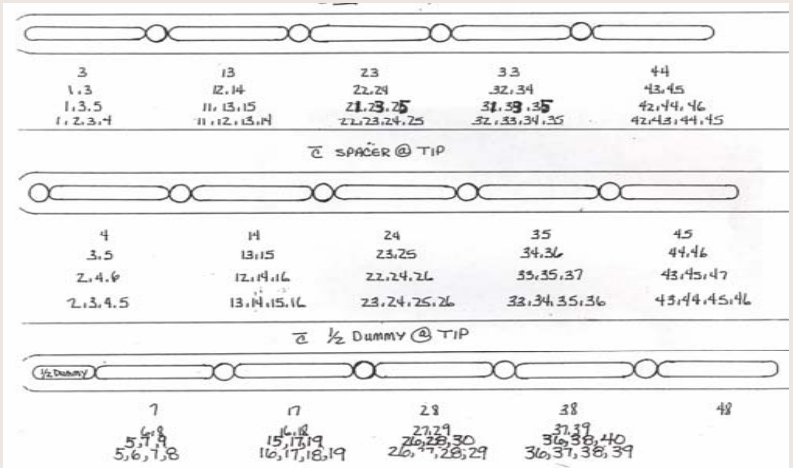


Note: each active pellet has a nominal activity of 5 mgRaeq

^{226}Ra to Selectron LDR Afterloaders

- ^{226}Ra treatment plans historical tandem and ovoids treatments
- Selectron loadings for “same” dose distribution
- Tables translate ^{226}Ra to Selectron, “sources” and “inches” tandem loadings
- MDACC ovoids - 33mm





LDR Afterloader Advantages

- Reduction of radiation exposure to personnel
- Reduction in rectal dose
- “Optimization” – variable geometry of active/inactive pellets

LDR Afterloaders Disadvantages

- Machine failure during pellet transfer
  - Air pressure
  - Power sags and surges
  - “out of round” pellets
- Visitors interrupt treatment, increase time patient in hospital

Facility Considerations

- Shielding
  - Maximum air kerma strength per hour
  - Maximum total air kerma strength per week
  - Uncontrolled areas - 1.0 mSv per year, no more than .02 mSv in any one hour, T = 1
  - Radiation workers, .05 Sv per year
- Location
  - Multiple shielded rooms adjacent
  - Near nurses' station, surveillance

Facility Considerations

- Ancillary services
  - Emergency power
  - Compressed air
  - Door interlock
  - Area radiation monitors
  - Emergency equipment, bail out pig
  - Radiation signs, instructions
- Audio-visual communications
- Equipment arrangement in room and outside
  - Afterloader, TCS, nurses' console, etc.

Licensing Issues

- Licensed by USNRC or State Agency
- Registry of Sealed Sources and Devices
  - Verify vendor registration before purchase of unit
- “Say what you mean, do what you say”
  - Whatever you state you will do in license, you ***must*** do
  - You can always do more, but never less

License Application

- Description of source and registry number
- Manufacturer and model # of afterloader
- Authorized users and qualifications
- Authorized medical physicist and qualifications
- Planned use of device
- Location of planned use

License Application

- Adequacy of shielding
- Floor plan
- Area radiation monitors
- Radiation detection devices – survey meters
- Audiovisual equipment
- Machine operation indicators
- Security of the area and the sources
- Maximum activity of specified isotope in the facility at any time

License Application

- Training of operators
- Personnel monitoring
- Details of Quality Control Program
  - Calibration techniques and frequency
  - Routine QC procedures and frequency
  - Leak tests procedures and frequency
  - Qualifications of individuals performing procedures

License Application

- Emergency procedures, location
- Manuals, location
- Disposal of decayed sources
- Records
- Fee for application
- Signature of executive level administrator

Training

- Physicists/dosimetrists – operation, programming, emergency procedures, radiation safety
- Nursing staff – start/stop, emergency procedures, radiation safety
- Physicians – emergency procedures, radiation safety

Afterloader Commissioning

- Source calibration
- Source positioning
- Timer accuracy
- Room and treatment unit surveys
- Interlock & indicator light checks
- Audiovisual device checks
- Accuracy of printouts
- Applicator tests

Treatment Planning System Commissioning

- Data input devices
- Data output devices
- Image reconstruction algorithms
- Dose calculation algorithms

Afterloader Quality Control

- Interlock checks
- Audiovisual device checks
- Area radiation monitor
- Accuracy of printouts
- Printer paper supply
- Door lights
- Indicator lights & audible alarms

Afterloader Quality Control

- Warning signs
- Manuals
- Air compressors
- Emergency power
- Timer accuracy
- Room and treatment unit surveys

Afterloader Quality Control

- Source calibration
- Source positioning
- Applicator tests

Problem

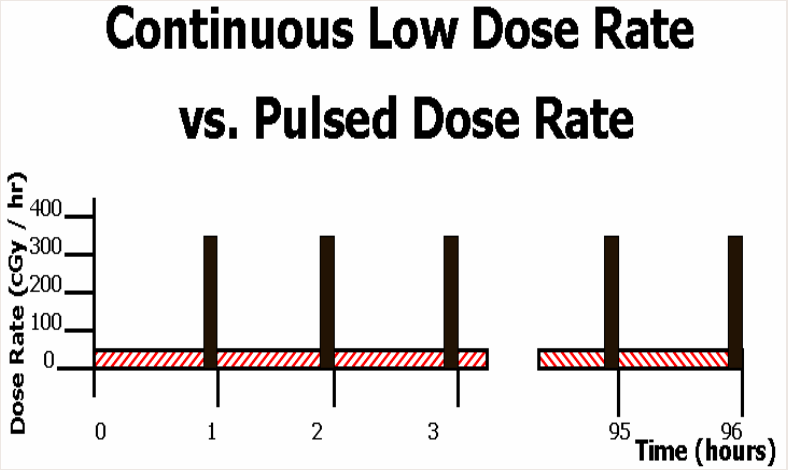
- Desire an intracavitary LDR brachytherapy program with remote afterloader.
- After 2009 Nucletron will not support the Selectron LDR remote afterloader.
- Manual ^{137}Cs sources are more difficult to obtain.
- PDR remote afterloader, potential solution

Nucletron PDR Afterloader

- Physical construction identical to Nucletron unit (mHDRv2)
- ^{192}Ir stepping source
- Source activity 18.5 – 74 GBq at installation
- Treatment Control Station software specific for PDR

PDR Remote Afterloader

- Simulates LDR with higher activity source exposed a fraction of each hour
- PDR source steps through the implant during irradiation pulse



PDR Afterloader Advantages

- Radiobiological models and measurements indicate PDR provides capability to simulate LDR
- Nursing care provided between pulses
- Patient has more certainty when treatment finishes
- Visitors between pulses
- Computerized optimization
  - 3D imaging, planning, volumetric information required for true optimization

PDR Afterloader Disadvantages

- Potential for failure to retract source
  - Low probability, never occurred
- AMC – Amsterdam
  - 5117 delivered pulses
    - 272 obstruction during check cable insertion
    - 5 obstruction during active source insertion
  - 417 treatments
    - 5 (1.2%) required adjustment
    - 5 (1.2%) discontinued, medical reasons

AMC – Amsterdam PDR Conclusions

- Errors occur and on rare occasion require treatment adjustment
- Errors don’t always occur on first pulse
  - Flexible catheters more problem than rigid applicators
- Check cable proven effective system to prevent problems with active source

Questions

- When do treatment interruptions that require treatment adjustment become a reportable event in US?
  - Patient intervention – No
  - Catheter kinked during treatment - depends???
    - If can adjust to original prescription - perhaps???
    - If can’t adjust to original prescription - probably???
  - If reportable, to whom ???
    - FDA for machine - ???
    - NRC/State for dosage - ???

Facility Considerations

- Shielding
  - Maximum air kerma strength per hour
  - Maximum total air kerma strength per week
  - Uncontrolled areas - 1.0 mSv per year, no more than .02 mSv in any one hour, T = 1
  - Radiation workers, .05 Sv per year
  - Shielding adequate for ^{137}Cs LDR, should be adequate for same (cGy in any one hour) treatments with ^{192}Ir PDR
- Location
  - Multiple shielded rooms adjacent
  - Near nurses' station, surveillance

Facility Considerations

- Ancillary services
  - Emergency power
  - Door interlock
  - Area radiation monitors
  - Emergency equipment, bail out pig
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- Floor plan
- Radiation area monitors
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License Application

- Training of operators
- Personnel monitoring
- Details of Quality Control Program
  - Calibration techniques and frequency
  - Routine QC procedures and frequency
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  - Qualifications of individuals performing procedures

License Application

- Emergency procedures, location
- Manuals, location
- Disposal of decayed sources
- Records
- Fee for application
- Signature of executive level administrator

TRAINING

- Higher activity source – training even more important
- Physicists/dosimetrists – operation, programming, emergency procedures, radiation safety
- Nursing staff – operation, emergency procedures, radiation safety, nurses “buy-in” essential
- Physicians – emergency procedures, radiation safety

Afterloader Commissioning

- Source calibration
- Source positioning
- Room and treatment head surveys
- Interlock checks
- Audiovisual device checks
- Accuracy of printouts
- Applicator tests

Afterloader Commissioning

- Transit dose, high number of source transfers
- Machine reliability, number of transfers
  - Nucletron specs 25,000, tested to 100,000
- Transfer tubes, what radius of curvature results in failure

Treatment Planning System Commissioning

- Data input devices
- Data output devices
- Data transfer from TPS to Treatment Control Station
- Image reconstruction algorithms
- Dose calculation algorithms

Afterloader Quality Control

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Afterloader Quality Control

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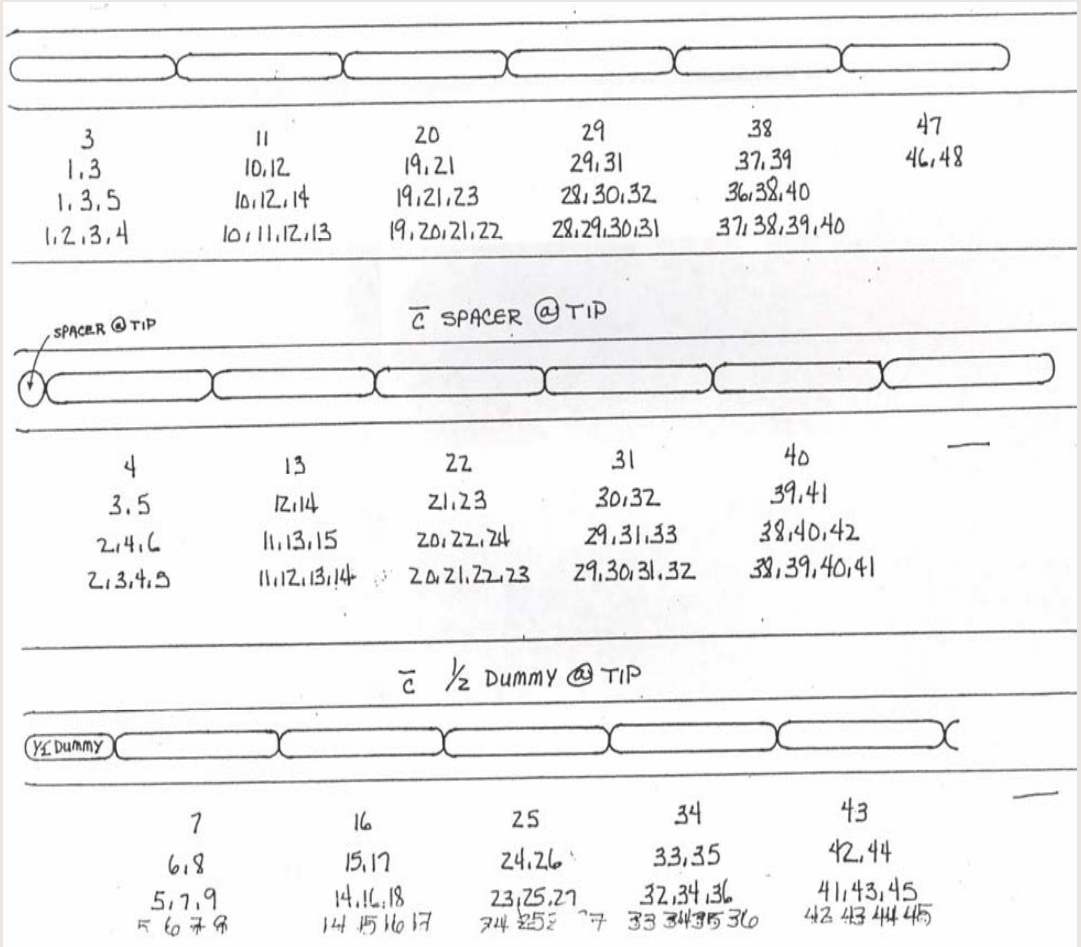
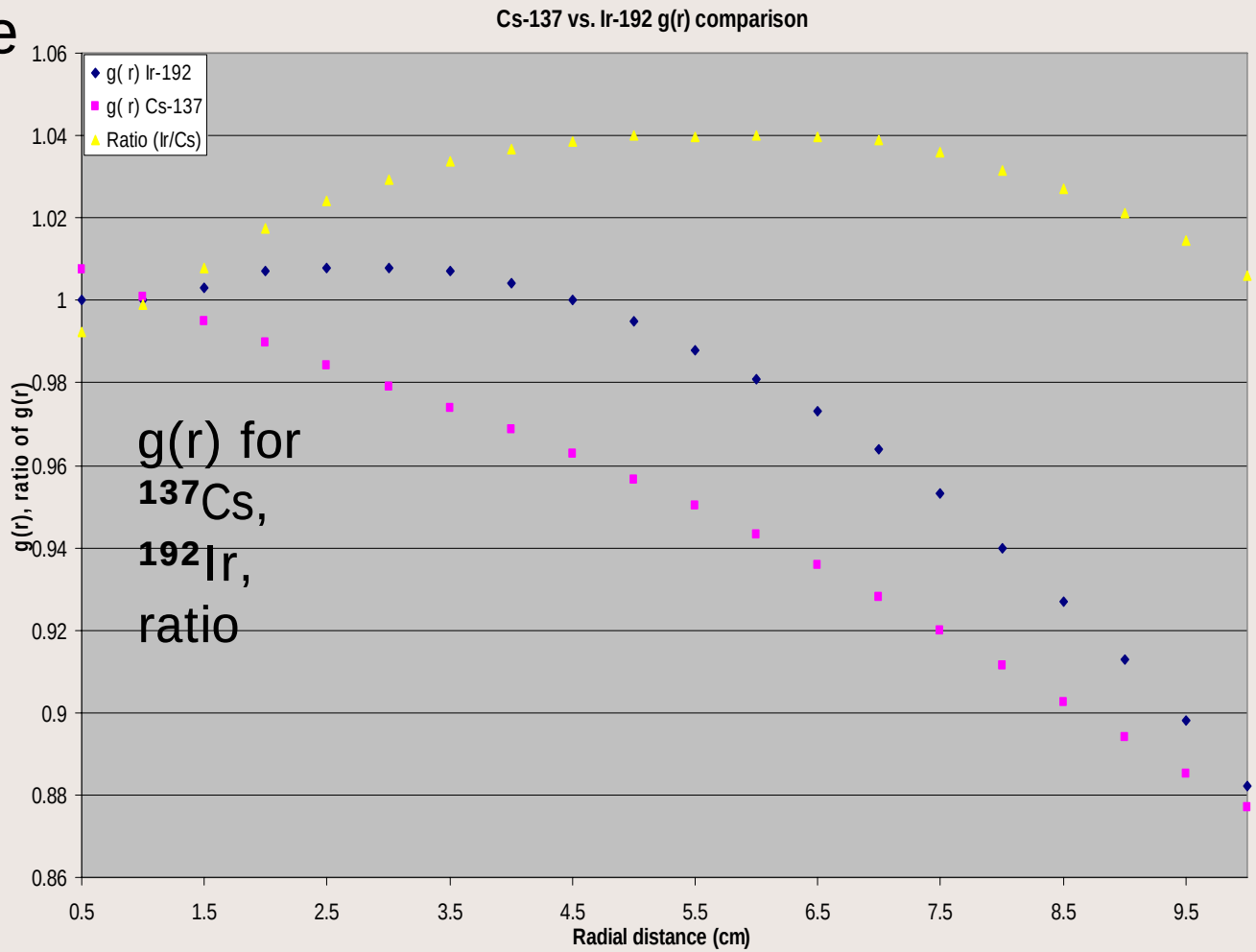
LDR to PDR Prescriptions

- Geometry based
- Point A dose
- 3D planning



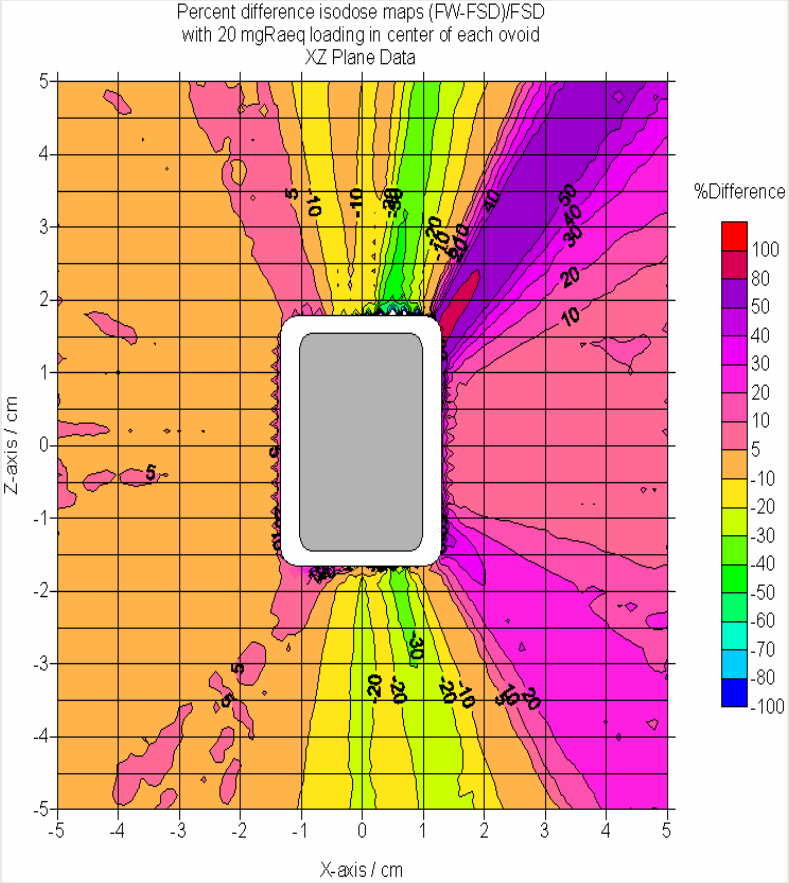
LDR to PDR Dose Distribution

- Radial dose function ^{137}Cs vs. ^{192}Ir
- Anisotropy effect
- Ovoid shielding



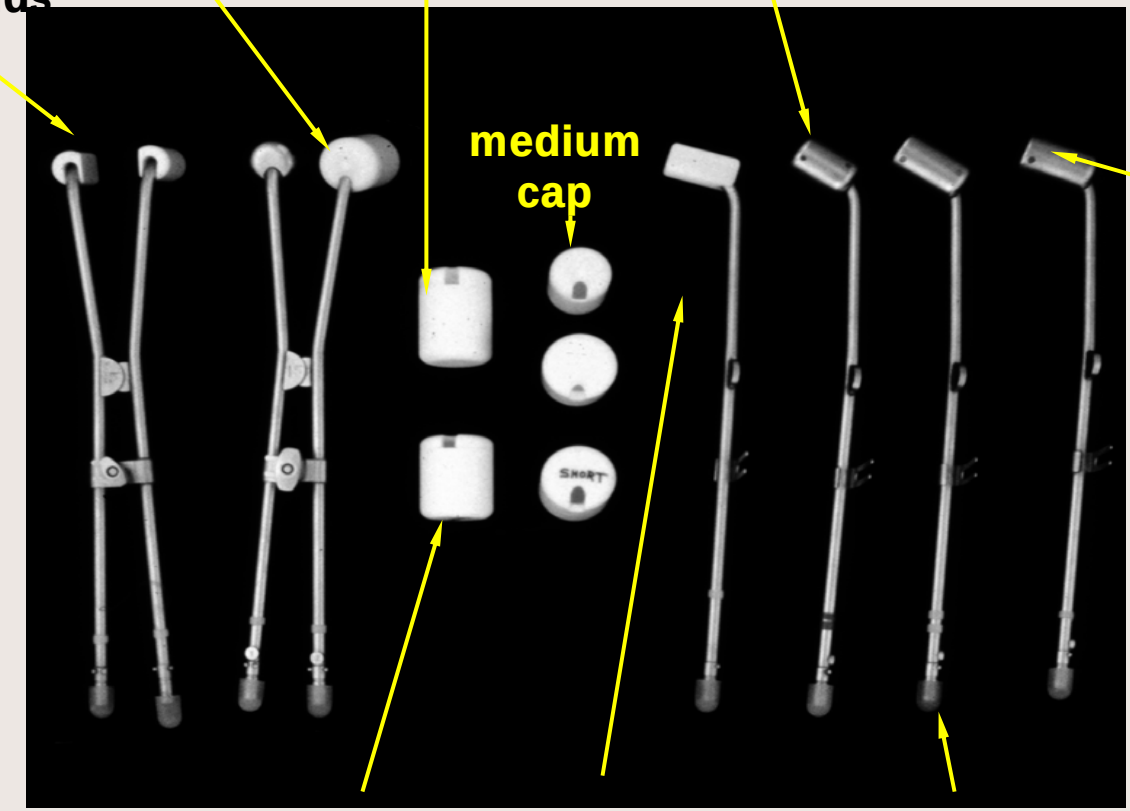
LDR to PDR Activity Distribution

- Tube sources, fixed geometry, fixed activity
- Selectron pellets, fixed activity, variable geometry active/inactive pellets
- PDR stepping source, variable geometry, variable dwell times

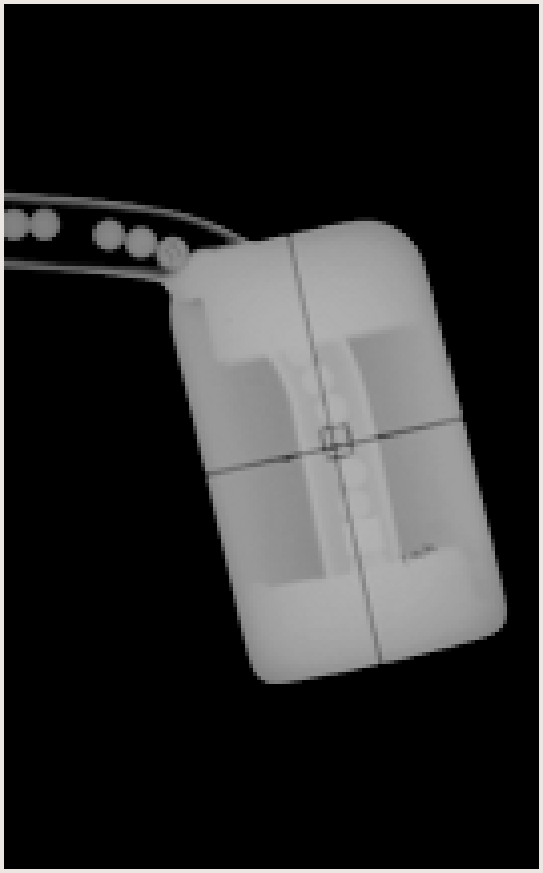


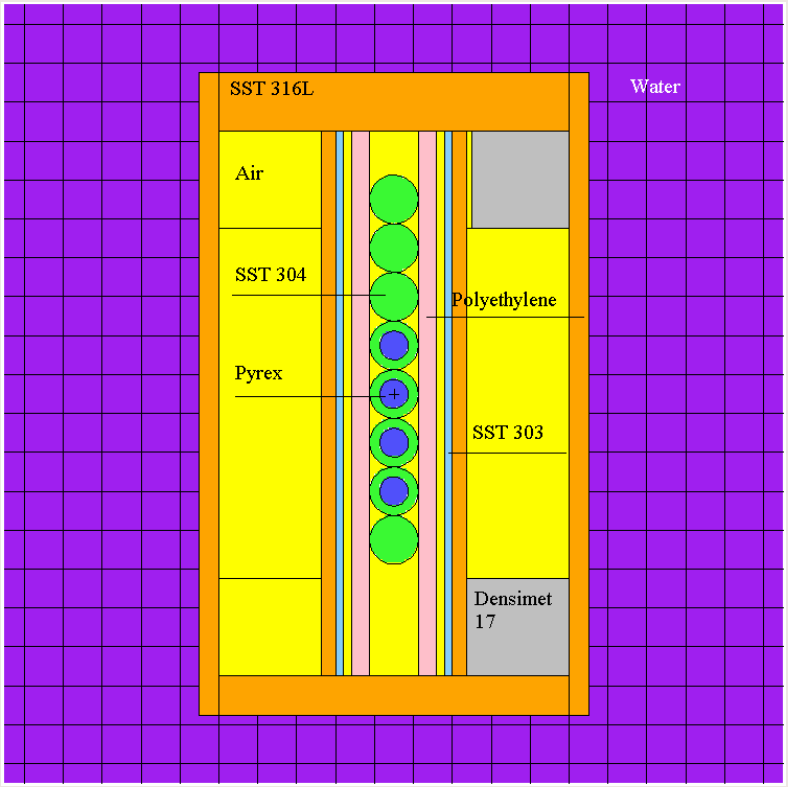
MCNPX2.5.e calculation
Price, et al., AAPM, Annual Meeting 2005, TU-D-T-617-1

Selectron LDR
Fletcher-Suit-Delclos Ovoids



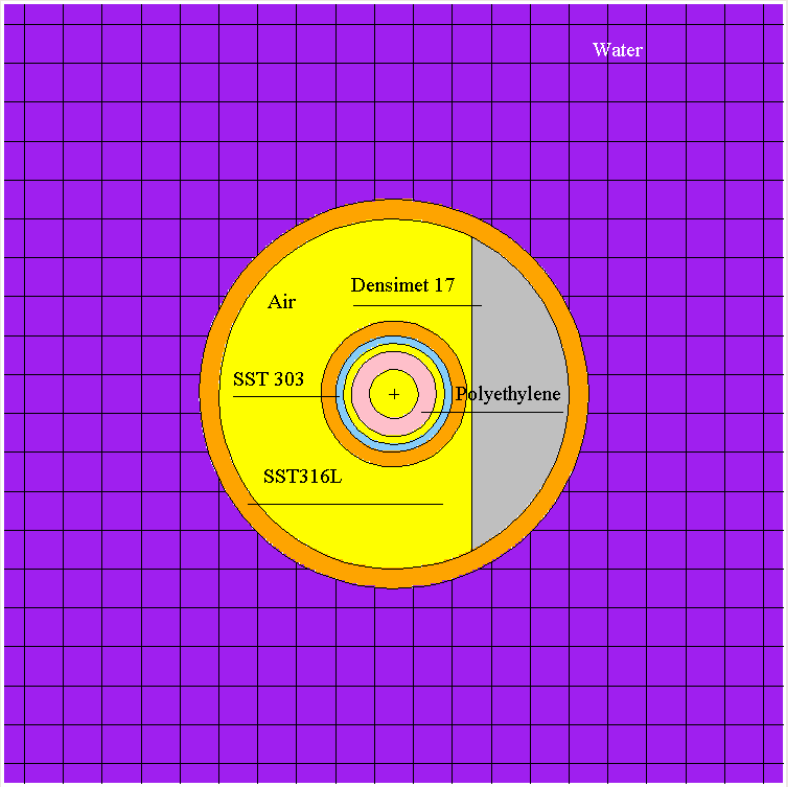
FSD Selectron Ovoid



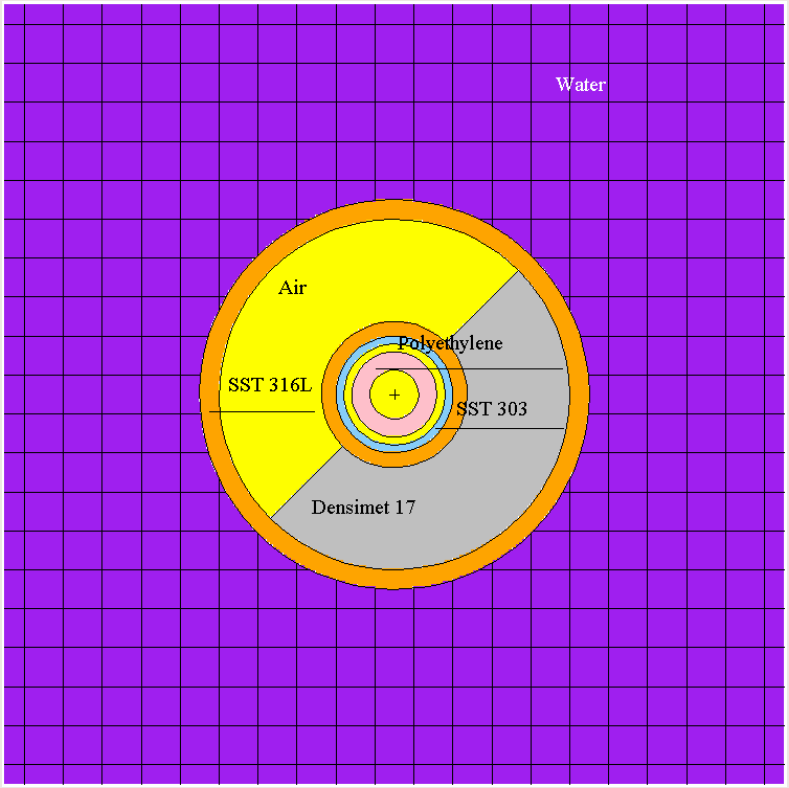


Gifford

FSD Selectron Ovoid



Bladder shield

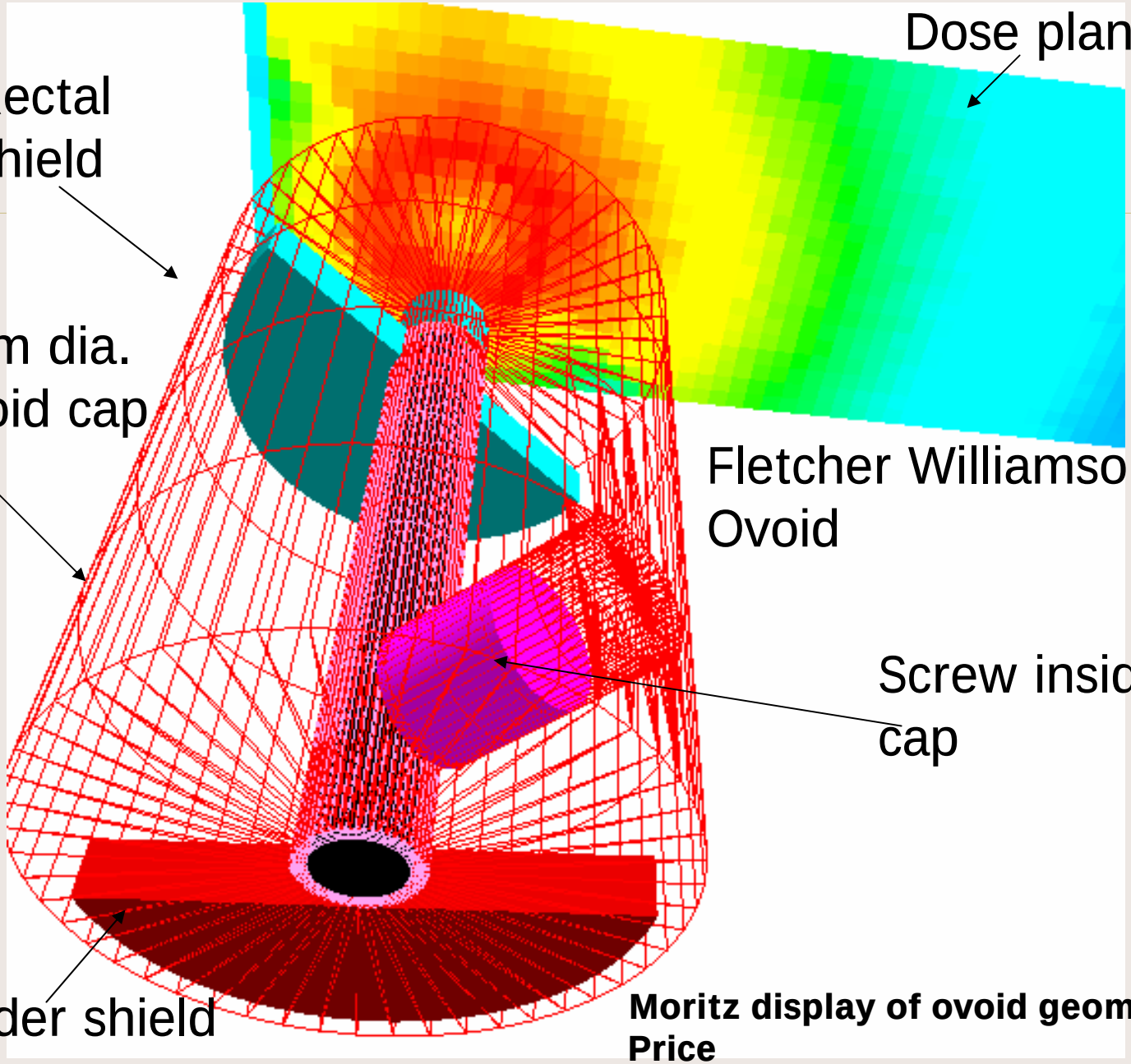


Rectal Shield

Gifford

Fletcher Williamson Tandem and Ovoids

Nucletron catalogue



Moritz display of ovoid geometry
Price

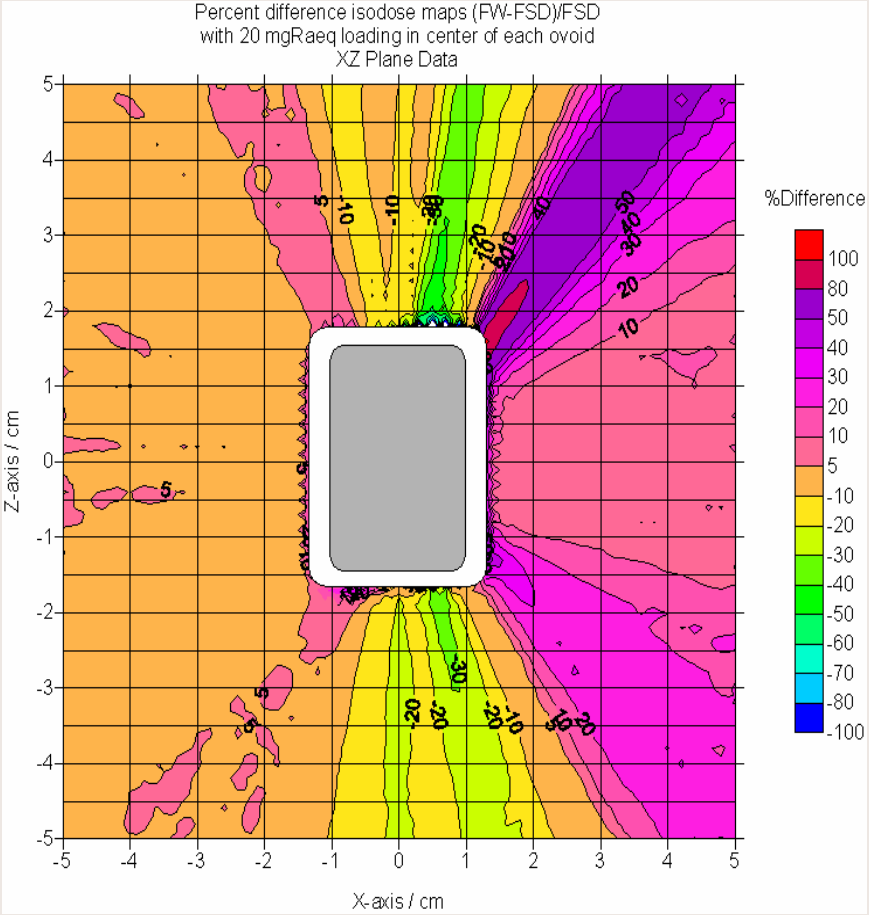
LDR to PDR
Ovoid Comparison

<u>% Difference map</u>

Small ovoid – PDR Fletcher Williamson compared to LDR FSD

20 mgRaeq, same active dwell positions for FW and FSD

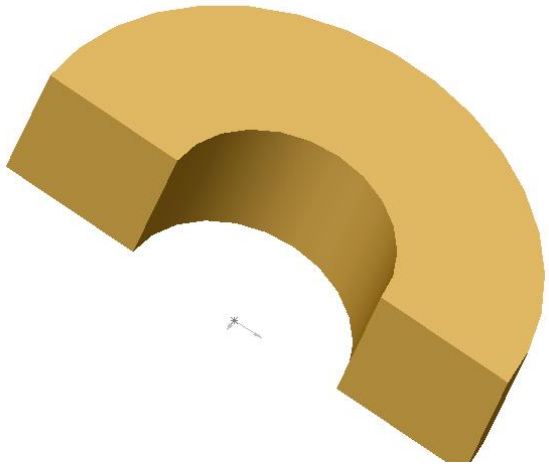
Dwell time same at each dwell position



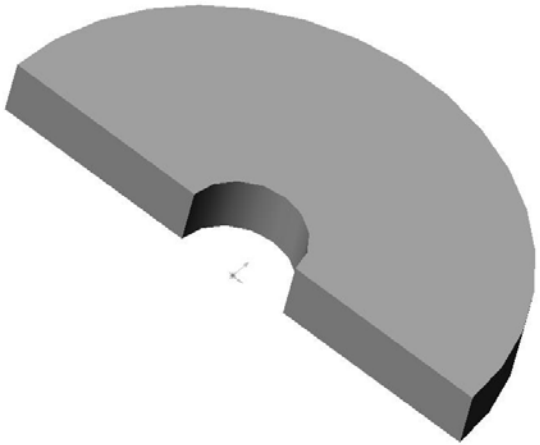
MCNPX2.5.e calculation
Price, et al., AAPM, Annual Meeting 2005, TU-D-T-617-1

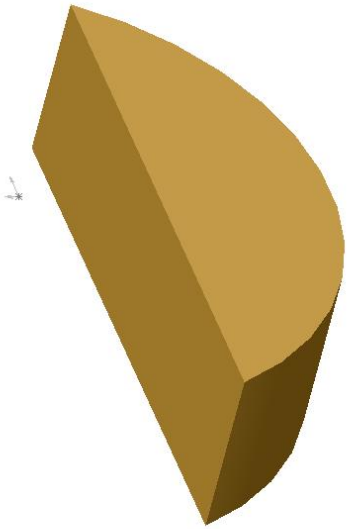
Rectal Shield

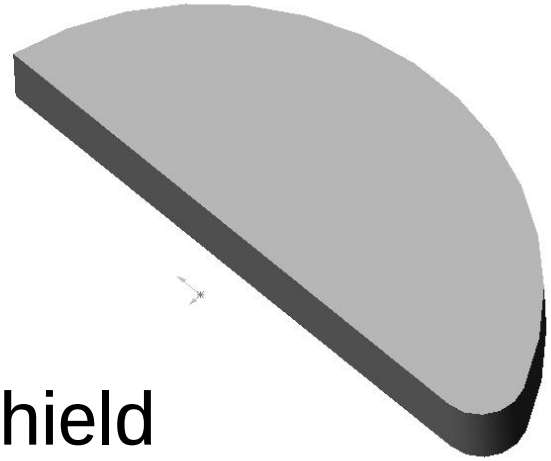
FSD (LDR)



FW (PDR)





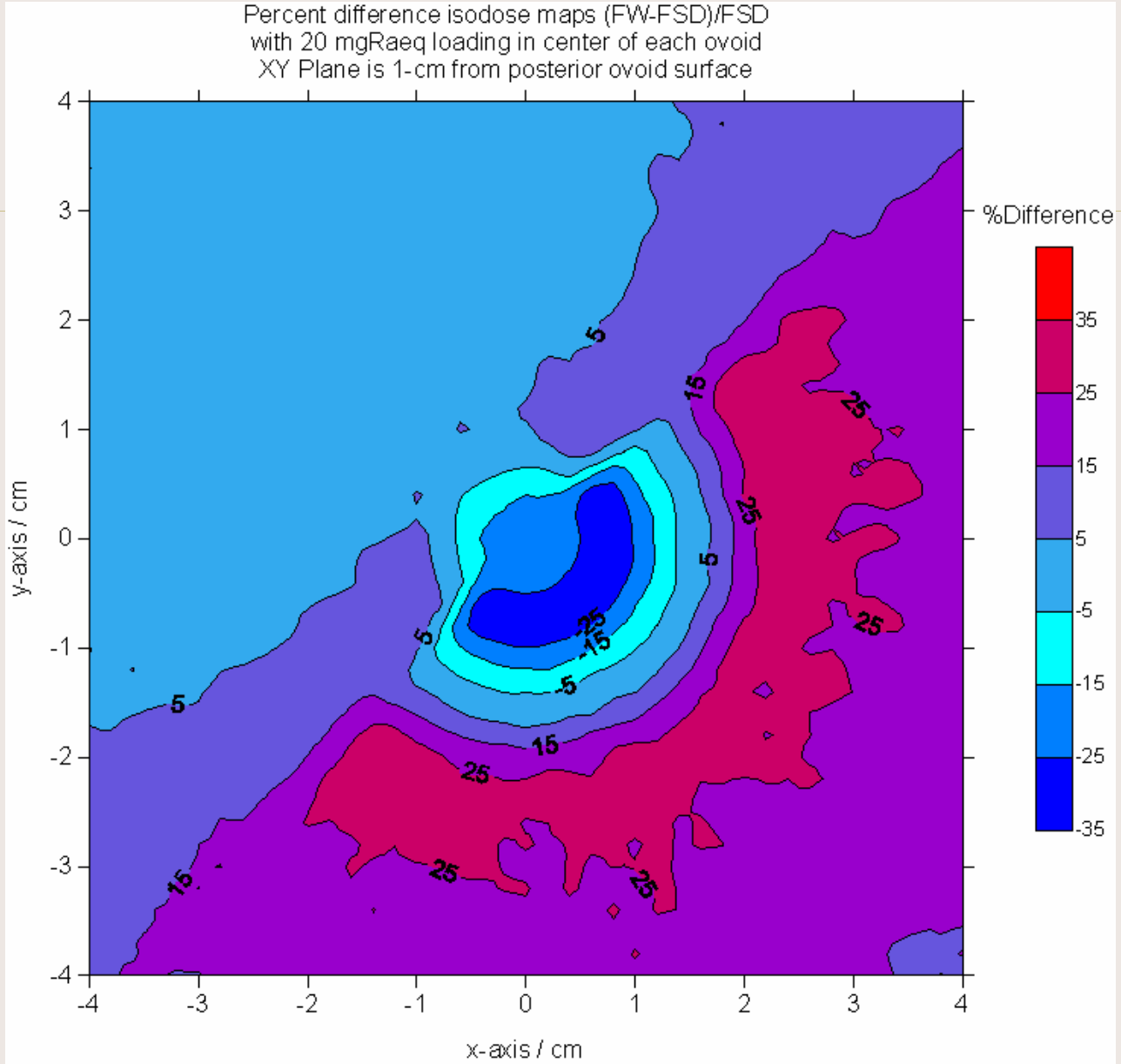


Bladder Shield

Rectal Shield Geometry

	Rectal FW	Rectal FSD
ID, mm	4	8
OD, mm	18	18
thickness, mm	2.1	5
Total surface, mm^2	344	458
largest face surface, mm^2	191	102
total shield volume, mm^3	254	510

Shield material for both FW and FSD is Densimet 17 (17 g/cm^3)



MCNPX2.5.e calculation Price, et al., AAPM Annual Meeting, 2005, TU-D-T-617-1

LDR to PDR UTMDACC Schedule

- First treatment in mid-October 05
- 18.5 GBq (0.5 Ci) source
- Change source every two months
- No weekend treatments
- Evaluate program in January 06

end

Bladder Shield Geometry

	Bladder	Bladder
	FW	FSD
Height, mm	7	5
OD, mm	18	18
thickness, mm	2	5
Total surface, mm^2	267	296
largest face surface, mm^2	91	58
total shield volume, mm^3	191	288

*** Material for both FW and FSD is Densimet 17 (17 g/cm³)**

FSD (LDR)

FW (PDR)